The following SWPPP development outline is provided to give SWPPP designers guidance for preparing SWPPPs. Note that not all site scenarios are contained in the checklist. However, the information in the checklist provides an excellent foundation upon which to build a comprehensive Stormwater Pollution Prevention Plan. A designer is responsible for fully understanding the requirements of the TN CGP, the TDEC EPSC Handbook and good engineering practices related to stormwater management on construction projects.

General Information/Narrative

☐ Provide a description of all construction activities at the site (utilities, cutting and filling, roadway construction, etc.). Describe the extent of cutting and/or filling activities at the site.

☐ Provide the total acreage to be permitted. Include a description of phases to keep the disturbed acreage at the project under 50 acres of total disturbance at any one time. Include a description of borrow and waste sites. Off-site borrow and waste areas must be included in the permitted acreage calculation unless the offsite borrow or waste area has been separately permitted.

☐ Provide contact information for the primary permit holder and any secondary permit holders. As operators are added to the site, they must be added as permit holders as well.

☐ Clearly provide the location of the site and any borrow/waste activities. Provide a USGS quadrangle showing the location of the site and waste and borrow areas. For the project site, show the locations of the outfalls on the quad map and correlate with the SWPPP.

☐ Provide a description of the site conditions prior to disturbance and after development has been completed. Estimate the amount of managed open space, forested, and built upon land at the site prior to and after development.

☐ Describe the soils at the site. Identify acid producing soils, hydric soils, highly erodible soils and soils with a high clay content. Consider soil characteristics in the design.

☐ Provide a calculation of the runoff coefficient of the site after construction activities are completed and how the runoff will be handled to prevent erosion at the permanent outfall(s).

☐ Provide a list of possible chemicals stored on the project. Indicate the types of pollution prevention measures that will be included on the project, including the person’s title that will be responsible for overseeing pollution prevention on the site.

☐ For projects that have separate and common stormwater features, such as residential developments or industrial parks, the developer/owner must describe how they will prevent erosion and/or control any sediment from portions of the property that will be sold prior to completion of construction; once the property is sold, the new operator must obtain coverage under the CGP, and assume operational control and responsibility of that portion of the site. If instead new owners desire separate coverage and to operate under a separate SWPPP, the new owner must clearly demonstrate how the new SWPPP and original SWPPP will not cause conflicting stormwater management issues.

EPSC Plan Information

☐ If the project disturbs less than 5 acres, provide at least two separate EPSC plan sheets. At least two phases shall be identified, with associated EPSC staging addressed. The plan phases shall be addressed separately in plan sheets, with each phase reflecting the conditions and measures necessary to manage stormwater runoff and EPSC during the initial land disturbance (initial grading) and at final grading.

- ☐ If the project disturbs more than 5 acres total, provide at least 3 separate EPSC plan sheets. Three phases shall be identified. The first plan sheet should reflect the conditions and measures necessary to manage stormwater runoff and EPSC, during the initial land disturbance (initial grading). The second plan sheet shall reflect the conditions and measures necessary to manage stormwater runoff and EPSC from interim land disturbance activities. The third plan sheet shall reflect the conditions and measures necessary to manage stormwater runoff and EPSC at final grading.
- ☐ Identify all outfalls from the project. Provide unique labels for each outfall. Provide a summary table that identifies the total drainage area, disturbed drainage area, and diverted drainage area (run-on that will not drain to the outfall) to each outfall. The table must indicate the name of the feature to which the outfall drains (e.g. stream, wet weather conveyance, lake).
- ☐ Show the approximate location for each EPSC or pollution prevention measure. Include standard symbols referenced in the TDEC EPSC Handbook. Provide standard details with specific sizes and construction materials, based upon the supporting calculations where appropriate.
- ☐ Identify on the plans the locations of the ARAP boundaries and reference the ARAP. For sites where stream diversions are necessary, show specific sequencing related to the construction of the diversion, the active construction in the natural channel, dewatering, and turning the stream back into the natural channel.
- ☐ Identify areas not to be disturbed by construction clearly on the plans, including stream buffers. Include specifications in the plan for how to delineate these areas, such as the installation of high visibility fencing or signage along the outer most edge of the buffer.
- ☐ Identify sinkholes on the plans and specify measures during construction and after construction to protect water quality and the integrity of the sinkhole.
- ☐ Provide a comprehensive legend, north arrow and scale.
- ☐ Clearly indicate the boundaries of the area to be covered by the permit. Also clearly indicated the areas that are not to be disturbed.
- ☐ Include topographic information to support the SWPPP design. The topographic information should extend to encompass the watersheds that contribute to the outfalls from the proposed site. This information should be used in determining the **total** drainage area (as opposed to the onsite disturbed drainage area).
- ☐ For sites that drain to Impaired (for sediment or habitat alteration) or Exceptional Tennessee Waters, measures must be designed for the 5-yr, 24-hr design storm. Provide a summary of supporting calculations to show the design criteria has been met. In addition, outfalls that have 5 acres or more of drainage are required to have a sediment basin or equivalent measure(s). If equivalent measure(s) are to be used, equivalency must be verified through design. Calculations for basin volumes must be included in the SWPPP.
- ☐ For all other sites, measures must be designed for the 2-yr, 24-hr storm event. Provide a summary of supporting calculations to show the design criteria has been met. In addition, outfalls that have 10 acres or more of drainage are required to have a sediment basin or equivalent

measure(s). If equivalent measure(s) are to be used, equivalency must be verified through design. Calculations for basin volumes must be included in the SWPPP.

- ☐ Provide internal and perimeter sediment controls and erosion prevention measures at all pipe outlets. Provide measures to protect adjacent or downstream wetlands, streams and other environmentally sensitive areas.
- ☐ Divert run-on around the project with diversions, berms or other measures. Design structural controls based upon the drainage area, disturbed area, slope and soils. When clay and other fine particle soils are present at the construction site, chemical treatment may be used in accordance with soil testing and the manufacturer's requirements to reduce turbidity in the runoff being discharged from the project.
- ☐ For steep slope sites, the SWPPP must include a description of measures that will be installed to dissipate the volume and energy of the stormwater runoff to pre-development levels. Multiple stormwater "turnouts" should be provided to keep slope lengths short and therefore keep the erosion potential lower. Each turnout must have erosion prevention addressed with outlet protection.
- ☐ Clearly indicate locations of stockpiles on the project, such as topsoil stockpiles. Provide EPSC controls around the stockpile area.
- ☐ If permanent stormwater management controls are included in the project, clearly locate the permanent control(s) and include the installation of the permanent measures in the construction sequence. Typically, permanent controls are not installed until the drainage area they serve has been completely stabilized.

