Sediment Basin Design Basics w/ Surface Dewatering Devices

Sediment Removal

- Gravity; Stokes Law
  \[ V_s = \frac{1}{18} \frac{d^2 g (SG - 1)}{\nu} \]
  - Particle diameter.
  - Liquid viscosity = f(temperature).
  - Particle density = 2.65 g/cc (165 #/ft^3)

- Assumptions:
  - Water velocity = Zero (0); quiescent
  - Water temperature = 68ºF
  - Laminar flow; Reynolds No. < 0.5
### Impact of Control Features

- Washed aggregate. Helps a little (2%)  
- Permanent pool. Helps 5 to 12%  
- Dewatering control devices  
  - Perforated risers. **Okay; not desired**  
  - Skimmers. **Great Improvement; 10%**  
  - Auxiliary spillways. **Better than no skimmer +6%**
- Basin lining. Reduces re-suspension, Good  
- PAM to remove clays. **Great**

### Impact of Control Features

- Geotextiles  
  - To filter sediment. **Not very effective.**  
  - As porous baffles. **Porous Jute/Coir w/ PAM & skimmer; Very Good**
- Dewatering time. Longer is better.  
- Delaying the dewatering process. Very good.  
- Infiltrating the captured water. Great if soils permit.

### Structure Sizing

- **Criteria:**  
  - Minimum Volume:  
    - 2 yr, 24 hr storm for drainage area (EPA 2012 CGP) or  
    - 3,600 ft³/ac in drainage area (EPA)
- **Criteria in Some States:**  
  - Minimum Volume Area  
    - 1,800 ft³/disturbed ac  
  - Minimum Surface Area  
    - 435 Q₁₂ or Q₂₅ (Rock or Perforated Riser)  
    - 325 Q₁₂ or Q₂₅ (Surface Outlet or Flashboard Riser)
### Sizing Example

- Determine the minimum volume and surface area for a Temporary Sediment Trap serving a 1.2-acre road construction site with a 2 acre watershed with a $Q_{10} = 7$ cfs.
- **Solution:**
  - Minimum Volume $= 3600(2) = 7200$ ft³
  - Minimum Surface Area $= 435(7) = 3045$ ft²

### Controlling Discharge

- Rock outlet
- Perforated Riser
- Skimmer
- Flashboard riser

### Rock Outlet

- When sediment laden water gets to the rock (porous) outlet, sediment remains in suspension.
Perforated Riser

- Will capture 80% of inflow fine sediment when water is held for 24 hours.

Skimmer

- Will capture 90% of fine (silts & clay) sediment when water is held for 24 hours.
- Surface Skimmer  Alternate Skimmers

Orifice Equation (cfs)

\[ Q = CA\sqrt{2gH} \]

- Perforated Riser & Skimmer are controlled by small orifices.
  - C = coefficient: 0.6
  - A = area of orifice, ft²
  - g = 32.2 ft/sec² or 9.81 m/sec²
  - H = driving head, ft
  - Q = flow rate, ft³/sec, cfs
**Orifice Equation (gpm)**

• Alternate form (gpm):
\[ Q = 12D^2 \sqrt{H} \]
- Where \( D \) = diameter, inches
- \( H \) = head, ft
- Last example: \( D = 0.75 \) in, \( H = 1.5 \) ft

\[ Q = 12(0.75)^2 \sqrt{1.5} = 8.1 \text{ gpm} \]

**Orifice Equation Example**

• A skimmer has a 2-in orifice and a head of 0.25 ft. What is the skimmer's discharge rate?
• Solution: \( D = 2 \) in; \( H = 0.25 \) ft

\[ Q = 12D^2 \sqrt{H} = 12(2)^2 \sqrt{0.25} = 24 \text{ gpm} \]

