ENVIRONMENTAL QUALITY

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Anaerobic Lagoons for Storage/Treatment of Livestock Manure

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Many livestock producers with confinement operations handle their animal waste as a liquid because of the laborsaving advantages. Anaerobic lagoons are an integral part of many liquid-handling systems. Lagoons are pondlike earthen basins sized to provide biological treatment and long-term storage of animal waste. A livestock lagoon is a small-scale waste treatment plant containing manure that is usually diluted with building wash water, water wasted at animal waterers, and rainfall. In a lagoon, the manure becomes partially liquefied and stabilized by bacterial action before eventual land application. Lagoons may contain one of three types of waste-stabilizing bacteria — anaerobic (inhibited by oxygen), aerobic (requiring oxygen) or facultative (maintained with or without oxygen). Lagoons are larger than manure storage basins, which do not provide significant biological treatment and, frequently, are designed for shorter storage periods. On the other hand, anaerobic lagoons are considerably smaller than aerobic lagoons, which are designed to provide a higher degree of treatment with less odor production. Anaerobic lagoons also decompose more organic matter per unit volume than aerobic ones. Due to the tremendous area required for aerobic lagoons to treat livestock waste, almost all livestock lagoons are anaerobic.

Anaerobic lagoons are a useful size and cost compromise between storage basins and aerobic lagoons. This guide will discuss anaerobic lagoon designs approved by the Missouri Department of Natural Resources (MDNR) for livestock manure storage and treatment.

Anaerobic processes, which occur without free oxygen, liquefy or degrade organic wastes with high biochemical oxygen demand (BOD). Well-designed and well-managed lagoons have a musty odor. Foul odors may indicate a malfunction. Even properly functioning lagoons may cause nuisance odors because of their size or location or because of topography, weather conditions, distance to other lagoons and separation distance from residences. **Do not use anaerobic lagoons where odors may be a nuisance.**

Advantages of anaerobic lagoons:

- Manure can be handled hydraulically with flushing systems, sewer lines, pumps and irrigation systems.
- The high degree of stabilization reduces odors during land application.
- High nitrogen (N) reduction minimizes the land area required to make use of the effluent.
- Long-term storage is provided at low cost.

Disadvantages of anaerobic lagoons:

- Public perception may be that a lagoon is an “open container of manure.”
- Undesirable odors may be produced during seasonal (spring and fall) changes due to “turnover” and spring start-up after the winter period of relatively little biological activity. Initial start-up in late spring or early summer is preferred.
- Undesirable odors may drift off premises during atmospheric temperature inversions.
- Undesirable odors may be present during land application by spray irrigation.
- Nutrient availability is limited if manure is used as a fertilizer (due to denitrification of N in the lagoon and most phosphorous (P) settles to the bottom).
- Potential cost of removing built-up solids if the lagoon is to be closed down and solids have been allowed to accumulate for several years without agitation during the annual pump-down. Also, the land area required to dispose of accumulated N and especially P may not be available nearby.

Location requirements

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

Since June 30, 1996, MDNR requires new water wells to be at least 300 feet from a livestock manure lagoon. For wells constructed between November 1, 1987, and June 30, 1996, MDNR rules recommend 300 feet separation from a well to a lagoon and require a minimum of 100 feet. If a permit or letter of approval is sought from MDNR for an operation where a lagoon 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 should be made for all lagoons 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 lagoons 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 exempted. The rule applies to new and expanded 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 lagoons are properly designed and operated. Odors are a subjective sensation, and the intensity may depend on the size of the lagoon, distance from the lagoon, topography, and wind as well as other weather conditions. Most livestock-related 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 livestock and poultry facilities. In some situations, especially in south Missouri, location may be dictated by soil and geological considerations, in addition to other factors, such as odors. Also, check for possible county ordinances concerning animal feeding operations.

Soil investigations

To construct a lagoon economically (without soil amendments, artificial liners or additional “hauled-in” clay soil), 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 lagoon, 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 lagoon site, done with a backhoe excavation or soil borings, is standard procedure in verifying a suitable location. For a cost-shared lagoon, a soils investigation performed by NRCS personnel or a soils consultant is required.

