Settling Basins for Open Feedlots

Separation of solids from open feedlot runoff is an important part of managing manure movement caused by rainwater and melting snow. Using gravity to remove solids by settling them to the bottom of a small pool (basin) is the most common and cost effective method for feedlot runoff solids separation.

Iowa law requires removal of settleable solids (those that will separate by gravity) from open feedlot runoff prior to releasing runoff liquids (settled effluent). This Iowa requirement applies to open feedlots of any size. Check your own state regulations for similar requirements. The minimum requirements to satisfy the Iowa law include:

- Settling must occur with runoff from a ten-year recurrence, one-hour storm.
- Runoff flow velocity must be reduced to no more than 0.5 feet per second, for at least five minutes.
- Liquid surface area in a full settling basin must be at least one square foot for every eight cubic feet per hour of runoff flow.
- Settling basins must include adequate capacity to store the settled solids between cleaning events.

Although these requirements sound confusing, some approximations make settling basin design relatively easy, and ensure the basin will meet the requirements and be effective.

Design storm size

Storm intensities can be found in weather data and tables, such as those found in the *Livestock Waste Facilities Handbook*, MWPS-18, from Midwest Plan Service ***www.mwps.iastate.edu***. The ten-year, one-hour storm in Iowa ranges from 2.1 to 2.5 inches per hour; 2.5 inches per hour is commonly and conservatively used statewide as the design storm.

Runoff velocity and basin area

When the requirement for runoff velocity reduction and basin surface area are combined, the resulting settling pool must have a surface area at least 1/39 of the feedlot area, and be at least eight inches deep. A pool with liquid surface and depth greater than these minimums will meet the velocity and area requirements of Iowa law. Larger and deeper settling pools will increase retention time and solids settling effectiveness. In order to exceed the minimum requirements and allow for additional storage capacity, a surface area of 1/20 of the feedlot area is commonly used.

Solids storage capacity

Solids accumulation rate in the settling basin depends on the lot surface type (concrete or earth), lot slope, and frequency of manure removal from the lot. Recommended solids storage volume for settling basins ranges from 0.12 to 1.2 inches of manure from the surface area of the

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feedlot. With a basin surface area 1/20 of the feedlot area, this results in design solids accumulation of 0.2 to 2 feet in the basin.

Basin size and shape

When all design criteria are considered, basins are commonly designed with a surface area at least 1/20 of the contributing runoff (feedlot) area and a minimum liquid depth of at least 2 to 3 feet. (Your state or financial funding source may have different requirements.) Additional basin area or depth allows for increased solids storage, temporary liquid storage, and solids removal efficiency, but added depth can make access for solids removal more difficult and increase the temptation for less frequent cleaning.

The bottom of the settling basin should be nearly flat to allow settling pool formation. A slope of no more than six inches toward the basin outlet can be provided to reduce ponding in the empty basin.

Avoid locating the basin outlet near the point where runoff enters the basin. Square, rectangular, and irregular shaped basins all work if the settling pool forms between the inlet and outlet of the basin.

Access for cleaning

If accumulated solids are to be removed with a tractor or wheel loader, an access ramp with a slope less than one-inch rise per foot of run and surfaced with roughened concrete is required. Concrete textured with half-inch deep grooves in a diagonal or diamond pattern works well for access ramps. Cleaning with a backhoe does not require an access ramp if the entire basin bottom can be reached from outside the basin. For cleaning flexibility and effectiveness, a full concrete bottom in the basin is best. As a minimum, the access ramp should connect to a concrete apron across the bottom of the basin to the basin outlet. The apron should be wide enough for cleaning equipment to turn around on the apron. A concrete "buck" wall at least four feet high should be at the end of the cleaning apron, unless the cleaning apron has access ramps at both ends.

Basins can be built with sloped earthen berms for walls if they are properly maintained. Vertical concrete walls on at least two sides of the basin can make solids removal more convenient and time-efficient. Because solids settling basins are not designed for long-term manure storage, concrete floors and walls need only be designed to support vehicle traffic and manure loading forces. Steel reinforcement in walls is beneficial. Floor reinforcement may be necessary only where vehicle loads are excessive or underlying soil provides inadequate support. Some states and financial funding sources may have concrete specification requirements.

Basin outlets

Solids settling basins need outlets for two purposes: overflow and dewatering. Both outlet types should be built for low risk of plugging with floating debris and sludge, and should be easy to clean and maintain.

Overflow

The overflow outlet allows large storm flows to pass through the settling basin providing solids settling while allowing overflow in a controlled location that prevents damage to the basin or erosion of the ground at the outlet location. In Iowa, design overflow outlets to handle at least five cfs (cubic feet per second) for each acre of feedlot and contributing runoff area.

Overflow outlets are often designed either as a notch weir or as an earthen spillway. Notched weir overflows are generally designed for 6 to 12 inches of flow depth, and width as necessary to handle the peak runoff flow rate. Actual weir flow capacity can be calculated using the weir formula or tables of weir flow. For approximation, at 3 inches of flow depth, each foot of weir width provides approximately one-third cfs of flow capacity. At 6 inches of flow depth, each foot of weir width provides approximately one cfs. At 12 inches of flow depth, each foot of weir width provides approximately three cfs. Adequate erosion protection must be provided on the downstream side of an overflow weir. A concrete splash pad or rip rap are often used.

Earthen spillway overflow outlets are designed and built like emergency spillways for farm ponds. Precise design procedures are available in pond design resources and consider spillway slope and crest length, along with vegetation type. For rough approximation on settling basin spillways, each foot of spillway width will carry approximately 1 to 2 cubic feet per second with a foot of water elevation above the spillway height. Care must be taken to protect the earthen berm of the settling basin against erosion at an overflow spillway. If possible, direct the overflow around the end of the earthen berm on undisturbed ground at a gentle grade. When this is not sufficient to prevent erosion, the overflow spillway may need reinforcement with concrete or other erosion control material.