**Orifice Equation (ft}^3/\text{d})**

• Alternate form (ft}^3/\text{d}):
\[ Q = 2310D^2 \sqrt{H} \]
- Where \( D \) = diameter, inches
- \( H \) = head, ft
- Last example: \( D = 2 \) in, \( H = 0.25 \) ft

\[ Q = 2310(2)^2 \sqrt{0.25} = 4620 \text{ ft}^3/\text{d} \]
Surface Skimmer Sizing

- Determine the desired outflow rate, $Q$ (ft$^3$/d) based on:
  - Volume of the basin, $V$ in ft$^3$
  - Desired dewatering time, $t_d$ in days.

$$Q = \frac{V}{t_d}$$

- Example: Dewater 21,000 ft$^3$ in 3 days.

$$Q = \frac{21000 \text{ ft}^3}{3 \text{ days}} =$$

Select skimmer based on desired flow rate from Table 4-1

<table>
<thead>
<tr>
<th>Skimmer Diameter (in)</th>
<th>Max. Outflow Rate (ft$^3$/d)</th>
<th>Driving Head (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>1,728</td>
<td>0.125</td>
</tr>
<tr>
<td>2.0</td>
<td>3,283</td>
<td>0.167</td>
</tr>
<tr>
<td>2.5</td>
<td>6,234</td>
<td>0.208</td>
</tr>
<tr>
<td>3.0</td>
<td>9,774</td>
<td>0.250</td>
</tr>
<tr>
<td>4.0</td>
<td>20,109</td>
<td>0.333</td>
</tr>
<tr>
<td>5.0</td>
<td>32,832</td>
<td>0.333</td>
</tr>
<tr>
<td>6.0</td>
<td>51,840</td>
<td>0.417</td>
</tr>
<tr>
<td>8.0</td>
<td>97,978</td>
<td>0.500</td>
</tr>
</tbody>
</table>

Skimmer Orifice Sizing

- Apply the orifice equation to size the orifice diameter & radius
  - If we use a 3-inch skimmer ($H = 0.250$ ft), we can size the orifice as:

$$D = \sqrt[3]{\frac{Q}{2310 \sqrt{H}}} = \sqrt[3]{\frac{7000}{2310 \sqrt{0.250}}} = 2.5 \text{ inches}$$

$$r = \frac{D}{2} = 2.5 / 2 = 1.3 \text{ inches}$$
Flashboard Riser

- Works like a skimmer but with more labor.

Dewatering Via Infiltration

- Can be effective into sandy soils.
- Compute the dewatering time knowing:
  - The soil's infiltration rate (permeability)
  - Depth of water in basin

\[ T_d = \frac{\text{water depth (inches)}}{\text{Infiltration rate (in/hr)}} = \frac{D}{I} \text{ (hours)} \]

Infiltration Rate

- Equals the soil’s permeability
  - Given by NRCS in ranges; ex. 0.6 to 2.0 in/hr.
  - Use permeability from slowest permeable soil horizon; usually B or C horizon.
  - Use the lower value.
  - That’s the lowest value from slowest layer.
Dewatering Time

- Example: 10,000 ft³ basin has a design depth of 1.5 feet. Soil has \( I = 0.6 \) in/hr.

\[
T_d = \frac{D(\text{in})}{I(\text{in/hr})} = \frac{1.5 \text{ ft} \times 12 \text{ in}}{0.6 \text{ in/hr} \times 1 \text{ ft}} = \]

Emergency Spillway

<table>
<thead>
<tr>
<th>Drainage Area (acres)</th>
<th>Minimum Emergency Spillway Width or Broad Crested Weir Length (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.0</td>
</tr>
<tr>
<td>2</td>
<td>6.0</td>
</tr>
<tr>
<td>3</td>
<td>8.0</td>
</tr>
<tr>
<td>4</td>
<td>10.0</td>
</tr>
<tr>
<td>5</td>
<td>12.0</td>
</tr>
</tbody>
</table>
Weir Equation

- Flow from an emergency spillway or a flashboard riser is controlled by the weir equation.

\[ Q = 2.5LH^{1.5} \]

- Where:
  - \( L \) = width of the weir, ft
  - \( H \) = the driving head (1 ft max), ft
  - \( Q \) = flow rate, cfs

Weir Equation Example

- How wide should an emergency spillway be to carry \( Q_{10} = 20 \) cfs with a maximum head of 0.5 ft.

