
Section 5

Liquid-Solid Separation

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Topics

- Settling basin design
- Alternative solids settling facilities
- Active versus passive management

Purpose

The liquid-solid separation component within a VTS is intended to:

- Intercept all open lot runoff
- Remove most settleable solids from feedlot runoff. Solids removal is critical to reducing nutrient and related pollutant loading on the VTA or VIB and minimizes vegetation damage due to solids accumulation.
- Release liquids to VTA or VIB in a controlled manner. Controlled release of liquids to a VTA at an appropriate time is critical to minimizing the potential for discharge.

This section describes the design features of the liquid-solid separation component critical to achieving these three goals.

Some of the information in this section is from Livestock Waste Facilities Handbook (MWPS-18), Chapter 5, Liquid Solids Separation. Printed with the permission of the Midwest Plain Service, 1985.

Liquid-solid separation is an essential pre-treatment component for both CAFO and AFO applications of a VTA or VIB.

Description

Liquid-solid separation within feedlot runoff is most commonly achieved by flow velocity reduction to allow settling of solids from the runoff. Settled solids can be collected from the liquid-solid separation component and land applied according to a nutrient management plan.

Settling basins are the most common type of liquid-solids separation used to treat runoff from an animal feeding operation feedlot or pen surface. Alternative settling facilities include settling benches, silt fences, and gravel spreaders. Settling tanks and settling channels can also be used in certain situations.

A settling basin, when preceding a VTA, may also be designed to delay or spread out the release of liquids over a significant period of time to minimize the risk of a discharge from the VTA. This may require the settling facility to include storage with active or passive control of the release of liquids over time.

The initial treatment of any open feedlot runoff control system should be solids removal, as is currently required by many state laws. Properly designed and managed solids settling basins should remove about 30 percent of the N and P from the runoff from swine lots and 50 percent or more of each from cattle lot runoff. For additional information on the performance of solids settling, see the literature review in section 9.

Solids removal design issues

Contaminated runoff from lots carries organic matter and other solids. Typical open lot runoff characteristics are summarized in table 5–1. See section 9 for additional information on characteristics.

Settling facilities are designed to intercept all lot runoff, settle out most of the solids, and release liquids to a VTA or VIB. Settling separates solids from dilute liquid slurry by reducing velocity. Fast moving liquids pick up and transport solids; when velocity slows, some of those solids settle by gravity.

Solids separation and periodic solids removal is the key to successful treatment of precipitation runoff from beef and dairy feedlot surfaces. Liquid that is to be released to a VTA or VIB should always have solids removed first minimizing solids, nutrient, and salt buildups within the vegetated area. Buildups of these materials would potentially harm vegetation in the treatment area and negatively impact soil structure and water intake characteristics.

Physical size of the settling facility is typically based upon two considerations:

- Solids settle at a rate of approximately 4 feet per hour. Based upon a selected depth for a settling basin, a minimum holding time (hydraulic retention time) can be established. For example, a 2-foot deep basin would require a 30-minute minimum holding time ($2 \text{ ft deep} \div 4 \text{ ft/h} = \frac{1}{2} \text{ h}$)
- A basin size designed to hold a selected frequency precipitation event. The most critical design situation is the high-intensity, short-duration rainfall event. A large water volume picks up manure and carries it in the runoff. Experience has shown that the 10-year, 1-hour storm (app. B) is

Table 5–1 Average chemical characteristics of runoff from beef cattle feed yards in the Great Plains (see sec. 9 for additional information on characteristics)

Source	Total solids (ppm)	Volatile solids (ppm)	Electrical conductivity (mmhos/cm)	Total nitrogen (ppm)	Total phosphorus (ppm)	Potassium (ppm)
Feedlot runoff ¹						
Average	11,200		6.5	580	120	1,020
Range	3,000–17,500		3.2–8.6	80–1,080	50–300	340–1,320

¹ Sweenten 1991

acceptable for designing settling facilities tied to VIBs and runoff holding ponds. A larger 25-year, 24-hour storm (app. B) may be appropriate for settling basins in advance of a VTA on a large CAFO, especially where runoff release to the VTA is actively or passively managed. When a larger storm occurs than the design volume, the percent of manure solids removed by the basin is reduced slightly. However, a system can manage larger runoff peak flows and lose little in treatment efficiency if the minimum holding time is not substantially reduced.

Control over the release of liquids from a settling basin into the VTA is a second critical design feature. Allowing feedlot runoff water to pass through the settling basin and into the VTA simultaneously with a rainfall event has the potential to exceed the infiltration capacity of the soil in the VTA and result in discharges. VTAs have gained limited acceptance within the regulatory community for CAFO applications due to this concern. Two options are available for controlled release of liquid from the settling facility to a VTA:

- Restrict the settling facility outflow to extend flow over 30 to 72 hours (passive runoff release control). This minimizes the contaminated runoff addition to the VTA during the storm event to minimize the chance of exceeding infiltration rates.
- Actively manage the outflow to avoid any release during a storm event (active runoff release control). Contaminated runoff stored in the settling facility would then be released after the storm event. If released at a slow enough rate, smaller VTAs may be possible while retaining a match between soil infiltration rate and release of liquid from the settling basin.

A combination of a settling facility with significant storage capacity (sized for a 25-yr, 24-h storm) in combination with active or passive release of liquids to the VTA will minimize the potential for a discharge from the VTA.

Settling basin design

A settling basin temporarily retains runoff and permits liquids to drain to a waste storage pond, lagoon, or VTA in a controlled manner. Solids remain in the basin for drying and later removal with a front-end loader or similar equipment.

The best basin shape is relatively large and shallow. If solids are removed from the basin with conventional solid manure handling equipment, basin depth should normally be 3 feet deep or less. Settled solids can be removed by driving unloading equipment on the basin floor. In arid areas where settling basins dry out readily, earthen basins may be satisfactory (fig. 5-1).

In humid areas, concrete bottoms or complete concrete basins may be necessary so equipment can enter the basin for clean out (fig. 5-2). Provide at least one vertical wall when constructing settling basins of concrete. This will provide a bucking wall for a front-end loader when removing separated solids from the basin.