Environmentally Sensitive Areas Information

- ☐ Provide a description of the receiving stream – Is it impaired, an Exceptional TN Water, an Outstanding National Resource Water? Is it covered by a TMDL? If so, how will the SWPPP address these issues?
  - Will any streams be relocated, crossed (even temporarily) or piped as a part of this project? If so, an ARAP and COE permit are likely required. These permits must be obtained prior to submitting the NOI.
  - Show the original location of the stream as well as the proposed realignment, piped section or mitigated section of the stream on the plans with associated control measures required by the ARAP or COE permit.
- ☐ Does the project site or the receiving stream have state or federally listed threatened or endangered species or critical habitat?
  - If so, the US Fish and Wildlife Services must be consulted for federal listings. The TDEC Natural Heritage Program must be consulted for state listed species.
  - Include any restrictions on work area or schedule in the plans, as required by USF&W or TDEC.
- ☐ Are there any wetlands on or adjacent to the project?
  - Locate wetland on the plans.
  - Include measures on the plans to protect the wetlands.
  - If they will be impacted by the project, an ARAP or COE permit may be required. These permits must be obtained prior to submitting the NOI.

Pollution Prevention Measures

- ☐ Identify the location(s) of the concrete washout area on site. Include a standard note to provide adequate signage on the project indicating the area as the concrete washout area.
- ☐ All chemicals and soluble materials stored onsite must either be stored in an enclosed, waterproof storage facility or provided with secondary containment capable of storing the contents of the total amount of chemicals stored. Spill cleanup materials must be located within the immediate proximity of the materials as well. All of this information must be included on the plans and in the written narrative of the SWPPP.
- ☐ Indicate the location of port-a-potties on the project. They should not be located close to streams, wetlands or storm drains.
- ☐ If maintenance is to be performed on vehicles on the site, the location of the maintenance area(s) must be indicated on the plans. Provide a listing in the SWPPP of pollution prevention best practices tools that should be used with vehicle maintenance activities, such as drip pans for oil drips and changes, oil recycling facilities, spill cleanup materials, and containers for recycling or disposing of other lubricants or oils related to vehicle maintenance and cleaning.
- ☐ Provide an area for the storage of construction related materials and debris. For trash on the project, a trash receptacle with a lid is required.
- ☐ Provide a description of any discharge associated with industrial activity other than construction stormwater that originates on site and the location of that activity and its permit number.

This Appendix is currently under construction.

The following example problem is for the design of a rip rap lined channel. This design is based upon U.S. Department of Transportation – Federal Highway Administration: Hydraulic Engineering Circular Number 15 (HEC15)and involves an iterative p Note that many designs typically have design constraints such as limited easement width or right of way. Each design must be consistent with the site layout and must clearly address the design constraints.

GIVEN:

Design a rip rap lined channel to non-erosively convey the 5 year storm event.

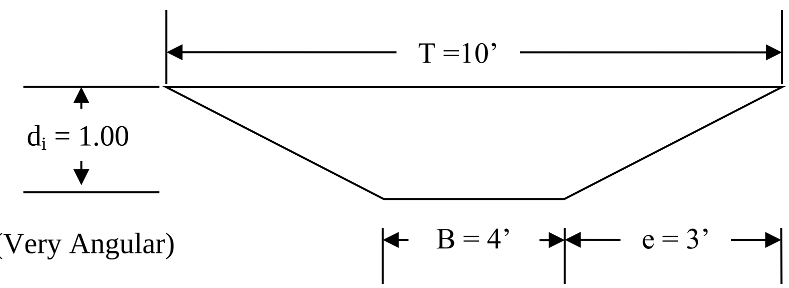
Q_5 = 17.4 cfs
3:1 side slopes (Z = 3)
S = 8% = 0.08
Trapezoidal Shape

REQUIRED:

Determine the required riprap D_{50} through an iterative process. Then compare the required D_{50} size to the trial D_{50} size. If D_{50} required < trial D_{50} then the rip rap size is adequate. However, a smaller more cost effective rip rap size should be considered if the trial $D_{50} \geq$ 110% of the required D_{50}.

SOLUTION:

Step 1: Q = 17.4 cfs
S = 8% = 0.08
$Z = \frac{e}{d} = 3$



Step 2: Trial D_{50} = 1.25' (Very Angular)

Step 3:

d_i = 1.00 ft

$A = Bd + Zd^2$ = 7.00 sq ft
$T = B+2dZ$ = 10.00 ft
$R = \frac{bd+Zd^2}{b+2d\sqrt{Z^2+1}}$ = 0.68 ft

d_a = A/T = 0.70 ft
$A_a = Bd + Zd^2$ = 4.27 sq ft
$T_a = B+2dZ$ = 8.20 ft
$Ra = \frac{bd+Zd^2}{b+2d\sqrt{Z^2+1}}$ = 0.51 ft

Step 4: d_a/D_{50} = 0.56 ≤ 1.5 therefore use Equation 7.27-4

$$n = \frac{\alpha d_a{}^{1/6}}{\sqrt{g}\, f(Fr) f(REG) f(CG)} = 0.078$$

$$b = 1.14 \left(\frac{D_{50}}{T_a}\right)^{0.453} \left(\frac{d_a}{D_{50}}\right)^{0.814} = 0.303$$

$v = Q/A_a$ = 4.075 ft/sec

$$Fr = \frac{v}{\sqrt{g\, d_a}} = 0.858$$

$$f(Fr) = \left(\frac{0.28Fr}{b}\right)^{\log(0.755/b)} = 0.912$$

$$f(REG) = 3.434\left(\frac{T_a}{D_{50}}\right)^{0.492} b^{1.025\left(\frac{T_a}{D_{50}}\right)^{0.118}} = 7.363$$

$$f(CG) = \left(\frac{T_a}{d_a}\right)^{-b} = 0.474$$

Note: Subcritical flow, Froude Number (Fr) less than 1, which is desirable. Now check trial flow.

Step 5:

$$Q = \frac{1.49}{n} A_a R_a^{\frac{2}{3}} S^{\frac{1}{2}} = 14.72 \text{ cfs}$$

This flow is not within 5% of 17.4 cfs; therefore return to step 3 and select a new depth (d_{i+1}).