Geological requirements

A geological report on the proposed lagoon 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 lagoon 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. Lagoons with artificial liners 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 seasonal high water table.

If the site evaluation indicates slight geological limitations, the above requirements may be waived. DNR 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 lagoon liners are available in MDNR's publication 10 CSR 20-8.020, *Design of Small Sewage Works.*

Anaerobic lagoon design — Size

Anaerobic lagoons are sized by volume. Proper design or sizing of a lagoon ensures that sufficient volume is available for treatment and the required storage period. The recommended storage period, before the lagoon must be pumped down, is 365 days. The total volume of a lagoon consists of several volume fractions:

1. **Minimum design or permanent volume.** This fraction provides sufficient dilution volume for the degradation of volatile solids by bacteria. This volume is not removed from the lagoon during pump-down operations. The design volume may be reduced by up to 50 percent if a settling basin or solids separator is used to remove the solids.
2. **Manure storage volume.** This fraction provides storage for the manure volume the lagoon will receive; it is removed when the lagoon is pumped. 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 provides storage for runoff plus any wash water or other fresh water used for cleaning buildings or lot areas. This volume also is removed from the lagoon during pumping operations.

   Runoff from open concrete areas ranges from about 3 feet / year in northwest Missouri to 4.5 feet / year in southeast Missouri. It is important to reduce the area draining directly into the lagoon to prevent unnecessary pumping. Surface water, unless needed for filling or dilution, should be diverted away from the lagoon. Volume components affected by rainfall (runoff volume and rainfall-evaporation volume) must be based on the wettest year in 10 years for MDNR approval.
4. **Net rainfall/evaporation on the lagoon surface and berm runoff.** This fraction provides storage for the net gain of rainfall minus lagoon surface evaporation plus berm area runoff (inside the centerline). This volume is removed when the lagoon is pumped. For the wettest year out of 10 years, the rainfall minus evaporation varies from about 1 foot per year in northwest Missouri to 3 feet per year in southeast Missouri.

   Similarly, dirt lot and berm runoff varies from about 2 feet per year in northwest Missouri to 3 feet per year in southeast Missouri.
5. **Sludge storage.** Some fraction of the manure solids entering a lagoon remains as bottom sludge. Although the sludge buildup rate has not been defined, most standards suggest a volume allowance for sludge accumulation if sludge removal is not accomplished during lagoon pumping. Agitation during pumping is highly recommended to reduce the sludge buildup.

   Current MDNR guidelines do not require that volume be provided for sludge storage; however, such a provision may be advisable.
6. **Freeboard.** Freeboard in the range of 1 to 3 feet above full pool level is recommended.

Figure 1 shows the volumes considered in lagoon design throughout Missouri. Surface area will vary with depth.

Table 2 shows typical lagoon sizes for various species of animals.These values are for reference only and should not be used in lieu of a specific design. For more details on lagoon design, refer to Midwest Plan Service publication MWPS-18 or ASAE Engineering Practice: ASAE EP403.3.