Access ramp slope should be 10:1 (horizontal length: vertical fall) or flatter, for front-end loaders. Basin bottoms are often provided with a slight uniform grade (0-5 in/100 ft) to the discharge point to ensure proper drainage at low flows and prevent ponding and encourage drying of the solids in the basin.

Build earthen basins with 3:1 side slopes; if erosion is a problem, use a 4:1 slope or flatter slope on the inlet side. The top width of earth basin ridges must be at least 12 feet wide if planned for vehicle traffic; a minimum 3-foot ridge top width would be required to maintain the design height of earthen settling basin ridges. Plant and maintain grass cover where possible on all settling basin ridges. The bottom of the basin where solids accumulate may need to be concrete in higher precipitation areas, while earthen bottoms are typically satisfactory in more arid climates.

Maintenance and pen clean-out frequency greatly influence settling basin treatment efficiency. A properly managed open lot and settling basin can retain up to 85 percent of the non-floating solids in the lot or basin, regardless of lot slope. Research indicates that solids can accumulate at a rate 0.5 acre-inch settled solids per acre of unpaved lot per year. This value is much less for paved lots.

The required frequency of basin cleaning varies considerably depending on basin size, type of lot surface, amount of manure on the lot surface, and storm runoff characteristics. In some instances, cleaning may be

necessary after each large storm, but a cleaning frequency of 2 to 6 times per year is adequate if the basin is designed large enough to store the accumulated solids. Provide temporary storage areas for separated sol-

ids (within the area from which runoff is collected) unless they are transported directly from the basin to the final end use (land application).

Figure 5-1 Earthen sidewall settling basin. For dry regions, an earthen base for the basin is acceptable. In higher rainfall areas, the base should be concrete.

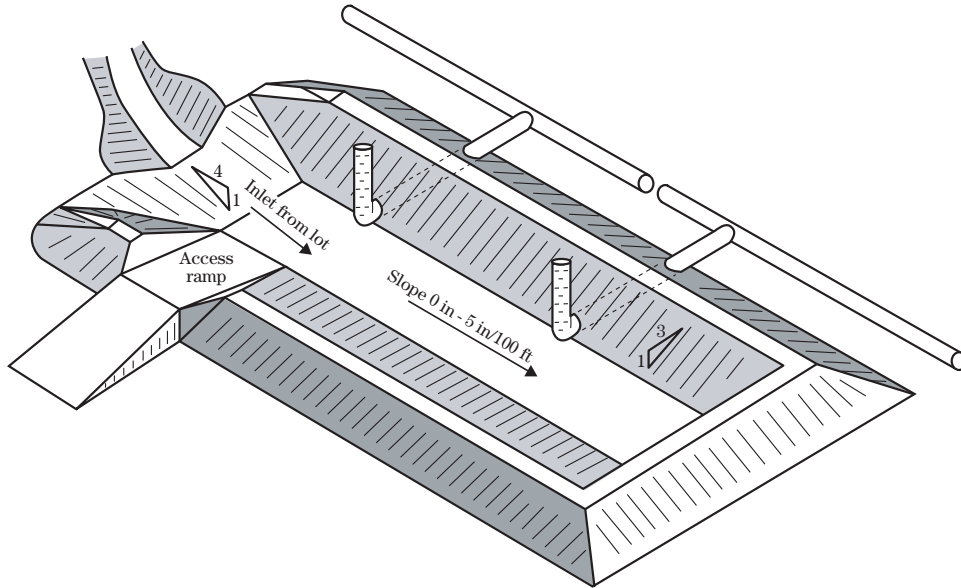
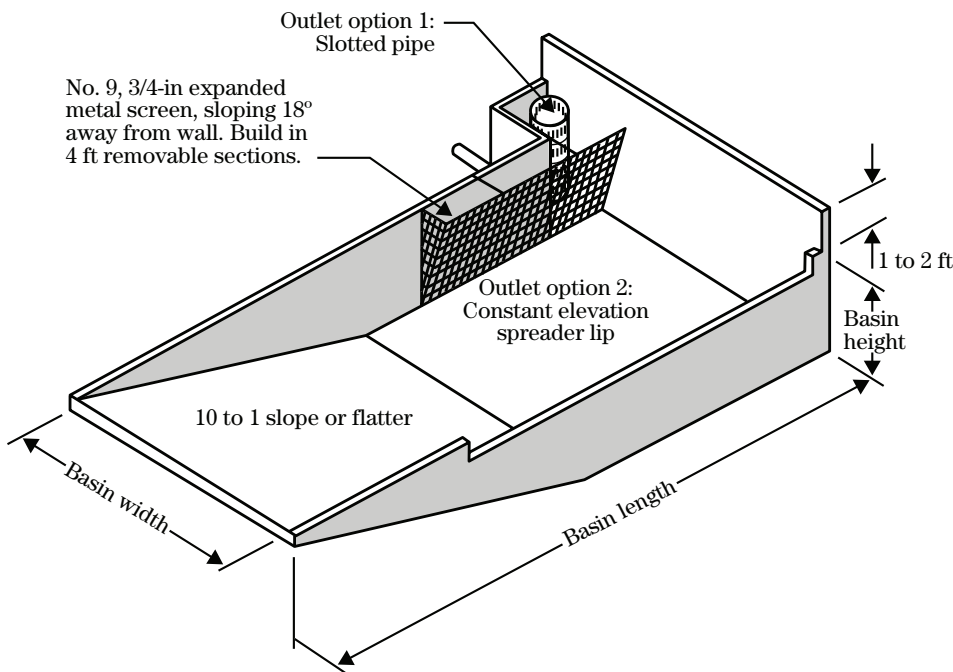


Figure 5-2 Concrete settling basin for regions with higher precipitation



Settling basin outlets

Several types of basin outlets are available to drain liquids from the full depth of the settling basin and dewater solids. Perforated or slotted pipe risers, and porous plank dam are examples.

Manure plugs, outlet openings, debris, and bedding tend to plug even large openings. As the settling basin drains, the liquid drains through fewer slots or perforated openings and solids concentration increases further adding to the plugging problems. Cleaning of outlet openings is commonly required to allow the settling basin to fully drain and solids to dry allowing their removal. The outlets should be designed for easy cleaning. A portable propane weed/brush burner will clean most debris from a metal screen but does not work on a PVC pipe.