Step 3(2): Using equation 7.27-2 obtain a new d_i (d_{i+1}):

$$d_{i+1} = d_i\left(\frac{Q}{Q_i}\right)^{0.4} = 1.07 \text{ ft}$$

$d_{i+1} = 1.07$ ft	$d_a = A/T = 0.74$ ft
$A = Bd + Zd^2 = 7.72$ sq ft	$A_a = Bd + Zd^2 = 4.61$ sq ft
$T = B+2dZ = 10.42$ ft	$T_a = B+2dZ = 8.44$ ft
$R = \frac{bd+Zd^2}{b+2d\sqrt{Z^2+1}} = 0.72$ ft	$Ra = \frac{bd+Zd^2}{b+2d\sqrt{Z^2+1}} = 0.53$ ft

Step 4(2): $d_a/D_{50} = 0.59 \leq 1.5$ therefore use Equation 7.27-4

$$n = \frac{\alpha d_a^{1/6}}{\sqrt{g}\, f(Fr) f(REG) f(CG)} = 0.080$$

$$b = 1.14\left(\frac{D_{50}}{T_a}\right)^{0.453}\left(\frac{d_a}{D_{50}}\right)^{0.814} = 0.313$$

$v = Q/A_a = 3.778$ ft/sec

$$Fr = \frac{v}{\sqrt{g\, d_a}} = 0.774$$

$$f(Fr) = \left(\frac{0.28Fr}{b}\right)^{\log(0.755/b)} = 0.869$$

$$f(REG) = 3.434\left(\frac{T_a}{D_{50}}\right)^{0.492} b^{1.025\left(\frac{T_a}{D_{50}}\right)^{0.118}} = 7.746$$

$$f(CG) = \left(\frac{T_a}{d_a}\right)^{-b} = 0.466$$

Step 5(2):

$$Q = \frac{1.49}{n} A_a R_a^{\frac{2}{3}} S_f^{\frac{1}{2}} = 15.99 \text{ cfs}$$

This flow is not within 5% of 17.4 cfs; therefore return to step 3 and select a new depth (d_{i+2})

Step 3(3): Using equation 7.27-2 obtain a new d_i (d_{i+2}):

$$d_{i+2} = d_{i+1}\left(\frac{Q}{Q_i}\right)^{0.4} = 1.11 \text{ ft}$$

d_{i+2} = 1.11 ft

$A = Bd + Zd^2$ = 8.14 sq ft

$T = B + 2dZ$ = 10.66 ft

$R = \frac{bd+Zd^2}{b+2d\sqrt{Z^2+1}}$ = 0.74 ft

d_a = A/T = 0.76 ft

$A_a = Bd + Zd^2$ = 4.80 sq ft

$T_a = B + 2dZ$ = 8.58 ft

$Ra = \frac{bd+Zd^2}{b+2d\sqrt{Z^2+1}}$ = 0.54 ft

Step 4(3): d_a/D_{50} = 0.61 ≤ 1.5 therefore use Equation 7.27-4

$$n = \frac{\alpha {d_a}^{1/6}}{\sqrt{g}\, f(Fr) f(REG) f(CG)} = 0.080$$

$$b = 1.14\left(\frac{D_{50}}{T_a}\right)^{0.453}\left(\frac{d_a}{D_{50}}\right)^{0.814} = 0.319$$

$v = Q/A_a$ = 3.624 ft/sec

$$Fr = \frac{v}{\sqrt{g\, d_a}} = 0.731$$

$$f(Fr) = \left(\frac{0.28Fr}{b}\right)^{\log(0.755/b)} = 0.847$$

$$f(REG) = 3.434\left(\frac{T_a}{D_{50}}\right)^{0.492} b^{1.025\left(\frac{T_a}{D_{50}}\right)^{0.118}} = 7.963$$

$$f(CG) = \left(\frac{T_a}{d_a}\right)^{-b} = 0.462$$

Step 5(3): $Q = \frac{1.49}{n} A_a {R_a}^{\frac{2}{3}} {S_f}^{\frac{1}{2}}$ = 16.75 cfs

This flow is within 5% of 17.4 cfs, therefore go to Step 6.

Step 6: $R_e = \frac{\sqrt{gdS}\, D_{50}}{\nu}$ = 185117 = 1.85*10^5

Note: The "d" used here is d_a + minimum freeboard of 0.5'

From Figure 7.27-4:

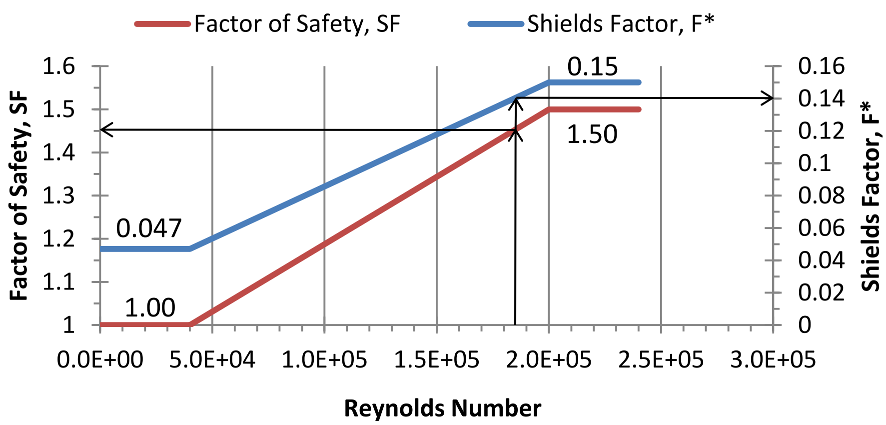
SF = 1.45

F* = 0.14

From Figure 7.27-4 interpolation or chart below:

$SF = ((R_e - 40{,}000) * (3.125*10^{-6})) + 1$
$= ((1.85*10^5 - 40{,}000) * (3.125*10^{-6})) + 1 = 1.45$

$F^* = ((R_e - 40000)*(6.4375*10^{-7})) + 0.047$
$= ((1.85*10^5 - 40000)*(6.4375*10^{-7})) + 0.047 = 0.14$



Reynolds Number, R_e	Shield's Parameter, F*	Factor of Safety, SF
$\le 4x10^4$	0.047	1
$4x10^4 < R_e < 2x10^5$	Linear Interpolation	Linear Interpolation
$\ge 2x10^5$	0.15	1.5

Step 7: Since slope is between 5% and 10%, use both Equation 7.27-11 and Equation 7.27-12 and choose the larger outcome.