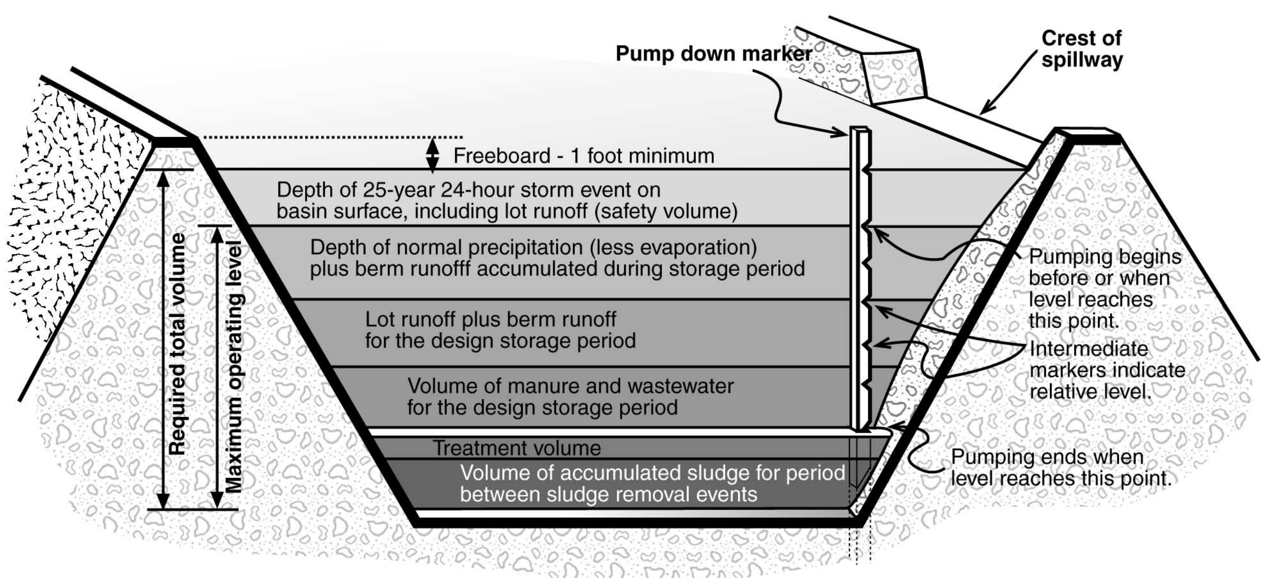

Figure 1. Schematic of volume fractions in lagoon design.

Table 2. Typical sizes of livestock and poultry lagoons in Missouri (365-day storage).

Number, size and species of animals	Total lagoon volume (cubic feet)	Cut volume[1] (cubic yards)	Waterline (feet x feet)	Average annual pump-down volume (acre inches[2])	Soil-plant filter (acres)*
1,000 150-lb finishing hogs	288,552	6,166	128.5 x 128.5	25.28	30
100 sows & litters @ 450 lb in farrowing houses	132,562	3,091	135 x 135	13.10	9
600 sows @ 400 lb in gestation barns	252,632	5,486	172 x 172	22.04	48
100 1,400-lb dairy cows in free-stall barn	493,596	9,964	224 x 224	33.75	21
120 1,000-lb beef feeder animals[3]	348,097	7,342	293 x 293	36.14	12
100,000 layers @ 3 lb	935,049	17,953	297.0 x 297.0	44.29	105
100,000 broilers @ 2 lb	1,209,963	22,721	328 x 328	45.30	112

[1] Cut volume for 15 ft lagoon depth, cut/fill ratio about 1.20
[2] One acre-inch = 27,154 gallons
[3] Collecting runoff from open concrete lots, assumes 200 sq ft /head and no solids separation.
* Acres required with the conservative approach, i.e., 100 pounds of N applied per acre per year.

Lagoon design — Geometry

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

Minimum depth should be 8 feet, although 8- to 20-foot depths are typical depending on animal numbers, runoff area, slope and underground geology. Deeper lagoons offer these advantages:

- A smaller surface area requiring less land.
- More thorough mixing of lagoon contents by rising gas bubbles.
- Minimum odors.
- Less ammonia loss to the atmosphere.
- Efficient use for mechanical aeration.

Earthen dike and bank slopes usually range from 2:1 to 3:1. A slope of 3:1 or less is recommended for the establishment of vegetative cover and for safe mowing. A minimum 10-foot top width is recommended; however, greater widths may be desirable for operation of tractors with agitators.

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

Construction techniques — Sealing

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

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 prevent leakage under the embankment.
3. **Excavation.** Rocks, sand lenses, gravel and other materials not suitable for sealing should be removed from the impoundment. Excavation should be sufficient to construct a seal in addition to obtaining proper lagoon volume.
4. **Embankments.** Lagoon embankments should be constructed to allow for settling (usually 5 percent extra), 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 fill. The minimum moisture content of the fill material and foundation should form a ball when kneaded by hand that will not easily separate. Experience has shown that with suitable soil material, three passes of a sheepsfoot roller (Figure 2) per 6-inch fill lift on the embankment or bottom seal will provide adequate compaction for sealing.
5. **Seal construction.** Lagoons must have a seal on the bottom and sides sufficiently impermeable to protect groundwater. Seal construction guidelines generally call for over-excavation and recompaction

Figure 2. A sheepsfoot roller is commonly used to compact the clay seal during construction of a lagoon.