Sediment Control BMPs

- Coir Fiber Baffles
- Rock Sediment Dams
- Skimmer Basin
- Tiered Skimmer Basin
- Riser Basin
- Infiltration Basin
**Design Considerations**

- Project phasing
- Scheduling of construction activities
- Cost-benefit issues
- Overall costs
- Equipment access
- Constructability
- Seasonality

**Stone Sizes**

<table>
<thead>
<tr>
<th></th>
<th>Min. (inches)</th>
<th>Median (inches)</th>
<th>Max. (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment Control Stone</td>
<td>~3/8</td>
<td>½-3/4</td>
<td>1.5</td>
</tr>
<tr>
<td>(washed, no fines)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No.5/No. 57</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structure Stone</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Class A</td>
<td>5</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Class B</td>
<td>5</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Class I</td>
<td>9</td>
<td>14</td>
<td>23</td>
</tr>
<tr>
<td>Class II</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Coir Fiber (Coconut) Baffles**

- **Purpose:** Increase sediment trapping efficiency by spreading water out over width of basin
- **Materials:**
  - Coir Matting (6.5 ft width, 700 g/m²)
  - Metal t-posts
  - 9 gauge wire (hi-tensile fencing wire)
  - UV coated plastic zip ties
  - 12 inch metal landscape staples
Coir Fiber (Coconut) Baffles

- Large rock dam with weir outlet
- Location: site perimeter
- Drainage area < 10ac
- Surf. Area: 435Q_{10} or Q_{25}
- Volume: 3600ft^{3}/ac
- Class I structure stone
- Sediment control stone on inlet face
- Earthen walls built above grade
- L:W ratio range 2:1-5:1
### Temp. Rock Sediment Dam - Type B
- Small rock dam with weir outlet
- Location: site perimeter
- Drainage area < 5ac
- Surf. Area: 435Q_{10} or Q_{25}
- Volume: 3600 ft^3/ac
- Class B structure
- Sediment control stone
- 3 coir baffles
- Earthen walls built above grade
- L:W ratio range 2:1-5:1

### Skimmer Basin w/ Baffles
- Rectangular basin
- 3 coir baffles
- Location: site perimeter
- Drainage area < 10ac
- Surf. Area: 325Q_{10} or Q_{25}
- Volume: 1800 ft^3/ac
- Surface outlet devices
  - Surface Skimmer
  - Weir
- Earthen walls (above grade)
- L:W ratio range 3:1-5:1
- Drawdown in 2-3 days (top 2 ft only)
- Max depth to weir, 3 ft
**Skimmer Basin w/ Baffles**

- 2 basins at different elevations
- 3 coir baffles
- Location: site perimeter
- Drainage area < 10ac
- Surface Area: 325Q_{10} or Q_{25}
- Volume: 1800 ft³/ac
- Surface outlet devices
  - Skimmer
  - Weir
- Earthen walls built above grade
- L:W ratio range 3:1-5:1

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**Skimmer Basin Detail**

- Rectangular basin
- Steel posts
- Drain pipes
- 12 inch slope
- Not to scale

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**Tiered Skimmer Basin**

- Rectangular basin
- 2 basins at different elevations
- 3 coir baffles
- Location: site perimeter
- Drainage area < 10ac
- Surface Area: 325Q_{10} or Q_{25}
- Volume: 1800 ft³/ac
- Surface outlet devices
  - Skimmer
  - Weir
- Earthen walls built above grade
- L:W ratio range 3:1-5:1
**Tiered Skimmer Basin**