Equation 7.27-11:

$$D_{50} \ge \frac{SF\ d\ S}{F^*\left(\frac{\gamma_S}{\gamma}-1\right)} = 0.64 \text{ ft}$$

$d = d_a$ + minimum freeboard of 0.5'
γ_s = specific weight of rock was assumed to be 165 lb/ft^3
γ = specific weight of water, 62.4 lb/ ft3

Equation 7.27-12:

$$D_{50} \ge \frac{SF\ d\ S\Delta}{F^*\left(\frac{\gamma_S}{\gamma}-1\right)} = 0.82 \text{ ft}$$

$$\tau_s = \gamma d_a S_o = 3.81 \text{ lb/ft}^2$$

$$\eta = \frac{\tau_s}{F^*\ (\gamma_s - \gamma) D_{50}} = 0.211$$

Note: The D_{50} used here is the trial D_{50} (1.25').

$$\beta = \tan^{-1}\left(\frac{\cos\alpha}{\frac{2\sin\theta}{\eta\tan\phi}+\sin\alpha}\right) = 16.33°$$

$\alpha = \tan^{-1}(S) = \tan^{-1}(0.08) = 4.57°$

$\theta = \tan^{-1}(1/Z) = \tan^{-1}(1/3) = 18.44°$

$\varphi = 42°$ (From Figure 7.27-5 using the trial D_{50} size (1.25') and Very Angular)

$$\Delta = \frac{K_1(1+\sin(\alpha+\beta))\tan\phi}{2\,(\cos\theta\tan\phi - SF\ \sin\theta\cos\beta)} = 1.284$$

$K_1 = 0.066Z + 0.67 = 0.066(3) + 0.67 = 0.868$

Note: $K_1 = .77\ (Z \leq 1.5)$
$= 0.066Z + 0.67\ (1.5 < Z < 5)$
$= 1.0\ (Z \geq 5)$

Therefore the required D_{50} size is 0.82 ft.

Step 8: Compare the required D_{50} to the trial size selected in Step 2. If the trial size is smaller than the required size, it is unacceptable for the design. Repeat the procedure from Step 2, selecting a larger trial size. If the trial size is larger than the required D_{50}, then the design is acceptable. However, if the required D_{50} is sufficiently smaller than the trial size, the procedure may be repeated from Step 2 with a smaller, more cost-effective stone size.

In the design example, the trial D_{50} is larger than the required D_{50} therefore the design is acceptable. However since it is significantly larger than the required D_{50}, return to Step 2 using the previous iteration's required D_{50} of 0.82 ft as the new trial D_{50}.

Step 2(2): Trial D_{50} = 0.82' (Very Angular)

Step 3(4):

$d_i = 1.00$ ft

$A = Bd + Zd^2 = 7.00$ sq ft

$T = B+2dZ = 10.00$ ft

$$R = \frac{bd+Zd^2}{b+2d\sqrt{Z^2+1}} = 0.68 \text{ ft}$$

$A_a = Bd + Zd^2 = 4.27$ sq ft

$T_a = B+2dZ = 8.20$ ft

$$Ra = \frac{bd+Zd^2}{b+2d\sqrt{Z^2+1}} = 0.51 \text{ ft}$$

$d_a = A/T = 0.70$ ft

Step 4(4): $d_a/D_{50} = 0.85 \leq 1.5$ therefore use Equation 7.27-4

$$n = \frac{\alpha {d_a}^{1/6}}{\sqrt{g}\, f(Fr) f(REG) f(CG)} = 0.065$$

$$b = 1.14\left(\frac{D_{50}}{T_a}\right)^{0.453}\left(\frac{d_a}{D_{50}}\right)^{0.814} = 0.353$$

$v = Q/A_a$ = 4.075 ft/sec

$f(REG) = 3.434 \left(\frac{T_a}{D_{50}}\right)^{0.492} b^{1.025\left(\frac{T_a}{D_{50}}\right)^{0.118}}$ = 10.29

$Fr = \frac{v}{\sqrt{g\, d_a}}$= 0.858

$f(Fr) = \left(\frac{0.28Fr}{b}\right)^{\log(0.755/b)}$ = 0.881

$f(CG) = \left(\frac{T_a}{d_a}\right)^{-b}$= 0.419

Step 5(4): $Q = \frac{1.49}{n} A_a R_a^{\frac{2}{3}} S_f^{\frac{1}{2}}$ = 17.56 cfs

This flow is within 5% of 17.4 cfs; therefore go to Step 6.

Step 6: $R_e = \frac{\sqrt{gdS}\, D_{50}}{\nu}$ = 118000 = $1.18*10^5$

Note: The "d" that is used here is d_a + minimum freeboard of 0.5'

From Figure 7.27-4:

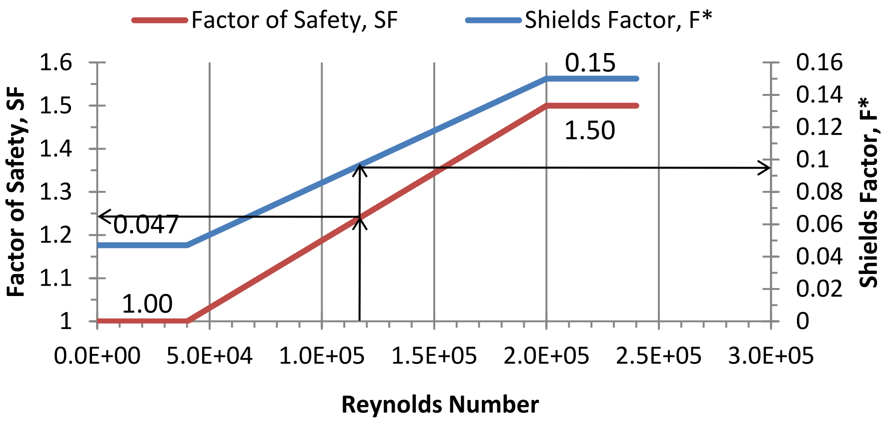
SF = 1.24

F* = 0.098

From Figure 7.27-4 interpolation:

SF = ((R_e – 40,000) * ($3.125*10^{-6}$)) + 1
= (($1.18*10^5$ – 40,000) * ($3.125*10^{-6}$)) + 1= 1.245

F* = ((R_e -40000)*($6.4375*10^{-7}$)) + 0.047
= (($1.18*10^5$ - 40000)*($6.4375*10^{-7}$)) + 0.047 = 0.098



Reynolds Number, R_e	Shield's Parameter, F*	Factor of Safety, SF
$\leq 4x10^4$	0.047	1
$4x10^4 < R_e < 2x10^5$	Linear Interpolation	Linear Interpolation
$\geq 2x10^5$	0.15	1.5

Step 7: Since slope is between 5% and 10% we must use both Equation 7.27-12 and Equation 7.27-13 and choose the larger outcome.

