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Earthen Pits (Basins) for Liquid Livestock Manure

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Storage structures for slurry (liquid) livestock manure range from low-cost earthen basins and moderate-cost concrete pits and tanks to higher-cost, glass-lined steel tanks. This publication deals with earthen pits, with and without concrete liners (Figure 1). Earthen pits (basins) may be located above, below, or partially below grade. Below-grade pits are easy to fill by scraping, whereas above-grade pits may require pumps for filling. Earthen pits (also known as manure storage ponds or basins) are usually constructed by excavation and forming earthen berms, and thus are partially below and partially above the original grade. Berms help to shield the contents from view and to exclude surface runoff. Earthen pits are similar to lagoons, but with less capacity and do not provide for significant dilution or biological treatment. They must be designed and constructed to prevent ground and surface water contamination. To be approved by the Missouri Department of Natural Resources (MDNR), earthen pits must have a suitable clay liner compacted to meet MDNR permeability specifications. The thickness of the clay lining depends on the geologic rating and the depth of waste in the pit.

Open manure storage structures should be located to minimize odor complaints and sight nuisances, but they should be located as near to the source of manure and polluted runoff as is practical. Even properly functioning pits may cause an odor nuisance because of their size or location or because of topography, weather conditions, distance to other pits or separation distance from residences. **Do not use open manure pits where odors may be a nuisance.** (See MU publication EQ378, *Selecting a Site for Livestock and Poultry Operations*, for other considerations.) Open pits should be fenced, as necessary, to exclude animals and children.

Location requirements

Ideally, earthen pits should be located lower than the manure source so that liquids can drain by gravity to the pit and wastes can be flushed to the pit by gravity. If wastes are scraped into the pit, proximity to the source is especially important. If wastes are drained, pumped, or flushed to the pit, proximity for economical operation is not as crucial.

Figure 1. A concrete-lined earthen pit may allow the use of steeper side slopes, which decreases the area required per unit of storage volume. It also provides a more pleasing appearance.

Since June 30, 1996, MDNR requires new wells to be at least 300 feet from a livestock manure storage structure. For wells constructed between November 1, 1987, and June 30, 1996, MDNR rules recommend 300 feet separation from a well to a pit and require a minimum of 100 feet. If a permit or letter of approval is sought from MDNR for an operation where a manure pit existed within 100 to 300 feet from a water supply before November 1, 1987, a favorable report must be obtained from the Missouri Division of Geology and Land Survey. (A geologic report must be made for all new pits regardless of proximity to wells.) Special circumstances may dictate separation distances greater than the requirement; these circumstances are evaluated on a case-by-case basis.

Location of manure basins with respect to “non-owned residences” (residences not owned by the animal feeding operation) and public buildings is an important consideration. Minimum distances of ¼ to ½ mile from property lines and non-owned residences have been suggested. For Class I concentrated animal feeding operations (CAFOs), the separation or buffer distances required by legislation of the 1996 Missouri General Assembly are shown in Table 1. The distances depend on the operation size (number of animal units) and are measured from the lagoon or the manure storage or confinement building to the nearest public building or occupied residence not owned by the animal production operation. Also, check for county ordinances concerning CAFOs.

Table 1. Separation or buffer distance required for various sizes of animal feeding operations.

DNR Classification	Size (animal units*)	Separation/buffer distance (feet)
IC	1,000 to 2,999	1,000
IB	3,000 to 6,999	2,000
IA	7,000 or more	3,000

*1 *animal unit* = 1.0 beef feeder or slaughter animal, 0.7 dairy cow, 2.5 swine weighing over 55 pounds, 15 swine weighing less than 55 pounds, 10 sheep, 30 laying hens, 55 turkeys, 100 broiler chickens or 0.5 horse.

Exceptions to the above buffer / separation distance requirements are as follows.

- CAFOs in existence at the time the rule went into effect are excepted. The rule applies to new CAFOs.
- The buffer / separation distance requirement may be waived pending written agreement from property owners within the buffer / separation distance.
- MDNR may make site-specific exceptions. Such proposed exceptions must be presented to the county governing body and may be overruled.