- Rectangular basin
- Location: site perimeter
- Drainage area < 100ac
- Surf. Area: $435Q_{10}$ or $Q_{25}$
- Volume: $3600 \text{ ft}^3/\text{ac}$
- Earthen walls built above grade
- L:W ratio range 2:1-5:1

Outlet devices
- Perforated riser pipe w/ sed. control stone
- Overflow Spillway

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**Riser Basin**

- Rectangular basin
- Location: site perimeter
- Drainage area < 100ac
- Surf. Area: $435Q_{10}$ or $Q_{25}$
- Volume: $3600 \text{ ft}^3/\text{ac}$
- Earthen walls built above grade
- L:W ratio range 2:1-5:1

Outlet devices
- Perforated riser pipe w/ sed. control stone
- Overflow Spillway
Infiltration Basin w/ Baffles

- Rectangular basin
- 3 coir baffles, equally spaced
- Location: site perimeter
- Requires highly porous soils—sand
- Drainage area < 10ac
- Surf. Area: $325Q_{10}$ or $Q_{25}$
- Volume: 1800 ft$^3$/ac
- Outlet devices
  - Infiltration
  - Weir (emergency spillway)
- Dug into ground
- L:W ratio range 3:1-5:1
### Summary

<table>
<thead>
<tr>
<th>Sediment Basin Type</th>
<th>Max. Drainage Area (acres)</th>
<th>Minimum Surface Area (ft² per cfs of Q₁₀ peak inflow)</th>
<th>Minimum Volume (ft³ per acre of drainage area)</th>
<th>Outlet Structure</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riser Basin</td>
<td>100 (10 acre min.)</td>
<td>435</td>
<td>3,600</td>
<td>Non-perforated Riser w/ Skimmer</td>
<td>Removes Sand, Silt and Clay***</td>
</tr>
<tr>
<td>Skimmer Basin</td>
<td>10</td>
<td>325</td>
<td>3,600</td>
<td>Skimmer</td>
<td>Removes Sand, Silt and Clay***</td>
</tr>
<tr>
<td>Tiered Skimmer Basin</td>
<td>10</td>
<td>325</td>
<td>3,600</td>
<td>Skimmer</td>
<td>Removes Sand, Silt and Clay***</td>
</tr>
<tr>
<td>Rock Filter Dam</td>
<td>&lt; 1</td>
<td>435</td>
<td>3,600</td>
<td>Riprap Dike</td>
<td>Removes Sand and Silt</td>
</tr>
<tr>
<td>Sed Basin Type II</td>
<td>&lt; 3</td>
<td>325* (435**)</td>
<td>1,800* (3,600**)</td>
<td>N/A</td>
<td>Removes Sand and Silt</td>
</tr>
</tbody>
</table>

* When used adjacent to drainage structures (e.g. inlets, catch basins, etc.)
** When used in conjunction with stone devices (e.g. rock checks, stone inlet protection, etc.)
*** With flocculant incorporated on upgrade measures

### Summary

Alternative Sediment Storage BMPs

<table>
<thead>
<tr>
<th>Ditch Grade</th>
<th>0 - 2%</th>
<th>2-3%</th>
<th>&gt;3%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternate BMP to Design</td>
<td>Wattles with PAM</td>
<td>Wattles with PAM alternating with Rock Check Dams</td>
<td>Rock Check Dams with a section of erosion control blanket on upstream side with PAM applied to top of the blanket at weir</td>
</tr>
<tr>
<td>Upgrade of Sediment Basin</td>
<td>Wattles with PAM</td>
<td>Wattles with PAM alternating with Rock Check Dams</td>
<td>Rock Check Dams with a section of erosion control blanket on upstream side with PAM applied to top of the blanket at weir</td>
</tr>
</tbody>
</table>

### Questions

- What are the advantages of using riprap and PAM in sediment storage?
- How do tiered skimmer basins differ from standard skimmer basins in terms of efficiency?
- What factors should be considered when choosing a sediment basin type?