Equation 7.27-11:

$$D_{50} \geq \frac{SF\ d\ S}{F^* \left(\frac{\gamma_S}{\gamma} - 1\right)} = 0.75 \text{ ft}$$

$d = d_a$ + minimum freeboard of 0.5'
γ_s = specific weight of rock was assumed to be 165 lb/ft^3
γ = specific weight of water, 62.4 lb/ ft3

Equation 7.27-12:

$$D_{50} \geq \frac{SF\ d\ S\Delta}{F^* \left(\frac{\gamma_S}{\gamma} - 1\right)} = 0.90 \text{ ft}$$

$$\tau_s = \gamma d_a S_o = 3.49 \text{ lb/ft}^2$$
$$\eta = \frac{\tau_s}{F^* (\gamma_s - \gamma) D_{50}} = 0.426$$

Note: The D_{50} that is used here is the trial D_{50} (0.82').

$$\beta = \tan^{-1}\left(\frac{\cos\alpha}{\frac{2\sin\theta}{\eta\tan\phi} + \sin\alpha}\right) = 29.55°$$

$\alpha = \tan^{-1}(S) = \tan^{-1}(0.08) = 4.57°$

$\theta = \tan^{-1}(1/Z) = \tan^{-1}(1/3) = 18.44°$

φ = 41.5° (From Figure 7.27-5 using the trial D_{50} size (1.25') and Very Angular)

$$\Delta = \frac{K_1(1+\sin(\alpha+\beta))\tan\phi}{2\,(\cos\theta\tan\phi - SF\ \sin\theta\cos\beta)} = 1.21$$

$K_1 = 0.066Z + 0.67 = 0.066(3) + 0.67 = 0.868$

Note: $K_1 = .77$ ($Z \le 1.5$)
$= 0.066Z + 0.67$ ($1.5 < Z < 5$)
$= 1.0$ ($Z \ge 5$)

Therefore the required D_{50} size is 0.90 ft.

Step 8: The trial D_{50} is smaller than the required D_{50} therefore the design is unacceptable. Return to Step 2 and use the previous iteration's required D_{50} of 0.90 ft as the new trial D_{50}.

Step 2(5): Trial D_{50} = 0.90' (Very Angular)

Step 3(5):

$d_i = 1.00$ ft

$A = Bd + Zd^2 = 7.00$ sq ft

$T = B+2dZ = 10.00$ ft

$$R = \frac{bd+Zd^2}{b+2d\sqrt{Z^2+1}} = 0.68 \text{ ft}$$

$d_a = A/T = 0.70$ ft

$A_a = Bd + Zd^2 = 4.27$ sq ft

$T_a = B+2dZ = 8.20$ ft

$$Ra = \frac{bd+Zd^2}{b+2d\sqrt{Z^2+1}} = 0.51 \text{ ft}$$

Step 4(5): $d_a/D_{50} = 0.78 \le 1.5$ therefore use Equation 7.27-4

$$n = \frac{\alpha {d_a}^{1/6}}{\sqrt{g}\, f(Fr) f(REG) f(CG)} = 0.068$$

$$b = 1.14\left(\frac{D_{50}}{T_a}\right)^{0.453}\left(\frac{d_a}{D_{50}}\right)^{0.814} = 0.341$$

$v = Q/A_a = 4.08$ ft/sec

$$Fr = \frac{v}{\sqrt{g\, d_a}} = 0.858$$

$$f(Fr) = \left(\frac{0.28Fr}{b}\right)^{\log(0.755/b)} = 0.886$$

$$f(REG) = 3.434\left(\frac{T_a}{D_{50}}\right)^{0.492} b^{1.025\left(\frac{T_a}{D_{50}}\right)^{0.118}} = 9.540$$

$$f(CG) = \left(\frac{T_a}{d_a}\right)^{-b} = 0.432$$

Step 5(5): $Q = \frac{1.49}{n} A_a {R_a}^{\frac{2}{3}} {S_f}^{\frac{1}{2}} = 16.86$ cfs

This flow is within 5% of 17.4 cfs, therefore go to Step 6.

Step 6(5): $R_e = \frac{\sqrt{gdS}\, D_{50}}{\nu}$ = 130000 = 1.30*10^5

Note: The "d" that is used here is d_a + minimum freeboard of 0.5'

From Figure 7.27-4:

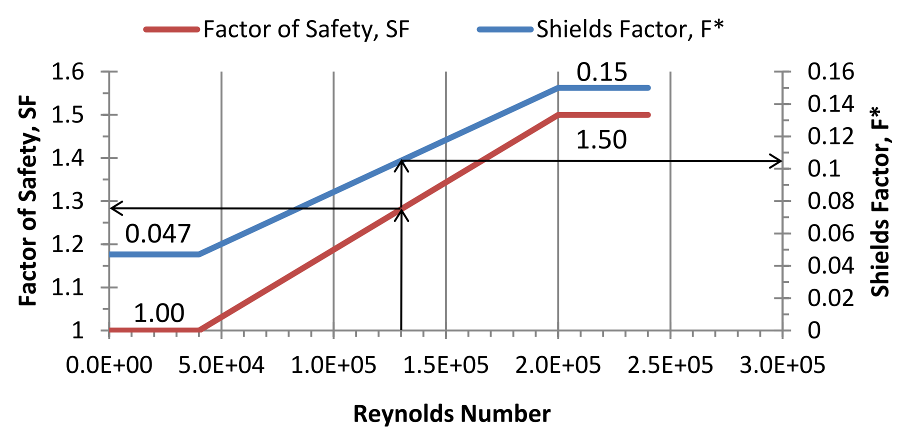
SF = 1.28

F* = 0.105

From Figure 7.27-4 interpolation:

SF = ((R_e – 40,000) * (3.125*10^{-6})) + 1
= ((1.30*10^5 – 40,000) * (3.125*10^{-6})) + 1= 1.28

F* = ((R_e -40000)*(6.4375*10^{-7})) + 0.047
= ((1.30*10^5 - 40000)*(6.4375*10^{-7}))+0.047 = 0.105



Reynolds Number, R_e	Shield's Parameter, F*	Factor of Safety, SF
$\leq 4x10^4$	0.047	1
$4x10^4 < R_e < 2x10^5$	Linear Interpolation	Linear Interpolation
$\geq 2x10^5$	0.15	1.5

Step 7(5): Since slope is between 5% and 10%,w use both Equation 7.27-11 and Equation 27-12 and choose the larger outcome.