Maintaining minimum buffer distances is no guarantee of avoiding odor complaints from neighbors, even if pits are properly designed and operated. Odors are a subjective sensation and the intensity may depend on the size of the pit, the distance from the pit and topography as well as wind and other weather conditions. Odors are heavier than air and will travel down valleys and other low areas for great distances without being diluted, especially during atmospheric temperature inversions, which occur most often during the evening and early morning hours when neighbors are likely to be outdoors.

See MU publication G1884, *Odors from Livestock Operations: Causes and Possible Cures,* for further discussion of odors from livestock operations. See MU publication EQ378, *Selecting a Site for Livestock and Poultry Operations*, for more details on location of animal facilities. In some situations, especially in south Missouri, location may be dictated by soil and geological considerations. Try to avoid a site where the bottom of the pit will be close to limestone, depending on soil type (permeability).

Soils investigation

For economical construction of an earthen pit (without requiring the use of soil amendments, an artificial liner or hauling a suitable clay soil from a remote location for sealing the pit), a suitable on-site clay soil is required. The ideal soil would have at least 30 percent fines content. Southwest Missouri block-structured red clay may not seal a pit, and a soil amendment, such as bentonite or soda ash, may be required to provide an acceptable seal. Natural Resources Conservation Service (NRCS) County Soil Surveys are a source of information during the preliminary screening for suitable sites. A soils investigation at a proposed pit site, done with a backhoe excavation or soil borings, is standard procedure in verifying a suitable location.

For a cost-shared pit, a soils investigation performed by NRCS personnel or a soils consultant is required. Only soils that fall within the Unified Soil Classification System designations of CH, CL, GC, and SC are accepted by MDNR as suitable clay liners. [Note: CH = clays of high plasticity; CL = clays of low to medium plasticity (gravelly, sandy or silty clays); GC = clayey gravels (gravel-sand-clay mixtures); SC = clayey sands (sand-clay mixtures)]

Geological requirements

A geological report on the proposed earthen pit site from MDNR's Division of Geology and Land Survey is required. If the site is in an area with karst terrain and is rated as having a severe collapse potential, an earthen pit will not be approved.

Sites having severe geological limitations but a moderate or slight collapse rating may be reviewed on a case-by-case basis. A pit with an artificial liner may be allowed at these sites. For sites having moderate geological limitations, a detailed soils investigation is required to determine the quantity and quality of the liner materials, the depth to bedrock and the depth to the seasonable high water table.

If the site evaluation indicates slight geological limitations, the above requirements may be waived. MDNR may require density tests (permeability) be taken on the finished liner before approval for operation. Barrel tests are required for Class IA operations; tests for other size classes are determined on a case-by-case basis.

Additional soils specifications for pit liners are available in MDNR's publication 10 CSR 20-8.020, *Design of Small Sewage Works.*

Earthen pit design

Earthen pit design — Size (volume)

Earthen pits are sized by volume. Proper design, or sizing, of an earthen pit ensures that sufficient volume is available for the required storage period. The minimum recommended storage period, before the pit must be pumped down, is 180 days. The total volume (size) of a pit is composed of the following volume fractions:

1. Permanent volume. This fraction of the pit volume provides a minimum of 2 feet of liquid above the highest point in the bottom of the pit. This amount of water should be pumped into the pit as soon as the clay liner is installed to prevent the liner on the bottom from drying and cracking. This volume fraction is not removed from the pit during pump-down operations.

2. Manure storage volume. This fraction of the pit volume provides storage for the volume of manure the pit will receive during the design storage period and is removed when the pit is pumped. This volume includes any wash water or other fresh water used for cleaning buildings or lot areas. Storage periods usually range from 6 to 12 months, with longer storage periods offering greater flexibility in scheduling pumping operations.

3. Runoff volume and other sources. This fraction of the pit volume provides storage for the runoff from open lots during the design storage period. This volume is removed from the pit during pumping operations. Volume components affected by rainfall (runoff volume and rainfall/evaporation volume) must be determined based on the wettest year in 10 years for MDNR approval. Runoff from concrete lots for the wettest year in 10 ranges from about 3 feet/year in northwest Missouri to 4.5 feet/year in southeast Missouri. Similarly, dirt lot runoff and runoff from the berm area inside the centerline of the berms varies from about 2 feet per year in northwest Missouri to 3.0 feet per year in southeast Missouri. It is important to reduce the area draining directly into the pit to prevent unnecessary pumpout. Surface water, unless needed for initially covering the clay seal on the bottom, should be diverted from the pit.