Consider adding a slanted expanded metal screen around the settling basin outlet to increase the screening area (fig. 5-2). These screens are usually expanded steel, usually .75 inch, No. 9 or heavy quarry screen, with about 1- to 1.5-inch openings. In practice, the screens tend to be bulky and are seldom removed during tractor cleaning of the basin. Therefore, place the screens on the sidewall, not the bucking (or end) wall. Any settling facility that passes runoff liquids through a screen requires screen cleaning of solids after each runoff event. This maintenance is critical to drying solids for their eventual removal.

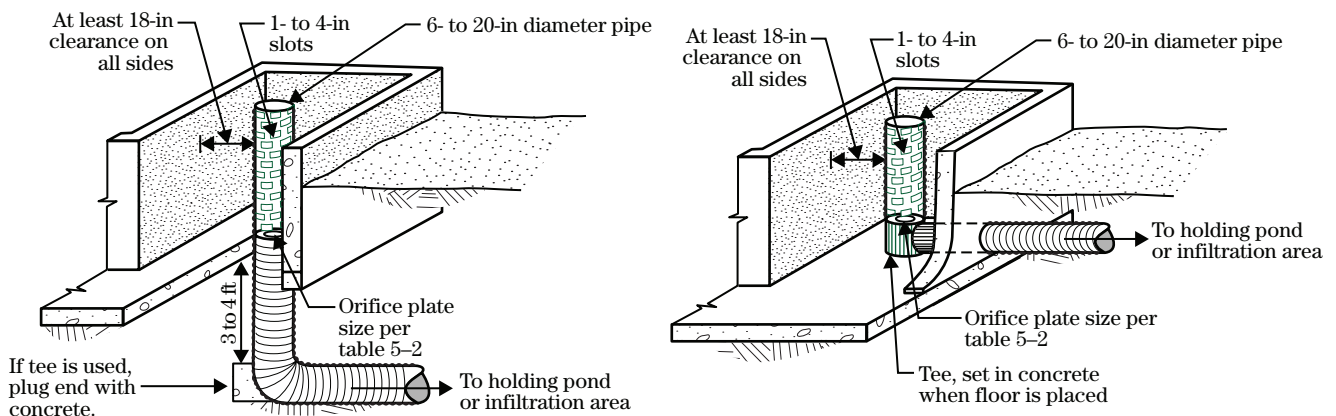
Perforated pipe outlets

Perforated pipe may be constructed with PVC plastic, galvanized steel (can have limited life), or concrete. The perforations can be 5/8- to 1-inch diameter holes or 1- by 4-inch slots. Where excessive clogging of perforated pipes is a problem, a removable trash screen ahead of the perforated pipe improves performance (fig. 5-2).

The outlet is sized to drain anticipated design discharge rates while providing adequate detention time. Basin outlet flow rate should be controlled with a properly sized orifice plate (fig. 5-3). Flow rate through the holes or slots in the perforated pipe should be checked to ensure that this estimate of flow rate exceeds that of the orifice. Because of the likelihood of clogging the holes or slots, a safety factor should be included in their design.

The outlet is sized to maintain sufficient flow to prevent overflow of the settling basin, while providing adequate detention time to allow solids to settle. When a settling basin is installed in conjunction with a VTA, the outlet flow may be controlled to slow the release of liquids over an extended period of time (30 h to 3 d). To achieve this level of control, a properly sized orifice plate is essential to achieving these objectives for settling basins tied to VTAs.

Figure 5-3 Riser pipe outlets for settling basins



Orifice plates should be sized to provide the design flow rate (table 5-2). They are placed at the base of the riser pipe, typically a PVC end cap with a hole of specified size drilled in the center. The orifice plate permits outflow control while permitting large perforations in the riser pipe to reduce plugging. The equation for estimating flow rate from an orifice plate (MWPS 1985) is:

$$Q_o = C \times A \times (2 \times g \times h)^{0.5} \tag{1a}$$

where:

- Q_o = flow rate of orifice in ft^3/s
- C = orifice constant: assumed to be 0.61. The actual value varies with type of orifice. The assumed value is conservative.
- A = open orifice area in ft^2
- g = 32.2 ft/s^2
- h = head on orifice in ft

With an orifice plate, make the flow rate of the slotted pipe (Q_s) at least 25 percent larger than the flow rate of the orifice (Q_o). Orifice plates should be vented with a .75-inch diameter PVC pipe, or PE tubing from just below the orifice plate to the elevation of the maximum anticipated settling basin depth. The equation for estimating flow rate through the slotted pipe (MWPS 1985):

$$Q_s = C \times A \times (2 \times g \times h)^{0.5} \tag{1b}$$

where:

- Q_s = flow rate of slots in slotted pipe in ft^3/s
- C = slot constant: assumed to be 0.61. The actual value varies with type of slot. The assumed value is conservative.
- A = open slot area in ft^2
- g = 32.2 ft/s^2
- h = head on openings in ft

The pipe height was divided into 0.5-foot increments. The head on all slots in the first 0.5-foot increment is assumed to be 0.25 foot. The head on the subsequent 0.5-foot pipe increments increases at 0.5 foot for each increment.

Porous dams

Select a material for porous dams that can be easily cleaned by scraping the surface with a hoe. Spaced planks, welded wire fabric, or expanded metal mesh can be scraped clean. Design of the spaced plank porous dams is illustrated in figure 5-4.

Porous dam outlets are acceptable for controlling runoff to holding ponds and VIBs. However, for settling basins designed with a slow release to a VTA, the porous dam approach is not recommended for this application. Plugging and challenges with construction of a porous dam with the desired flow rate makes this outflow approach unacceptable for this application.