Equation 7.27-11:

$D_{50} \geq \frac{SF\ d\ S}{F^*\left(\frac{\gamma_S}{\gamma}-1\right)}$ = 0.71 ft

d = d_a + minimum freeboard of 0.5'
γ_s = specific weight of rock was assumed to be 165 lb/ft^3

γ = specific weight of water, 62.4 lb/ ft3

Equation 7.27-12:

$$D_{50} \geq \frac{SF\ d\ S\Delta}{F^*\left(\frac{\gamma_s}{\gamma}-1\right)} = 0.86 \text{ ft}$$

$$\tau_s = \gamma d_a S_o = 3.494$$

$$\eta = \frac{\tau_s}{F^*\ (\gamma_s-\gamma)D_{50}} = 0.361$$

Note: The D_{50} that is used here is the trial D_{50} (0.90').

$$\beta = \tan^{-1}\left(\frac{\cos\alpha}{\frac{2\ \sin\theta}{\eta\tan\phi}+\sin\alpha}\right) = 26.03°$$

$\alpha = \tan^{-1}(S) = \tan^{-1}(0.08) = 4.57°$

$\theta = \tan^{-1}(1/Z) = \tan^{-1}(1/3) = 18.44°$

$\varphi = 41.8°$ (From Figure 7.27-5 using the trial D_{50} size (1.25') and Very Angular)

$$\Delta = \frac{K_1(1+\sin(\alpha+\beta))\tan\phi}{2\ (\cos\theta\tan\phi - SF\ \sin\theta\cos\beta)} = 1.21$$

K1 = 0.066Z + 0.67 = 0.066(3) + 0.67 = 0.868

Note: $K_1 = .77\ (Z \leq 1.5)$
$= 0.066Z + 0.67\ (1.5 < Z < 5)$
$= 1.0\ (Z \geq 5)$

Therefore the required D_{50} size is 0.86ft.

Step 8(5): **Specify Riprap with D_{50} = 12" = 1' for this channel.**

The trial D_{50} is slightly larger than the required D_{50} which is preferable. Ideally the trial D_{50} will be no more than 10% larger than the required D_{50}. One can then use this D_{50} size to specify the appropriate common riprap size, which in this case would be riprap with a D_{50} of 12" or 1'. The use of Excel is strongly recommended for performing these iterations.

The following example problem is for the design of a sediment basin and only addresses the hydraulic capacity and storage capacity. This design assumes a uniform basin geometry – a trapezoidal volume with a flat rectangular bottom surface. Note that basins can have many design constraints, such as available space, topography and proximity to receiving stream, that influence the final basin shape, location and geometrical configuration. Each design must be compatible with the site layout and must clearly address the design constraints. Detailed grading plans are required to ensure that the basin design can be constructed as intended on the site, given the site topography and space limitations.

This design follows the steps outlined in Chapter 7, Section 7.31. (The initial basin planning step should include consideration of determining the best location and general layout for the basin. The following steps provide a general approach toward developing the basin hydraulic design for storage and spillways.

GIVEN:
Design a sediment basin for an outfall to an *impaired* stream for the following assumptions and conditions:

1. Total drainage area = 10 acres
2. Time of concentration, T_c = 7.4 min (TR-55 analysis)
3. Construction site SCS Curve Number, CN = 91 (TR-55 analysis)
4. Incoming 5-year, 24-hour peak flow, Q_p = 47 cfs (TR-55 generated non-routed inflow to the sediment basin)
5. Incoming 25-year, 24-hour peak flow, Q_p = 47 cfs (TR-55 generated non-routed inflow to the sediment basin)
6. Assume that stormwater runoff enters the basin at the upper forebay end
7. Assume a minimum 4L:1W rectangular pond having 2H:1V interior side slopes where the incremental volume of basin depth is calculated from $V = \frac{(A_t+A_b)d}{2}$ where
   V = Volume of basin (ft^3)
   A_t = Basin top surface area (ft^2)
   A_b = Basin bottom surface (ft^2)
   d = incremental or total depth (ft)
8. Assume a permanent pool depth of 2 ft
9. Wet storage (permanent pool) basis = 67 CY/acre (1,809 ft^3/acre)
10. Total Dry Storage basis (Basin + Forebay) = 67 CY/acre (1,809 ft^3/acre)
11. Forebay storage = 25% x 67 CY/acre = 16.8 CY/acre (452 ft^3/acre)

REQUIRED DESIGN ELEMENTS:

- Wet, dry & forebay storage volumes
- Permanent pool - principal spillway riser crest elevation
- Riser pipe size
- Principal spillway conduit (barrel) pipe size
- Floating skimmer design: overall size selection and orifice diameter
- Emergency Spillway design: trapezoidal X-section, control crest elevation, width and side slopes
- Embankment dam crest elevation
- Bottom of pond elevation

SOLUTION:

Step 1: Set the basin geometry.

- Set the basin length to width ratio at 4L:1W
- Determine the storage volume needed (Total = sum of the wet, dry, and forebay storage volumes below riser crest)

  Total storage volume = (134 CY/ac) x (10 ac) = 1,340 CY = 36,180 ft^3

  Wet storage required at permanent pool = (67 CY/ac) x (10 ac) = 670 CY = 18,090 ft^3

  Total dry storage, including forebay vol. required = (67 CY/ac) x (10 ac) = 670 CY = 18,090 ft^3

  - Dry storage in forebay= (16.8 CY/ac) x (10 ac) = 68 CY = 4536 ft^3
  - Dry storage in main basin = 18,090 ft^3 - 4536 ft^3 = 13,554 ft^3
- Determine the required minimum surface area at the riser elevation, A_s

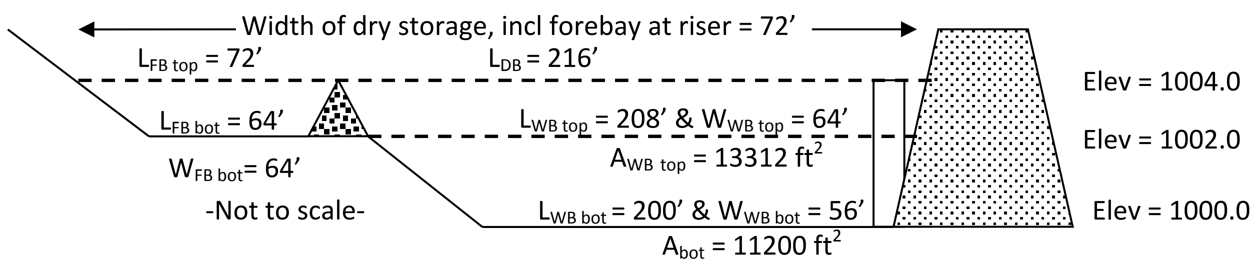
  $A_s = 0.01Q_p$ = (0.01) x (47 cfs) = 0.47 ac = 20,473.2 ft^2

  Determine a basin shape that provides the 4L: 1W surface geometry.