4. Net rainfall/evaporation on the pit surface. This fraction of the pit volume provides storage for the net gain of rainfall over evaporation on the pit surface. This volume is removed when the pit is pumped. For the wettest year in 10, the rainfall minus evaporation varies from about 1 foot/year in northwest Missouri to 3 feet/year in southeast Missouri.

5. Freeboard. Freeboard in the range of 1 to 3 feet above full pool level is recommended.

Figure 2 shows the volume fractions considered in the design of manure pits in Missouri.

Manure storage pits are designed to contain the waste and wastewater from the livestock facility for the wettest year in 10. In addition, the basin must be able to contain a 25-year, 24-hour rainfall event. Manure storage pits are designed with an emergency spillway in the event a rainfall event greater than the 25-year, 24-hour storm occurs. The emergency spillway will protect the berm integrity while controlling where the overflow from the runoff event goes.

Additional design guidelines for earthen pits may be found in MDNR's publication 10 CSR 20-8.020, *Design of Small Sewage Works*, under Waste Water Stabilization Ponds, and NRCS's Standard and Specification No. 425 for Waste Storage Ponds.

Table 2 gives typical pit sizes for various herd sizes in Missouri. These values are averages only and should not be used in lieu of a specific design. For more details on design of earthen basins for manure, refer to Midwest Plant Service publication MWPS-18, *Livestock Waste Facilities Handbook,* or contact your Natural Resources Conservation Service NRCS engineer or your regional agricultural engineering extension specialist. The engineers have a computer program for designing earthen basins and lagoons.

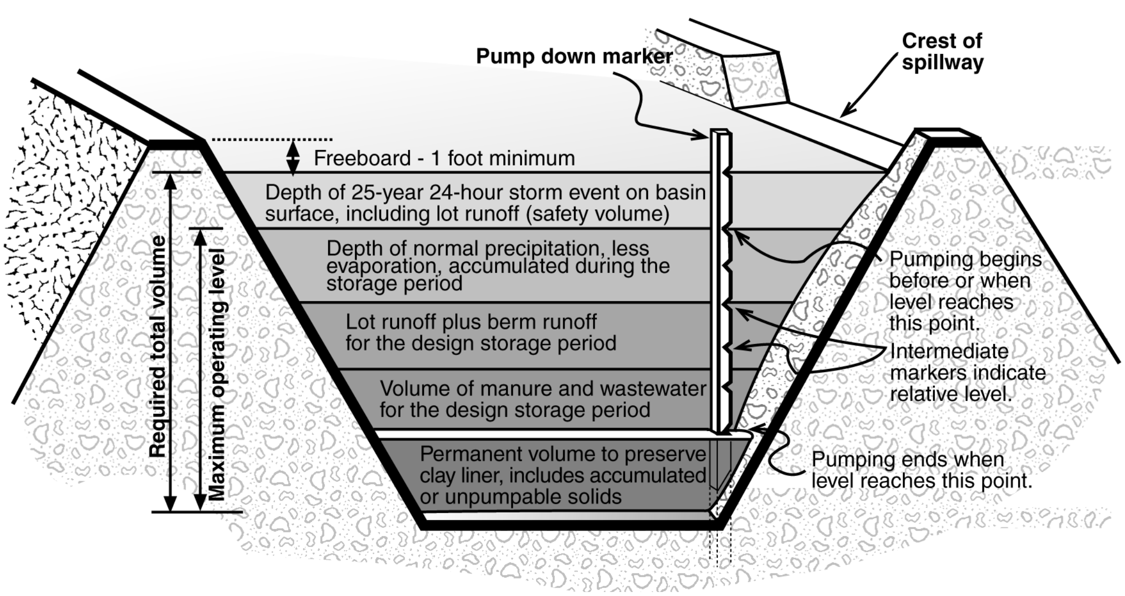

Figure 2. Schematic of volume fractions in design of earthen basin for liquid livestock manure.

Table 2. Typical sizes of earthen pits to store beef manure and lot runoff in central Missouri, 250 sq ft /head dirt lot and manure scraped into the pit.