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 two percent below and four 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 lagoon, the thicker the required seal, up to 4.6 feet thick for a water depth of 25 feet.

A given permeability or leach rate, such as 1×10^{-7} cm / sec, is a typical seal construction specification. Soil amendments such as bentonite, soda ash or artificial liners may be required to obtain a proper seal. The lagoon seal should be covered with water immediately after construction to prevent drying and cracking (at least two feet above the highest bottom elevation).

Lagoon inlets

Inlets should be located near the center of the longest side of the lagoon, if possible, or at several locations in large lagoons. This allows the solids to be distributed and not allowed to accumulate near the edge. One discharge point per acre will avoid large concentrations of solids at one point and help minimize odors during spring warm-up. Multiple inlets should be fed equally from a distribution box.

If manure will enter the lagoon through a pipe or sewer line, the line should enter the lagoon below the minimum pump-down level, or above the full pool level. This prevents ice from breaking the inlet pipe. The pipe should extend into the lagoon and have a minimum of 3 feet of liquid underneath it.

Inlets above the liquid surface are susceptible to freezing at the end if small dribbling flows are present. Also, cold air can move up the sewer line into the building if a trap is not provided. Pipe inlets below the minimum pump-down level are generally preferred. Inlet pipes must be rigidly supported.

Submerged inlets carrying trickling flows with relatively high solids content are susceptible to plugging as solids accumulate or “float” where the lagoon water backs up into the pipe. Frequent flushing (at least once a day) eliminates this problem. Sewer lines with submerged discharges, carrying trickle flows into lagoons, should have a minimum of one foot of head above the maximum lagoon level for each 100 feet of run. All sewer lines should be designed with cleanouts at 50-foot intervals.

Solids exclusion — Sludge removal — Agitation

Bedding and fibrous material will break down very slowly, or not at all, in a lagoon. It is recommended this material be excluded from the lagoon if at all possible. Nondegradable material leads to excessive sludge buildup or the formation of crusts on the lagoon surface, both of which interfere with pumping operations.

Agitation during annual pump-down (Figure 3) should be considered as a means of reducing sludge buildup. Sludge removal may be justified if sludge levels build to a significant percentage of total lagoon volume. Although a somewhat difficult and expensive operation, regular sludge removal can extend the life of a lagoon virtually indefinitely. Sludge is high in P and N; therefore a large area of land will be required for applying several years’ accumulation of sludge.

Figure 3. A propeller-type agitator can be used to resuspend settled solids (sludge) from the bottom of a lagoon during pump-down.

Start-up — Management

Proper lagoon design and construction are fruitless if the lagoon is not properly managed. Many problems associated with lagoons can be solved with proper management.

Lagoons should be filled with water to one-third to one-half of the design volume before manure is introduced into the lagoon. This will ensure sufficient dilution is available for the establishment of bacterial activity. This will also minimize start-up odors. Starting a lagoon in the late spring or early summer months will establish a bacterial population before cold weather and will help prevent excessive odors the following spring.

Lagoons perform best when they are loaded continuously. Therefore, a waste management system should be devised that loads the lagoon at least weekly, and preferably daily. Flushing systems provide ideal loading conditions for lagoons. Slug loading may produce odors.

Pumping and irrigating from the lagoon is the single most important management item. In addition to preventing overflow and the associated pollution potential, pumping removes dissolved and suspended solids and allows room for the addition of dilution water through rainfall or other means. Try to irrigate when odors are apt to be least offensive, that is, on days with low humidity or when breezes are blowing away from neighboring residences.