Figure 5-4 Porous dam outlet design for settling basins (MWPS 1985)

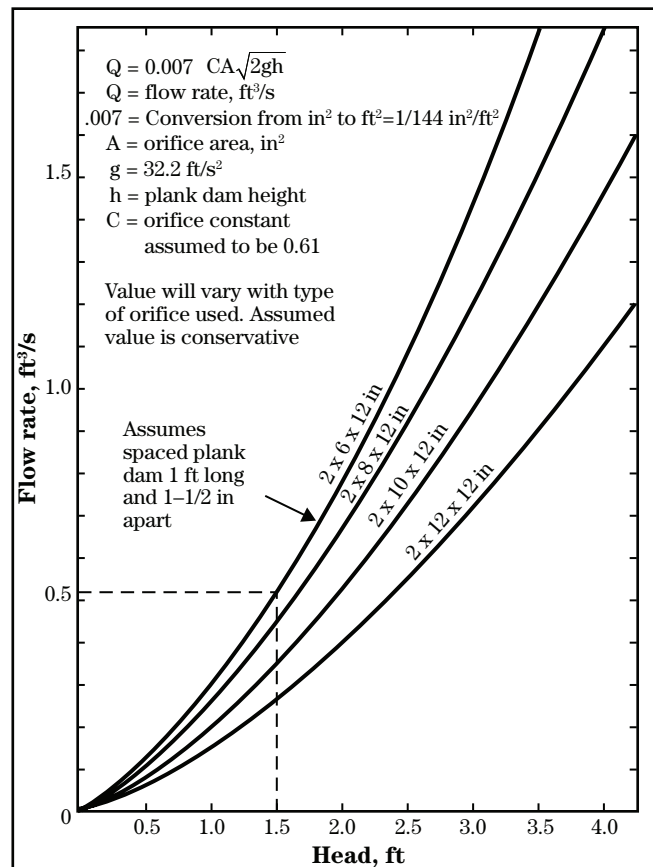


Table 5-2 Orifice plate opening design for settling basins. Boxed values refer to example in appendix C (MWPS 1985)

Diameter area		Head, ft						
in	ft ²	1.0	1.5	2.0	2.5	3.0	3.5	4.0
		-----Flow rate, ft ³ /s-----						
1.00	0.005	0.027	0.033	0.038	0.042	0.046	0.050	0.053
1.25	0.009	0.042	0.051	0.059	0.066	0.072	0.078	0.083
1.50	0.012	0.060	0.074	0.085	0.095	0.104	0.112	0.120
1.75	0.017	0.082	0.100	0.116	0.129	0.142	0.153	0.163
2.00	0.022	0.107	0.131	0.151	0.169	0.185	0.200	0.214
2.25	0.028	0.135	0.165	0.191	0.214	0.234	0.253	0.270
2.50	0.034	0.167	0.204	0.236	0.264	0.289	0.312	0.334
2.75	0.041	0.202	0.247	0.285	0.319	0.350	0.378	0.404
3.00	0.049	0.240	0.294	0.340	0.380	0.416	0.449	0.480
3.25	0.058	0.282	0.345	<u>0.399</u>	0.466	0.488	0.527	0.564
3.50	0.067	0.327	0.400	0.462	0.517	0.566	0.612	0.654
3.75	0.077	0.375	0.460	0.531	0.593	0.650	0.702	0.751
4.00	0.087	0.427	0.523	0.604	0.675	0.740	0.702	0.751
4.25	0.099	0.482	0.590	0.682	0.762	0.835	0.902	0.964
4.50	0.110	0.540	0.662	0.764	0.855	0.936	1.011	1.081
4.75	0.123	0.602	0.737	0.852	0.952	1.043	1.127	1.204
5.00	0.136	0.667	0.817	0.944	1.055	1.156	1.248	1.334
5.25	0.150	0.736	0.901	1.040	1.163	1.274	1.376	1.471
5.50	0.165	0.807	0.989	1.142	1.276	1.398	1.510	1.615
5.75	0.180	0.882	1.081	1.248	1.395	1.529	1.651	1.765
6.00	0.196	0.961	1.177	1.359	1.519	1.664	1.797	1.922
6.25	0.213	1.043	1.277	1.474	1.648	1.806	1.950	2.085
6.50	0.230	1.128	1.381	1.595	1.783	1.953	2.110	2.255
6.75	0.249	1.216	1.489	1.720	1.923	2.106	2.275	2.432
7.00	0.267	1.308	1.602	1.849	2.068	2.265	2.447	2.615
7.25	0.287	1.403	1.718	1.984	2.218	2.430	2.624	2.806
7.50	0.307	1.501	1.839	2.123	2.374	2.600	2.890	3.002
7.75	0.328	1.603	1.963	2.267	2.535	2.776	2.999	3.206
8.00	0.349	1.708	2.092	2.416	2.701	2.958	3.195	3.416

Settling basin emergency spillway

At shallow depths, the design flow into the basin exceeds outflow, so detention results. As the basin fills, outflow rate increases. When the basin is full, outflow rate should equal inflow rate. With feedlot runoff, however, outlet openings often clog to some degree, reducing the outflow rate. To prevent overflowing, provide a larger basin outlet (spillway) to handle peak flow when the basin is completely full (fig. 5-5).

Settling basin sizing

Runoff solids settle at a rate of 4 feet per hour. Therefore, a detention time of 30 minutes in the settling basin is an acceptable design criterion for a 2-foot deep basin, where no other criterion is available. When local design criteria are not available, use the following design procedure. An example using this procedure is illustrated in appendix C.

Step 1

Determine rainfall volume for a 10-year, 1-hour storm (fig. B-1) and the 25-year, 24-hour storm (fig. B-1) if the settling basin is matched to a VTA.

Step 2

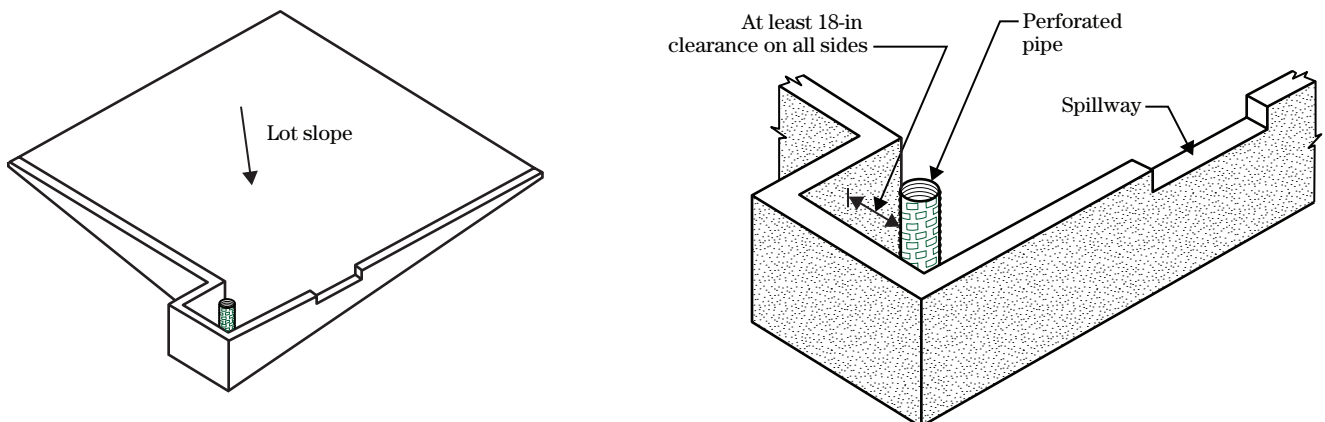
Peak flow rate off the lot:

$$\text{Peak flow rate} = \frac{(\text{lot area} \times \text{rainfall intensity})}{43,200} \quad (2)$$

Units: Peak flow rate in ft³/s
 Lot area in ft²
 Rainfall intensity (in/h) for 10-yr, 1-h storm
 is approximated as volume/1-h duration
 43,200 is derived from 3,600 s/h x 12 in/ft

Step 2 produces an estimate of peak flow rate and may be unsatisfactory for larger open lots. The runoff rate from a lot depends on three basic factors: surface con-

Figure 5-5 Spillway should be included for storm intensities that exceed design capacity and flow rate of settling basin



dition, slope(s) of the surface, and flow length. The small lots can be represented by the longest flow path from the top of the lot to the inlet to the settling basin. Larger lots have more than one flow surface, normally to an interceptor ditch that collects the flow from multiple surfaces and conveys them to the settling basin. Relatively slow velocities result in the overland section and rapid flows in the ditches. There is a wide range of conditions including flow, length, and slope(s). A more precise methodology is presented in the NRCS Engineering Field Handbook, chapter 2.

Step 3

Surface settling rate equals 4 feet per hour if the basin will be at least 2 feet deep. If site limitations (lack of fall away from lot) restrict depth to less than 2 feet, over design the basin area by using a surface-settling rate less than 4 feet per hour (2 ft/h is a reasonable compromise).

Step 4

Basin surface area:

$$\text{Area} = \frac{(\text{flow rate off lot} \times 3,600 \text{ s/h})}{\text{surface settling rate}} \quad (3)$$

Units: Area in ft²
Flow rate off lot in ft³/s
Surface settling rate in ft/h (from step 3)

Step 5

Basin liquids storage depth:

$$\text{Liquid storage depth} = \frac{\text{Liquid storage volume}}{\text{surface settling rate} \times \text{detention time}} \quad (4)$$

Units: Surface settling rate in ft/s (from step 3)
Detention time in h. 1/2 h is considered a minimum.
Maximum depth is 4 ft because excessive depth makes access difficult and hinders dewatering.

Step 6

The larger volume from the calculation based on detention time or storm event size should be selected for the liquid storage volume. First, calculate liquid storage volume based upon selected detention time:

$$\text{Liquid volume} = \text{Liquid storage depth} \times \text{basin surface area} \quad (5)$$

Units: Liquid volume in ft³
Liquid storage depth in ft (step 5)
Basin surface area in ft² (step 4)

A settling basin volume should also be checked to ensure a liquid storage capacity for a 10-year, 1-hour storm if preceding a holding pond or a VIB, or a 25-year, 24-hour storm if preceding a VTA (see app. B, fig. B-1). See appendix B for estimating runoff from a single storm event.

The larger volume of detention time estimate and storm event estimate should be selected. If the storm event estimate is larger, the liquid depth should remain constant and surface area recalculated.

Step 7

Solids storage volume:

$$\begin{aligned} \text{Solids storage volume} = & \text{Sludge buildup rate} \times \text{feedlot area} \\ & \times \text{fraction of year} \times \frac{43,560 \text{ ft}^2/\text{a}}{12 \text{ in/ft}} \end{aligned} \quad (6)$$

Units: Solids storage volume in ft³
Sludge buildup rate in a-in/a/yr
Feedlot area in a
Fraction of yr between basin solids removal

Use a sludge buildup rate of 0.5 acre-inch/acre of unpaved lot per year, and 0.1 acre-inch/acre of paved lot per year. Increase these values by 50 percent if lots have steep slopes (>8–10%) or are poorly maintained (pens cleaned less frequently than twice per year).

Step 8

Solids storage depth:

$$\text{Solid storage depth} = \frac{\text{solids storage volume}}{\text{basin surface area}} \quad (7)$$

Units: Solid storage depth in ft
 Solids storage volume in ft³
 Basin surface area in ft²

For vertical wall structure, use area at top of structure.
 For sloped wall structure, use average area of top and bottom of structure.

Step 9

Overall basin depth:

$$\text{Overall basin depth} = \text{liquids depth} + \text{solids storage depth} \quad (8)$$

Units: Liquids depth in ft (step 5 or 6)
 Solids storage depth in ft (step 8)

Step 10

Size the sloping screen prior to riser pipe (if used). Screen area is sized to limit flow velocity through the screen to less than 2.5 feet per minute when basin is full. Assume an expanded metal screen has 60 percent open area.

$$\text{Screen area} = \frac{(\text{flow rate off lots} \times 60 \text{ s/min})}{(0.6 \times 2.5 \text{ ft/min})} \quad (9)$$

Units: Screen area in ft²
 Screen length in ft
 Flow rate off lots in ft³/s
 Screen height in ft

Step 11

Basin length:

$$\begin{aligned} \text{Minimum basin length} &= \text{Ramp length} + \text{screen length} \\ &= (\text{Overall basin depth, ft} \\ &\quad \times \text{ramp slope}) + \text{screen length} \end{aligned} \quad (10)$$

Units: Minimum basin length, ft
 Ramp length, ft Ramp slope should be 10:1 or flatter
 Overall basin depth, ft
 Screen length, ft

Step 12

Basin width

$$\text{Basin width} = \frac{\text{Basin surface area, ft}^2}{\text{basin length}} \quad (11)$$

Units: Basin surface area, ft²

Basin length in feet should not be less than minimum basin length calculated in step 11. If site limitations restrict basin width, increase basin length and recalculate. The basin width must be at least 10 feet wide for equipment access to remove solids.