No. of 1,000-pound beef feeders	Total pit volume (cubic feet)	Depth (feet)	Waterline (feet x feet)	Average annual pump-down volume (acre-inches)
60	32,085	12	83.3 x 83.3	5.89
120	57,442	15	101.2 x 101.2	10.53
180	82,140	15	114.3 x 114.3	15.05
240	106,518	15	125.2 x 125.2	19.51
300	130,699	15	134.7 x 134.7	23.93
600	250,095	15	171.5 x 171.5	46.63
1,200	485,750	15	223.1 x 223.1	88.14

Earthen pit design — Shape

Circular or square pits facilitate mixing and are usually more economical to construct. Rectangular pits may be used; length-to-width ratios of 3:1 or less are recommended. Avoid narrow appendages isolated from the main body of liquid; they contribute little volume and may be a source of nuisance conditions.

Minimum depth should be 8 feet; 8- to 20-foot depths are typical, depending on animal numbers, runoff area, the slope of the site, and underground geology. Pits deeper than 8 feet offer these advantages:

- A smaller surface area requiring less land.
- Minimum odors.
- Efficient use of mechanical agitation.

Slopes of earthen dikes and banks usually range from 2:1 to 3:1; approved slopes are 3:1 or less to favor the establishment of vegetative cover and for safe mowing (4:1 is recommended for the outer slopes). A minimum 10-foot top width is recommended.

An emergency spillway should be provided at a minimum of one foot below the top of the berm after allowance is made for settlement. The emergency spillway should be located as close to natural ground as possible. This spillway is intended only for dam protection in extreme flooding and is not to be used as a spillway in lieu of pumping down the pit.

Construction techniques — Sealing

Proper pit construction will ensure that groundwater resources are protected and the pit will perform as required during its useful life. The following steps are included in most guidelines for accepted construction techniques and methods for earthen pits.

1. Site preparation. All trees, grass and organic matter should be removed from the site. Topsoil should be stockpiled adjacent to the construction site for later placement on the top and exposed slopes for establishing grass cover. After the foundation area is stripped, it should be prepared to bond with the fill by removing loose, dry material, scarifying, disking, adjusting moisture and compacting as necessary.

2. Cutoff trench. A cutoff trench may be required to remove sand, gravel or other water-conducting materials (to help ensure against leakage under the embankment).

3. Excavation. Rocks, sand lenses, gravel and any material not suitable for sealing should be removed from the impoundment. Excavation should be sufficient to construct a seal in addition to obtaining proper pit volume.

4. Embankments. Pit embankments should be constructed to allow for settlement (usually 5 percent extra for settlement), mowing and erosion prevention. Suitable excavated materials free of sod, roots, frozen soil, stones more than 6 inches in diameter, or other objectionable material should be used for the fill. The minimum moisture content of the fill material and foundation should be such that, when kneaded in the hand, the fill material will form a ball that will not readily separate.

5. Seal construction. Earthen pits must have a seal on the bottom and sides sufficiently impermeable to protect groundwater. Seal construction guidelines generally call for over-excavation and recompaction of seal material in lifts not exceeding 6 inches compacted depth (not more than 9 inches deep before compaction). The lower 6 inches of the bottom seal may be scarified and compacted in place to eliminate removal and replacement. The seal material should be within 2 percent below and 4 percent above the optimum moisture content for compaction. In general, a minimum of a 1-foot thick clay seal must be provided on the bottom and sides of a lagoon. The deeper the pit, the thicker the required seal, up to 4.6 feet thick for a liquid depth of 25 feet.

A given permeability or leach rate, such as 1×10^{-7} centimeter / second, is a typical seal construction specification. Experience has shown that with suitable soil material, three passes of a sheepsfoot roller per 6-inch fill lift on the embankment or bottom seal will provide adequate compaction for sealing. Soil amendments such as bentonite or soda ash or, in extreme cases, artificial liners, may be required to obtain a proper seal. The pit seal should be covered with water immediately after construction to prevent drying and cracking of the seal (at least 2 feet above the highest bottom elevation).