  - Try 72 ft x 288 ft

  - A_s = 72ft x 288 ft = 20,736 $ft^2 \geq$ 20,473.2 ft^2 ← Therefore OK

- The required surface area needs to be split between the basin and the forebay. The widths will be the same but the sum of the lengths should be equal to the total length of 288 ft. *(Note: the thickness of the forebay berm, normally around 4 or 5 ft, is not included here in determining wet and dry storage, but would need to be added to the overall basin length and shown in the plans):*



Note: In order to determine the Wet Storage Volume (from bottom to the given permanent pool depth of 2') an intermediate surface elevation at the permanent pool needs to be calculated. For this example the surface area at the permanent pool is 157' x 64'.

Step 2: Establish basin elevations.

Determine the riser height that corresponds to the required storage volumes. From the storage volume, determine storage volumes at specific elevations:

$$V = \frac{(A_t + A_b)d}{2}$$

- Assume a trial riser height of 4 ft (elev. 1004.0 ft)
  - Set the elevation of the bottom of pond = 1000.0 ft and Permanent Pool Elev. = 1002.0
  - Pond Dimensions at bottom of pond (elev 1000.0) = 149' x 56' = 8344 ft^2 for 2:1 SS
  - Pond Dimensions at permanent pool (elev. 1002.0) = 157' x 64' = 10,048 ft^2 for 2:1 SS

- **Wet Storage (From bottom to permanent pool) = 24,512 ft^3 ≥ 18,090 ft^3 <u>therefore OK</u>**

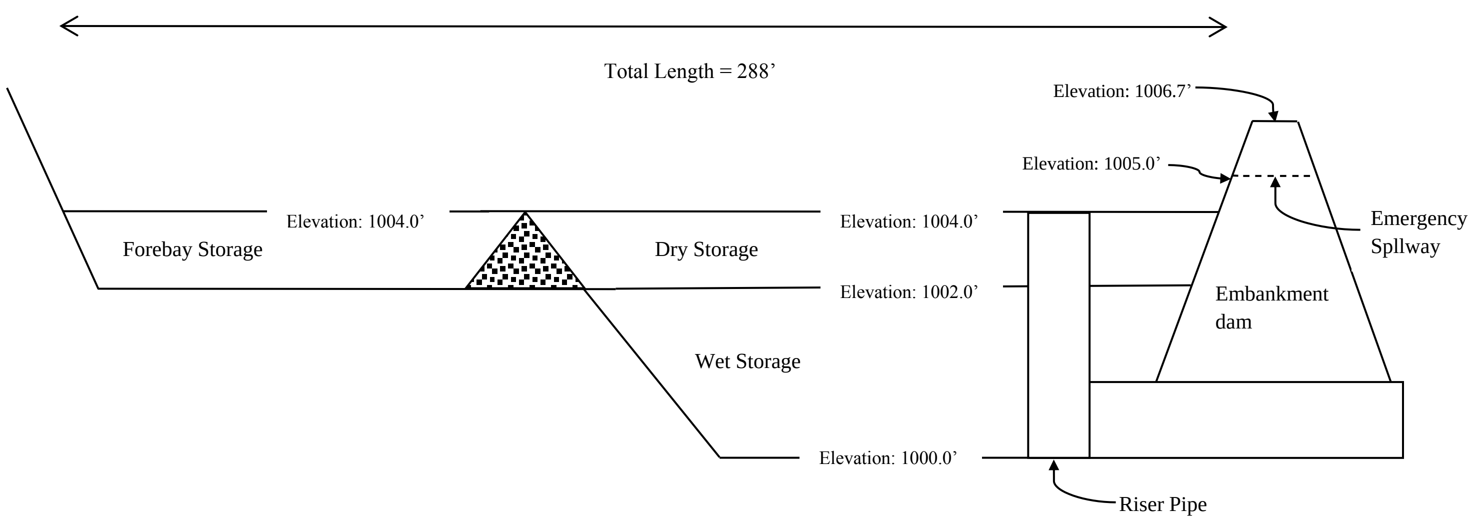
- Forebay Dimensions at bottom (elev. 1002.0) = 64’ x 64’ = 4096 ft^2 for 2:1 SS
- Forebay dimensions at top (elev. 1004.0) = 72’ x 72’ = 5184 ft^2 for 2:1 SS
- **Forebay Storage = 9,280 ft^3 ≥ 4,536 ft^3 <u>therefore OK</u>**

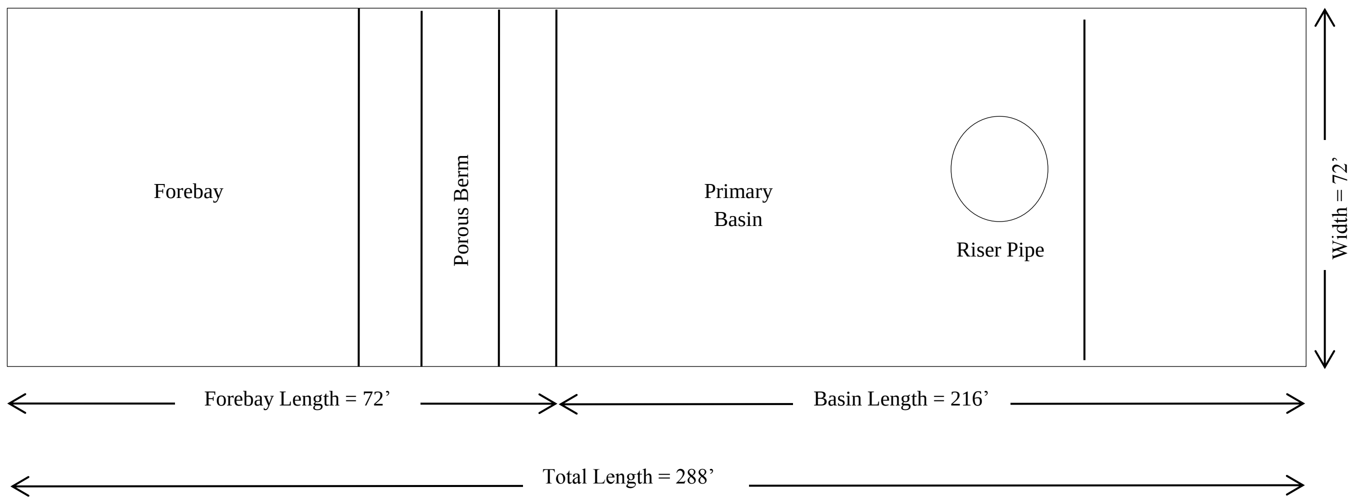
- Main dry pond dimensions at perm pool (elev 1002.0) = 157’ x 64’ = 10,048 ft^2 for 2:1 SS
- Main dry pond dimensions at top (elev 1004.0) = 216’ x 72’ = 15,552 ft^2 for 2:1 SS
- **Dry Storage (from Elevation 1002’ to elev. 1004’) = 28,864 ft^3 ≥ 13,554 ft^3 <u>therefore OK</u>**