Step 13

Flow rate from basin to VTA

For a settling basin that precedes a VTA, flow rate should equal design storm volume spread over a 30- to 72-hour period. This would be encouraged for VTAs applied to all size livestock operations and specifically recommended for EPA permitted CAFO operations. The exception would be where the VTA's lower end is bermed or the runoff is collected in a holding basin. The outlet will need to have an orifice plate that provides control over outflow rate.

a. Estimate flow rate:

$$\text{Outlet flow rate} = \frac{\text{liquid volume}}{(\text{flow period} \times 3,600)} \quad (12)$$

Units: Outlet flow rate, ft³/s
 Liquid volume, ft³ as estimated by the storm event method in step 7
 Flow period, h (30–72 h recommended)
 3,600 is the conversion from h to s

b. Size orifice from table 5–2

c. Determine the required open area/feet of pipe height from table 5–3 for the riser pipe.

- d. Increase the open area of the riser pipe by 25 percent.
- e. Size the riser pipe diameter using table 5-4. Minimum riser pipe diameter should be at least 2 inches greater than orifice diameter.

Step 14

Select an underground discharge pipe from figure 5-6. Size the pipe to discharge at the peak flow rate off the lot. Determine pipe slope as shown in figure 5-6.

For a settling basin that precedes a holding pond or VIB, allow outflow to equal the peak flow rate off the lot (step 2) when the basin is full, using the following procedure:

- a. For a riser pipe with an orifice, follow the procedure described above with the exception of selecting flow rate from step 2.
- b. For a perforated pipe without an orifice plate, determine the required open area/foot of pipe height from table 5-3. Then size the riser pipe diameter using table 5-4.
- c. For a porous dam, determine required dam length from figure 5-4.

Figure 5-6 Capacity of pipe. Although developed for clay tile drainage lines, these charts approximate the capacity of low pressure lines (MWPS 1985, fig. 4-5).

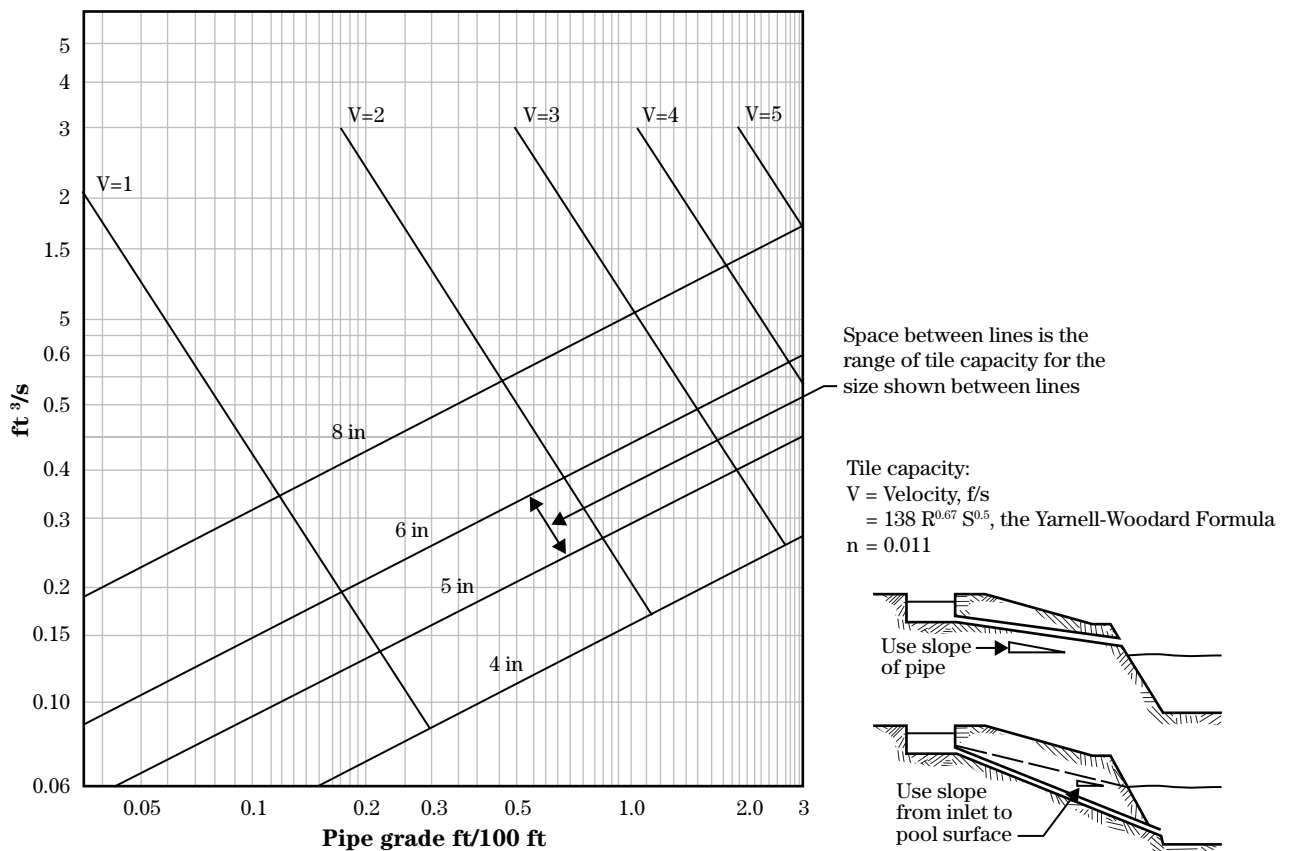


Table 5-3 Riser pipe open slot design for settling basin outlets. Determine open slot area per linear ft of pipe for design flow; then, increase that value by 25%. Boxed values refer to example in appendix C (MWPS 1985).