Concrete-lined pits

Concrete-lined pits are an option where suitable soil is not available for sealing an earthen pit. Concreting may provide a more pleasing appearance and allow the use of steeper side slopes, which decreases the area required per unit of storage volume (Figure 1). Concrete is normally placed in a single pour across the bottom and around the side slopes up to the top of the berms. To simplify construction, (expansion) joints are eliminated by increasing the reinforcing steel to minimize temperature and shrinkage cracking. For a 4-inch thick concrete liner (laid on plastic or sand), No. 3 rebar at 9.2 inches on centers each way, or 6 x 6-W6.5 x W6.5 wire mesh, is minimum reinforcement for temperature and shrinkage. A concrete mix with 6.5 bags of cement per cubic yard, 5.5 to 6 gallons of water per bag of cement, 5 to 8 percent entrained air, and 1.5-inch maximum aggregate size is recommended. An alternate specification is to call for a 4,000 PSI mix with 5 to 8 percent air and a maximum 5-inch slump. Typical concrete slopes of 1:1 to 2:1 require the use of a "stiff" mix to prevent the mix from slumping on the steep slopes.

Table 3 shows estimated construction costs of a concrete liner for a typical manure storage basin for a 100-head beef feeder operation.

Table 3. Estimated costs (in year 2000 dollars) for lining a typical manure storage basin for a 120-head beef feeder herd (1,000 lb average weight) with concrete.

Lot runoff (square feet)	Storage (days) 120	180	365
15,000	$7,820	$9,110	$12,580
30,000	10,270	11,900	16,220
45,000	12,200	14,100	19,120

Assumptions: A square earthen basin 8 feet deep plus 1 foot of freeboard with 2:1 inside slopes, 39-inch annual rainfall, with a 4-inch-thick reinforced concrete liner @ $150/cubic yard in place, to hold manure and runoff from a dirt lot.

Transferring manure to storage

Manure in the slurry form is usually transferred to the storage basin by scraping or by using a pump designed for semisolids. Semisolids may be scraped directly into the basin, usually from a push-off slab, or scraped into a reception pit. Manure may be drained from the reception pit to the basin by gravity through a large pipe (typically 24 inches or more in diameter) or pumped to the basin by either a ram-type or an impeller-type pump.

Reception pits are usually designed with capacity for one day's waste production; a pit 6 feet long, 4 feet wide and 6 feet deep will serve 120 head of 1,000 pound feeders. A depth of 6 feet will usually provide sufficient head to overcome entrance losses at the discharge pipe. At least 6 feet of head from the elevation of the emergency spillway to the reception pit discharge is recommended. Rounded corners and a pit floor slope of at least 10 percent to the discharge pipe helps reduce problems caused by manure building up and drying on pit surfaces. PVC pipe and corrugated plastic pipe with smooth inside surfaces cause less resistance to flow than pipes with rougher surfaces and joints.

Pit inlets

If manure will enter the pit through a pipe or sewer line, the line should enter the pit below the minimum pump-down level. (Inlets above the liquid surface are susceptible to freezing where exposed at the end.)

The inlet discharge should be located near the center of the longest side of the pit, if possible, or at several locations in large pits, so that solids are distributed and not allowed to accumulate near the edge. Ideally, the pipe should extend to near the center of the pit. One discharge point per acre of pit will avoid large concentrations of solids at one point. Multiple pipe inlets should be fed equally from a distribution box. All sewer lines should be designed with cleanouts at 50-foot intervals.

Solids removal — Agitation

Bedding and fibrous material will break down very slowly, or not at all, in a pit. Nondegradable material leads to sludge buildup or the formation of crusts on the surface, both of which require vigorous agitation for removal from the pit during pumping operations (see Figure 3). Agitation before and during pump-down is necessary to ensure that solids in sludge or crusts are removed. Otherwise, the effective volume of the pit will be severely reduced in a short period of time.

Agitation is accomplished by using high-horsepower, propeller-type agitators (see Figure 4) or by recirculation with high-capacity pumps.

Figure 3. Without agitation a pit can become overgrown.

Figure 4. Agitation of a pit with a propeller-type, 3-point mounted agitator.

Figure 5. A concrete ramp allows all-weather access to the pit.

Access ramps and pump platforms

Concrete access ramps and pumping / agitation platforms should be provided as needed for all-weather access to the tank for agitating, pumping or mechanically removing solids (see Figure 5). Ramp slopes should be no steeper that 10:1 for tanker / spreader access and no steeper than 5:1 for tractor / agitator or tractor / pump access. Grooves or ridges 1 inch or more deep across the ramp should be formed into the concrete before it sets to improve traction. Concrete platforms built into the inside slope of earthen pit berms greatly facilitate positioning of pumping and agitating equipment.

Startup — Management

Earthen pits should be filled with water 2 feet above the highest point of the pit bottom to prevent cracking of the clay liner before manure is introduced into the pit.