- **Total Dry Storage, including Forebay = 9,280 ft^3 (24%) + 28,864 ft^3 (76%) = 38,144 ft^3 ≥ 18,090 ft^3 <u>therefore OK</u>**

Therefore the trial riser height of 4 ft is acceptable

Set the bottom of basin elevation = 1000.0 ft
Set the permanent pool elevation = 1002.0 ft
Set the riser crest elevation = 1004.0 ft





Step 3: Design spillways

Principal Spillway

(A) Establish principal spillway elevation = 1004.0 ft

- Assume riser diameter = 36" = 3 ft
  Circumference = 113" = 9.42' of weir length
- Assume rectangular sharp crested weir w/ a coefficient of 3.33
  (Note: The riser operates as a sharp-crested weir up to a certain head and then switches to orifice flow.)
- Hydraflow Express gives a depth of 1.31' for 47 cfs. At the minimum freeboard of 1' from top of principal spillway to emergency spillway, the emergency spillway will convey a portion of the 5-year, 24-hour design storm.
- *Conduit Pipe Size (The capacity of the service spillway is usually limited by the outlet pipe.)*
  From Hydraflow Hydrographs an outlet pipe size = 24" = 2' has adequate capacity.

Emergency Spillway (Flow credit is given to the service spillway but not the dewatering device.)

(B) Emergency spillway elevation = 1004.0' (Principal Elevation) + 1' (minimum freeboard) = 1005.0 ft

- 25-year, 24-hour storm event: Q_p = 67 cfs
- Emergency spillway design flow = 67 cfs - 31.37 cfs (flow credited to 3-ft diameter principal spillway at 1-ft head over crest) = 35.63 cfs
- Assume a weir length = 20'
- Hydraflow Express gives a flow control depth of 0.66 ft
- Top of Berm Elevation = 1005.0' (Emergency Spillway Elevation) + 0.66' (depth of 25 yr storm) + 1' (minimum freeboard) = 1006.7 ft
- Emergency Spillway Sideslopes = 4:1

Step 4: Dewatering Device (Skimmer)

Need to dewater the dry storage (38,144 ft^3) in 72 hours

- Choose a 4-inch skimmer which has a capacity of 60,327 cubic feet in 3 days.
- Determine the orifice size for the manufacturer's given orifice head and discharge coefficient. The head will vary depending upon the manufacturer's design depth of submergence for a given orifice diameter. Use the following Skimmer size vs. orifice head table based on the Faircloth® skimmer as an example.

Skimmer Size (inches)	Head (h) on orifice in ft
1.5	0.125
2	0.167
2.5	0.208
3	0.25
4	0.333
5	0.333
6	0.417
8	0.5

*The flow (cfs) through an orifice can be computed as:

$$Q = CAo\sqrt{2gH} = C\,\pi r_o^2\sqrt{2gH}$$

where C is the orifice coefficient (assumed to be 0.59), A_o is the orifice cross-sectional area in ft^2, r_o is the orifice opening radius (ft), g is the acceleration of gravity (32.2 ft/sec^2), and H is the driving head on the orifice center in feet.

Rearranging the previous equation, the desired orifice radius in feet can now be calculated using the following equation:

$$r_o = \sqrt{\frac{Q}{14.87 * \sqrt{H}}}$$

Where flow, Q, is based on draining the total dry volume in 3 days as follows:

$$Q_d = \frac{V}{t_d} = \frac{38{,}144\ ft^3}{3\ days} = 12{,}715\ \frac{ft^3}{day} = 0.147 \text{ cfs}$$

Try a 4-inch skimmer, which has a flow capacity rating for draining up to 60,327 cubic feet in 3 days and has an orifice head, h = 0.333 ft

$$r_o = \sqrt{0.147\frac{ft3}{sec}/(14.87 * \sqrt{0.333\ ft})} = 0.131 \text{ ft} = 1.6 \text{ inches}$$

Therefore, use a 4- inch skimmer with an orifice diameter d_o of 3.2 inches

*Note: Skimmer manuafacturer charts or software may be used as an alternative method for sizing orifice.

In Summary:

<table>
<tr><td rowspan="4">EXAMPLE BASIN 1</td><td>RISER PIPE DIA. (FT)</td><td>BARREL PIPE DIA. (FT)</td><td>PERMANENT POOL ELEVATION (FEET, AMSL)</td><td>PRINCIPAL SPILLWAY ELEVATION (FEET, AMSL)</td><td>EMERGENCY SPILLWAY ELEVATION (FEET, AMSL)</td></tr>
<tr><td>3</td><td>2</td><td>1002.0</td><td>1004.0</td><td>1005.0</td></tr>
<tr><td>EMERGENCY SPILLWAY WIDTH (FT)</td><td>EMERGENCY SPILLWAY SIDESLOPE</td><td>TOP OF EMBANKMENT ELEVATION (FEET, AMSL)</td><td>BOTTOM OF BASIN ELEVATION (FEET, AMSL)</td><td>SKIMMER (ORIFICE) SIZE (INCHES)</td></tr>
<tr><td>20</td><td>4:1</td><td>1006.7</td><td>1000.0</td><td>4 (3.2)</td></tr>
</table>

Option: The above parameters can be entered into hydraulic routing software to refine the design. This would likely result in more credit being given to the principal spillway for a portion of the 25-year, 24-hour storm flow and the overall depth and volume of the basin may be able to be reduced. Following the design presented above will result in a conservative design (i.e. storage > 134 CY/acre). A minimum 25% of the dry storage volume will be provided as part of the forebay at the pond inlet. In other words, this volume can be credited to the overall dry storage (such that 75% of the required total dry storage volume is provided in the primary basin).

Note: This sediment basin design example does not include required emergency spillway lining calculations and design nor does it include service spillway outlet structure apron design and calculations. Furthermore, the sediment basin design example does not discuss required service spillway anti-buoyancy pad, anti-vortex & trashrack, dam design analysis, anti-seep collars, details of surface skimmer connection to riser & skimmer base pad, or forebay berm design.