Open slot area/ft of pipe height, in ² /ft	Head, ft							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
-----Flow rate, ft ³ /s -----								
4	0.034	0.093	0.169	0.259	0.361	0.473	0.596	0.728
6	0.051	0.139	0.253	0.388	0.541	0.710	0.894	1.091
8	0.068	0.186	0.338	0.518	0.721	0.947	1.192	1.455
10	0.085	0.232	0.422	0.647	0.902	1.183	1.480	1.819
12	0.102	0.279	0.507	0.776	1.082	1.420	1.788	2.183
14	0.119	0.325	0.591	0.906	1.262	1.657	2.086	2.546
16	0.136	0.371	0.675	1.035	1.443	1.894	2.384	2.910
18	0.153	0.418	0.760	1.164	1.623	2.130	2.682	3.274
20	0.170	0.464	0.844	1.294	1.803	2.367	3.980	3.638
22	0.187	0.511	0.929	1.423	1.984	2.604	3.277	4.001
24	0.204	0.557	1.013	1.542	2.164	2.840	3.575	4.365
26	0.221	0.603	1.097	1.682	2.344	3.077	3.873	4.729
28	0.238	0.650	1.182	1.811	2.525	3.314	4.171	5.093
30	0.255	0.696	1.266	1.940	2.705	3.550	4.469	5.456
32	0.272	0.743	1.351	2.070	2.885	3.787	4.767	5.820
34	0.289	0.789	1.435	2.199	3.066	4.024	5.065	6.184
36	0.306	0.836	1.519	2.329	3.246	4.260	5.363	6.548
38	0.323	0.882	1.604	2.458	3.426	4.497	5.661	6.911
40	0.340	0.928	1.688	2.587	3.607	4.734	5.959	7.275

Table 5-4 Sizing of riser pipe. Capacity of smooth plastic riser pipe (ft³/s) at design water depth

Riser diameter, in	Head, depth of water over inlet							
	0.5	1	1.5	2	2.5	3	3.5	4
ft ³ /s								
3	0.18	0.26	0.31	0.36	0.41	0.44	0.48	0.51
4	0.33	0.47	0.57	0.66	0.74	0.81	0.87	0.94
6	0.76	1.08	1.32	1.52	1.70	1.87	2.01	2.15
8	1.37	1.93	2.37	2.74	3.06	3.35	3.62	3.87
10	2.15	3.04	3.72	4.30	4.81	5.27	5.69	6.08
12	3.11	4.40	5.38	6.22	6.95	7.61	8.22	8.79
14	4.24	6.00	7.35	8.48	9.48	10.39	11.22	12.00
16	5.55	7.85	9.61	11.10	12.41	13.59	14.68	15.70

Minimum riser pipe diameter selected should be the largest of the following three possibilities: (1) the diameter of the mainline, (2) 2 in larger than the planned orifice diameter, or (3) the diameter from table 5-4 with capacity of 1.5 times design flow rate.

Alternative solids-settling facilities

Several alternative, low-cost solids-settling facilities may be practical in some circumstances. All of these alternatives balance reduced cost against greater maintenance requirements. If maintenance requirements are not followed closely, higher solids will move into the VTA or VIB, increasing the potential for loss of vegetation and short-circuiting in the VTA.

These alternative solids-settling facilities do not provide control over the rate of feedlot runoff entering the next stage of treatment. Thus, high-intensity storms will cause high flow rates from these settling options into the VTA. For a CAFO permitted under current EPA regulations, precise control of the release timing or rate of flow into the VTA is important for reducing the risk of runoff exiting the VTA. Thus, application of these alternative solids-settling facilities in permitted CAFOs would not be recommended unless this concern is offset by lower risk system options (sec. 3) or more conservative VTA sizing.

Settling bench

A settling bench (fig. 5-7) is an area of relatively flat slope of a width such that the low velocities produce runoff flow rates producing significant solids settling. Maintaining vegetation on the settling bench improves settling efficiency. Solids must be removed at appropriate intervals to maintain the settling and distribu-

tion function. Reseeding of grass will likely be necessary after each solids removal.

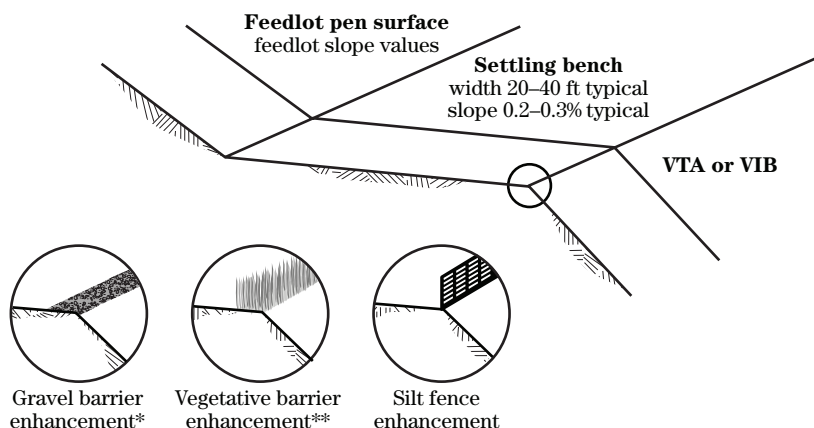
Design recommendations:

- Width: 20 to 40 feet
- Minimum length: Preferably the width of the bottom edge of the feedlot
- Slopes: 0.002 to 0.003 feet per foot towards the VTA
- Location relative to feedlot and VTA. It is preferable to locate the bench just below the feedlot pens (not within the pen itself) since flow may already be distributed over a fairly wide area. The settling bench should also be located directly between the feedlot and VTA or VIB.

Operation and maintenance recommendations:

- Monitor solids accumulation closely; remove any significant solids which will disrupt distributive flow.
- Solids removal will impair the grass stand; therefore, seeding may be required after solids removal.
- Grade control will be required on the bench to maintain the flow producing characteristics of the bench.
- A geotextile fabric placed below the bench surface may be beneficial for allowing vehicle traffic for solids removal only in higher rainfall climates.

Figure 5-7 Typical settling bench



* Reference: "Ground Level Lip Spreader for Barnyard" Pennsylvania NRCS Drawing
 ** Reference: "Vegetative Barrier" Texas NRCS Conservation Practice Standard Code 501

Geotextile fabric (silt fence)

A barrier or series of barriers of semi-porous material is set at right angles to the flow (<http://www.salixacc.com/siltfence.html>). This method can be used without additional settling options, or in conjunction with a settling bench to remove suspended solids.