Pumping operations should begin before or when the manure level reaches the upper pump-down mark to ensure that space (safety volume) is always available to hold the 25-year, 24-hour storm (about 6 inches in Missouri). MDNR guidelines call for pumping the pit when the liquid level reaches the upper pump-down mark, or before. The volume between the upper pump-down mark and the spillway is the volume of the 25-year, 24-hour storm. This volume is called the safety volume.

If the open-lot surface area contributing to the pit inflow is greater than 70 percent of the pit area, the safety volume depth is computed using the following formula:

$$\text{Safety volume depth} = 0.67 \text{ feet} + \frac{\text{square foot lot surface} \times 0.5 \text{ feet}}{\text{square foot pit liquid surface area}}$$

Refer to Figure 2 to see how the safety volume depth (safety zone) is measured. Permanent markers should be installed at the depth to initiate pumping the pit and at the depth at which to stop pumping (2 feet above the highest point in the bottom of clay-lined pits).

Pump-down or manure level markers

Pump-down or manure level markers, or indicators, are a simple but important component of a manure storage facility. Such a marker enables the operator to ascertain quickly and easily the degree of fill of the manure storage facility, the point at which pumping or emptying should begin, and the point at which it should end. The presence of a durable, easily read marker gives inspection or regulatory personnel confidence that a manure storage facility is being managed properly.

Experience has shown that pump-down markers must be made of durable materials and properly installed to afford the long life needed. The operator or inspector should be able to ascertain the following information when observing a pump-down marker.

1. When pumping operations should begin.
2. When pumping operations should end.
3. Level at which overflow will occur.
4. Fraction of total storage that is currently filled.

A common practice is to install steel fence posts at the upper and lower pump-down levels for earthen impoundments. While this approach provides basic information on beginning and ending pump-down, experience has shown that more knowledge is needed. Also, fence posts installed in this manner are subject to damage and displacement. A good pump-down marker will indicate the level, or elevation, of manure throughout the possible range (from lower pump-down level to overflow, or spillway) in the storage facility. Intermediate markings are desirable to better estimate available storage volume in the lagoon and as an aid in determining the acre-inches to be pumped down (for pumping when the pit is partially full). Experience has shown that a 6" x 6" treated wood post properly imbedded makes a good pump-down marker. Notches or other indicators can be carved into the post to show pertinent elevations. Painted numbers or colors on the pole are not durable enough to maintain readability over

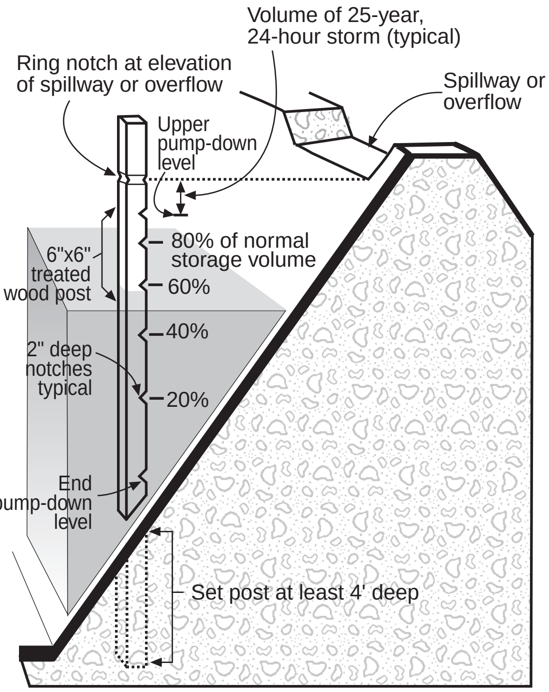

Figure 6. Pump-down marker in an earthen pit.

a number of years. Figure 6 shows a type of marker designed to meet the above criteria.

Pump-down and land application

Preparation for pit pump-down should start before the liquid level reaches the upper pump-down marker to leave the proper safety volume to contain a 25 year, 24 hour rainfall event. Agitation before and during pump-down is recommended to remove settled solids and achieve maximum nutrient recovery. If the pit is to be agitated, a sample for nutrient testing should be taken after agitation. See MU publication EQ215, *Laboratory Analysis of Manure*, for details on sampling and tests.