If lagoons are not pumped and diluted, salt concentrations may increase to levels that can inhibit bacterial activity. Salt levels in mature lagoons should be monitored yearly to ensure they remain at safe levels. Electrical conductivity (EC) is a convenient field measurement that indicates salt content. EC levels above 10,000 micro mhos / cm indicate probable decreased bacterial activity, a buildup of solids, and increased odor.

If odors are a problem, take lagoon samples frequently to measure pH. If pH is below 6.7, add hydrated lime or caustic soda (lye) @ 1 lb / 1,000 ft^2 of lagoon surface each day until the pH is neutral (pH = 7). Even with a normal pH of 6.7 to 7.2, the lagoon can have excess odorous volatile acids.

Pumping operations should begin before or when the lagoon level reaches the upper pump-down mark to ensure space (safety volume) is always available to hold the 25-year, 24-hour storm (about 6 inches in Missouri). The MDNR guidelines call for pumping the lagoon when the liquid level reaches the upper pump-down mark. 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 lagoon inflow is greater than 70 percent of the lagoon area, the safety volume depth is computed using the following formula:

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

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 lagoon, 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 lagoon 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 lagoon. 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 post are not durable enough to maintain readability over a number of years. Figure 4 shows a type of marker designed to meet the above criteria.

Permanent markers should be installed to show the level at which pumping the lagoon should begin (1 foot or more below full pool level) and the level at which pumping should stop. Intermediate markings, such as at each foot, are desirable to better estimate the volume of effluent in the lagoon. A depth gage with markings every foot or less from the design level to the full pool

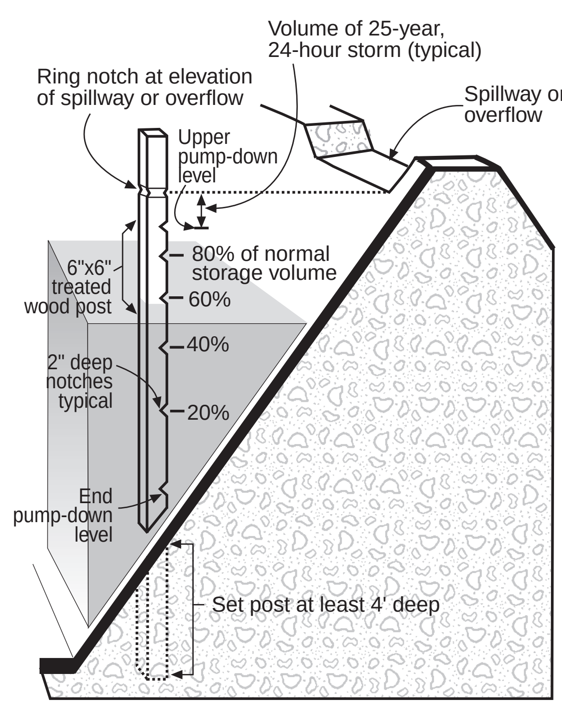

Figure 4. Pump-down marker in an anaerobic lagoon.

level can be an aid in determining the acre-inches to be pumped down each time.

Pump-down and land application

Preparation for lagoon pump-down should start before the lagoon 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 lagoon 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 lagoon effluent. Sprinkler irrigation or use of a towed-hose tractor-mounted applicator are the current practical methods of transporting and applying large volumes of lagoon effluent.

Under the Unified National Strategy for Animal Feeding Operations, the desired outcome is for all concentrated animal feeding operations to develop and implement a comprehensive nutrient management plan (CNMP). CNMPs should address, as necessary, feed management, manure handling and storage, a nutrient management plant for land application of manure, land management, record keeping, and other options for making use of 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 lagoon 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.

Closure of a lagoon

A nutrient management plan is required by MDNR for closure of permitted facilities. Sludge removal for closure of a lagoon when a livestock operation is terminated will, under ordinary circumstances, require a much greater land application area than has been required for regular pump-downs during the normal operation of the lagoon. 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 lagoons 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 removal procedure may be to continue to operate the lagoon 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.