Dewatering

The second outlet function needed for settling basins is dewatering. Dewatering allows the accumulated manure solids to dry sufficiently for handling and removal with solid manure equipment. Inadequate dewatering forces accumulated manure solids to be handled as a slurry.

Longer retention time in the settling basin increases the amount of solids removed by settling. Research shows settling for one to three days provides significantly better solids removal than the five-minute minimum retention time required by Iowa law, especially for runoff from concrete open lots. In certain conditions, retention beyond three days can lead to increased nitrogen conversion to ammonia, which is toxic to fish. The definition of a solids settling facility in Iowa law excludes structures that hold the settled effluent for more than seven consecutive days following a rainfall event. Considering these factors, dewatering outlets should be designed and managed to empty the settling basin within one to three days following a rainfall event. If longer-term storage of settled effluent for land application is desired, a separate settled effluent storage basin can be added to the system.

Dewatering outlets can be actively controlled or passive. Passive dewatering outlets act as an orifice to slowly release settled effluent from the settling basin. Several designs are commonly used.

Perforated riser pipe

A perforated riser pipe connected to a horizontal drain line can act as a dewatering outlet. The drain line must empty on the ground surface below the settling basin and cannot be connected to drainage lines that empty to streams or other water sources. The number and size of the openings in the riser pipe control the dewatering flow rate. Holes or slots should be at least one-inch wide to minimize plugging with manure solids. A protective trash rack made from treated lumber with vertical gaps of 0.75 inches between planks can provide additional protection from large floating solids and equipment damage. The *Livestock Waste Facilities Handbook*, MWPS-18, from Midwest Plan Service ***www.mwps.iastate.edu*** provides a detailed design procedure for perforated riser pipe design. For approximation, with two feet of liquid depth (average head of one foot), a one-inch hole will flow approximately 12 gallons per minute (36 holes for one cfs).

Slotted dam

Slotted picket dams (spaced plank dams) have often been used for dewatering outlets. The Livestock Waste Facilities Handbook (information above) has a detailed design procedure for these outlets. In many cases, these outlets were sized to pass peak storm flows through the dewatering outlet, and therefore were not capable of forming a settling pool under lower intensity storms. Slotted dams do work well as trash racks protecting other dewatering outlets, and are often seen around perforated riser pipe outlets.

Weep hole

A single weep hole can serve as a dewatering outlet. The hole is designed using orifice flow equations and placed at the bottom of the settling basin. It may be a simple hole through the basin wall, a hole into a box drop inlet or riser pipe, or a pipe or tube through the basin berm. If the hole is sized to dewater the basin over a period of four hours or more, it will be sufficiently small to allow formation of a settling pool even during rainfall events considerably smaller than the design storm. Orifice flow depends on the shape of the inlet and head pressure, but for settling basin outlets, flows can be estimated from Table 1.

Table 1. Orifice flow (cfs)

Water depth above Orifice (feet)	Orifice diameter (inches)				
	2	3	4	5	6
1	0.11	0.24	0.42	0.67	0.96
2	0.15	0.34	0.59	0.95	1.4
3	0.19	0.42	0.73	1.2	1.7
4	0.22	0.48	0.84	1.3	1.9

Weep hole diameter less than two inches can lead to frequent plugging. Weep hole dewatering outlets should always be accompanied by a controlled overflow outlet. Weep holes need not be round. Square or rectangular orifices will have flow capacities similar to round holes with equal opening area (square inches).

Dewatering outlet control

When infiltration of dewatering flow is desired, having control over the dewatering outlet is highly beneficial. Flow can be delayed until rainwater on the infiltration area has soaked in and the area is capable of accepting additional water. Flow can also be dosed in fractions of the basin storage at one time. Dewatering outlets with drain tubes or weep holes can be outfitted with valves for outlet control. Knife gate (slice gate) valves are available in corrosion resistant materials suitable for this purpose. Riser pipes can be covered with a solid sleeve pipe that is manually lifted for flow control. The inlet or outlet end of a dewatering drain tube can be outfitted with a flexible line that can be raised or lowered to control the level to which the basin is dewatered. Pumping systems offer both dewatering outlet control and flexibility for moving effluent longer distances or to higher elevations. Outlet controls may require consideration for freeze protection of plumbing.

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Effluent management

Settled open feedlot effluent contains nutrients, organic material, and pathogens that can cause water quality impacts if it reaches streams or lakes. Iowa law requires that settled effluent be managed to avoid negative impacts to receiving water resources. For best water quality protection and economic return from the nutrient value in the effluent, distribute the effluent where it can infiltrate into the soil for use by plants. For details about crop irrigation and vegetated treatment systems, refer to these resources:

Small Feedlot Runoff Management Using Low-Pressure Flood Irrigation
http://afo.unl.edu/lpeapj/pages/index.jsp
http://www.extension.org/sites/default/files/w/6/61/8_VTS.pdf

Settling basin management

Settling basins, like any other part of the manure management system, require continuing maintenance for proper performance. Basin management includes keeping the outlet(s) clear and operating properly and removing accumulated manure solids. Required frequency of solids removal depends on manure removal and maintenance of the livestock pens, and upon the amount of solids storage built into the basin and the suitability of the basin floor for all-weather access.

Earthen settling basin berms should be managed to prohibit trees, animal burrows, and erosion. Regular inspection is required and mowing may be helpful. Solids settling is just one part of open lot runoff management. Clean water diversion and managing the release/distribution of effluent are other critical parts of runoff management for water quality protection.

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