Land application is the most desirable method for making use of the nutrients and organic matter in liquid manure (slurry). Tankwagons or towed-hose tractor-mounted applicators are the current practical methods of transporting and applying the large volumes of liquid manure. Slurry can be applied by sprinkler irrigation, but odor problems may occur if the manure is not incorporated as soon as possible.

Under the Unified National Strategy for Animal Feeding Operations, the desired outcome is for all concentrated animal feeding operations (CAFOs) to develop and implement a comprehensive nutrient management plan (CNMP). CNMPs should address, as necessary, feed management, manure handling and storage, a nutrient management plan for land application of manure, land management, record keeping, and other options for using the nutrients in manure. In addition to considering nutrients, the plan should address other pollutants, such as pathogens, to minimize effects of animal feeding operations on water quality and public health.

At a minimum, the nutrient management plan should prevent the application of nutrients at rates that will exceed the capacity of the soil and planned crop needs and also prevent pollution. Soils, crop removal and manure should be tested to determine nutrient needs and content. Manure application equipment should be calibrated to ensure that the quantity of material being applied is what is planned. Records of crops removed annually and the total amount of effluent applied should be kept to maintain the desired nutrient balance. Electronic totalizing flow-rate meters in the towed-hose pumping system are frequently used by custom applicators to calibrate the equipment and record the amount applied per acre. These meters are also a component in variable rate application using GPS to vary and record the rate of application.

Closure of an earthen manure pit

A nutrient management plan is required by MDNR for closure of permitted facilities. Sludge removal for closure of an earthen pit when a livestock operation is terminated may require a much greater land application area than has been required for regular pump-downs, if the pit has not been agitated during regular pump-downs. The land area required may be dictated by the amount of P and K in the sludge rather than by the nitrogen content of the sludge. To obtain the required land application area often requires hauling the sludge a considerable distance and, possibly, obtaining a spreading agreement from another landowner to meet MDNR requirements for land application rate.

Sludge removal without allowing several months for the sludge to dry following removal of the liquid effluent is usually an extremely expensive procedure (such as dredging) and on large pits with many years accumulation, may cost several hundred thousand dollars. One university estimates sludge removal costs at $0.005 to $0.05 per gallon.

An alternative to a one-time sludge removal procedure may be to continue to operate the pit with annual applications to the available acreage based on a nutrient management plan and periodically adding water and using agitation and pumping to gradually remove the solids.

Safety and appearance

Efforts should be made to make a pit as pleasing in appearance as possible. Earthen berms and embankments should have a good grass cover for appearance and erosion control and should be mowed and maintained on regularly. Such practices help ensure good access to all parts of the pit as well as improving appearance. If an earthen pit is within public view, it may be desirable to plant a row of trees for a visual screening. A well-maintained pit is less likely to attract attention and cause controversy than a pit with an offensive appearance.

A fence should be provided to prevent access byf children, trespassers and livestock to the pit. The location of the fence should permit mowing of the berms. Post warning signs (DANGER MANURE STORAGE — KEEP OUT) and keep the gate locked.

Under some topographical conditions, a pit may be constructed such that it can be emptied or drained by gravity through a 12-inch or larger pipe into a tankwagon. This approach has a relatively high risk of pollution should there be a failure or improper use of the valve in the discharge pipe. Therefore, this technique generally should not be considered. If a gravity drain is used, it is recommended that a safety valve be included in the gravity drain system to prevent a discharge in the event of failure of the main valve used to control the flow in the gravity drain pipe fails.

For further information

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MU publications

G 1884, *Odors from Livestock Operations: Causes and Possible Cures*
G 9181, *Agricultural Phosphorus and Water Quality*
G 9182, *Managing Manure Phosphorus to Protect Water Quality*
EQ 201, *Reduce Environmental Problems with Proper Land Application of Animal Wastes*
EQ 202, *Land Application Considerations for Animal Wastes*
EQ 215, *Laboratory Analysis of Manure*
WQ 324, *Solids Removal from Livestock Manure Lagoons*
WQ 327, *Irrigating Lagoon Effluent*
EQ 378, *Selecting a Site for Livestock and Poultry Operations*

Midwest Plan Service Publications

MWPS-18, *Livestock Waste Facilities Handbook*
MWPS-30, *Sprinkler Irrigation Systems*

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NRAES-89, *Liquid Manure Application Systems Design Manual*

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