Recommended design and construction criteria

- Silt fences should not impound water more than 18 inches in depth from a 10-year, 1-hour storm assuming no drainage through the fabric.
- Place silt fence on the contour, turning ends upslope in order to impound water.
- Soil should be sliced and fabric placed and compacted.
- Post spacing should not exceed 6 feet.
- Fabric is wired directly to the posts.
- Steel T-posts weighing at least 1.25 pounds per foot of post are required.

Recommended operation and maintenance

- Silt fence may need to be replaced at 1- to 2-year intervals. Geotextiles usually cannot be recycled. Check with the supplier of the material as to recycling opportunities. Also, visit with the local landfill as to the costs for disposal of this material.
- Inspect fence after every runoff event. Watch for undercutting of fence by water.
- Remove solids on a regular basis to prevent substantial buildup of materials.

Gravel spreader/barrier

Gravel spreader/barrier is a small ridge of graded gravel with a uniform elevation and width used as a solids removal and settling enhancement. This practice lends itself well to use with a settling bench. Placed at the downstream edge of a settling bench, it reduces sheet flow velocities, traps solids, and enhances flow distribution. Gravel benches could also be placed at the upper end of a VIB allowing the solids settling and VIB to be combined into a single structure.

Recommended design criteria

- Height of barrier 6 inches, top width 1 foot
- Ends of barriers turned upslope

Operation and maintenance

- Gravel will require periodic maintenance due to accumulated solids plugging the flow paths through the gravel. Gravel may need to be replaced or redistributed to a level grade.
- Remove solids on a regular basis to prevent substantial buildup of materials.

Vegetative barrier

Permanent strips of stiff, dense vegetation along the general contour of slopes or across concentrated flow areas are installed to reduce erosion, manage runoff flow, and trap solids (NRCS Conservation Practice Standard 601, Vegetative Barrier, <http://www.nrcs.usda.gov/technical/Standards/nhcp.html>). This method will normally be used in conjunction with other practices such as a filter strip or VTA.

Recommended design and construction criteria

- Vegetative barriers will be planted to vegetation having large enough stems to keep the barrier upright during runoff events.
- Gaps between plants will be no greater than 3 inches at the end of the first growing season.
- Species must be adapted to local soil and climate conditions, be easily established, long-lived, and manageable.
- Species will be selected that exhibit characteristics required for adequate function.
- Barriers may be established from transplanted vegetation or from seed.
- Barrier widths will be the largest of 3 feet wide or 0.75 times the design vertical interval.

Recommended operation and maintenance

- Establishment failures will be replanted or re-seeded immediately; short gaps in seeded barriers may be re-established with transplanted plant material.
- Mowing herbaceous barriers may be used as a management practice to encourage the development of a dense stand and prevent shading of other vegetation. Mowing will not be closer than 15 inches or the recommended height for the species, whichever is taller. Mowing in concentrated flow areas is discouraged because it will lower the vegetative stiffness index (VSI) by reducing average stem diameter.

- Weed control will be accomplished by mowing, spraying, or wick application of labeled herbicides.
- Vegetation in the barrier will be tolerant to or protected from herbicide used in surrounding cropped fields.
- Washouts or rills that develop will be filled and replanted immediately. Short gaps in established barriers will be re-established with transplanted plant material.
- Vegetative barriers will not be used as a field road or turn row. Vegetative barriers in concentrated flow areas will not be crossed with machinery.
- Vegetative barriers will not be crossed with water furrow plows or similar implements to cut drainage ditches to allow the passage of surface and subsurface water. If necessary, water should be drained by underground outlets installed up gradient of the barrier.
- Crop tillage and planting operations will be parallel with vegetative barriers.
- Pest control in adjacent fields will be performed with techniques and pesticides that will not damage the vegetative barrier.

Active versus passive management

Two distinct strategies are suggested for management of the outflow from a settling basin to a VTA. The producer's choice as to the appropriate management strategy may depend upon whether state or federal regulations apply to the facility and regulatory agency's interpretation as to how a VTA should be managed.

Active management

Active management of release of liquid from the settling basin involves producer control over release of all collected runoff until the liquid can infiltrate readily into the soil. This approach would minimize outflow onto the VTA when soils are frozen or saturated. The producer would actively prevent release of liquids until desired soil conditions were acceptable.

Advantages of active management strategy

- The least risk of a discharge from the VTA
- Maximum solids removal from the runoff
- May allow a smaller VTA (see sizing discussion in sec. 6)

Disadvantages of active management strategy

- The settling basin must be sized, designed, and managed as a runoff holding pond.
- The advantages of reduced seepage from the holding pond to ground water and air emission offered by the VTA system are less.
- For wetter climates, very large holding pond structures need to be installed in advance of the VTA.

Passive management

Passive management of the outflow of the settling basin into a VTA allows continuous outflow during the storm event. To minimize risk of VTA discharge, the flow rate from the settling basin is carefully controlled by the sizing of the settling basin discharge. Successful functioning of this system is dependent upon the ability to control flow so that it is released over an extended period of time, 30 to 72 hours after the storm event. This produces a situation where the settling basin liquid addition to the VTA represents only a small fraction of the precipitation falling directly on the VTA, and, thus, adds little risk to increased runoff. Because the contaminated runoff liquids are applied to the up-

per end of the VTA, the risk of runoff is further reduced.

Advantages of passive management strategy

- Low risk of runoff from the VTA
- Environmental failures of the collection and distribution system due to poor management are eliminated.
- Although the settling basin has significant size, it is still less than required for a holding pond.
- Liquids remain in the settling basin for less than 72 hours after any one storm event, reducing the risk of seepage to ground water and aerial emissions.

Disadvantages of passive management strategy

- Discharge from the VTA may occur for runoff events resulting during frozen soil conditions or for more intense storms that occur during extended wet periods.
- Permitted CAFO may need to record discharges and sample discharge for reporting to the permitting authority.

If outflow of the settling basin is to a holding pond or VIB, the preferred management strategy should always be a passively managed system. Both the holding pond and VIB have little chance of a discharge, unless poorly managed and the storm event exceeds the design storm capacity of a 25-year, 24-hour event. Alternative settling facilities will always be operated as a passive system as determined by the nature of their design.

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