Recycling lagoon effluent for flushing

Intakes for recycle pumps are frequently floated about two feet below the surface to minimize disturbing the surface crust or pumping sludge. The pump intake should be located remote from the waste inlet. A wet well should be considered as a convenience for installing and servicing the recycle pump. For information on recycling systems, refer to MU publication G1158, *Recycling Lagoon Water for Manure Flushing Systems.*

Some operators choose to recycle effluent from the second stage of a two-stage lagoon system in an effort to reduce the level of odors and pathogenic organisms in the buildings, and, possibly, to reduce crystallization problems in the recycle lines. Pumping from the second stage may reduce plugging problems during irrigation from dairy and beef lagoons. The second-stage lagoon may be added to increase lagoon capacity when an expansion in herd numbers occurs. A lagoon system with two or more stages may create a dilemma in recycling the nutrients that accumulate in the first stage.

A 6- or 8-inch overflow pipe transports the solids-free wastewater from the first to the second stage in a two-stage lagoon. It should be located as far as possible from the inlet(s) to the first stage so that no untreated waste enters the second stage. The inlet of the overflow pipe should be submerged a foot or more below the surface of the liquid to prevent any floating solids from reaching the second-stage lagoon or clogging the inlet (see Figure 5).

Safety and appearance

Efforts should be made to make a lagoon as pleasing as possible. Berms and embankments should have a good grass cover for appearance and erosion control and should be mowed and maintained regularly.

Such practices help ensure access to lagoon areas and improve appearance. If a lagoon is within public view, a

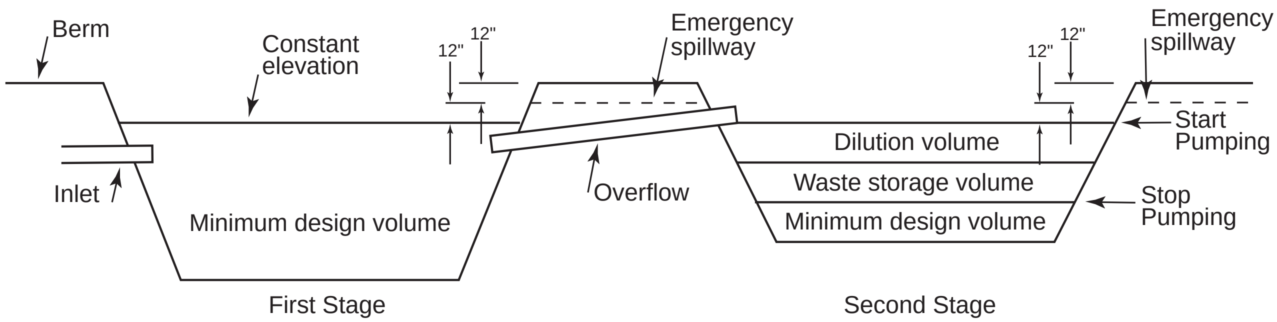

Figure 5. A two-stage anaerobic lagoon designed for the treatment of livestock manure.

row of trees will help hide the view and may deflect winds (and odors) upward from the lagoon. A well-maintained lagoon is less likely to attract attention and cause controversy than a lagoon with an offensive appearance.

A fence should be provided to prevent access by children, trespassers and livestock. Post warning signs (SEWAGE TREATMENT FACILITY — KEEP OUT) and keep the gate locked.

For further information

Agricultural Waste Management Field Handbook. Part 651, National Engineering Handbook. Washington, D.C.: Natural Resources Conservation Department, U.S. Department of Agriculture, 1992.

ASAE Engineering Practice: ASAE EP379.2 (November 1997). *Control of Manure Odors*. ASAE Standards, 2000. St. Joseph, Michigan.

ASAE Engineering Practice: ASAE EP393.3 (December 1998). *Manure Storages.* ASAE Standards, 2000. ASAE, St. Joseph, Michigan.

Natural Resources Conservation Service, Missouri Specifications, USDA / NRCS, Columbia, Mo. 65201.

Rules of the Department of Natural Resources, Division 20 — Design of Small Sewage Works. Chapter 8, Design Guidelines, 10 CSR 20-8.020. 1989. Clean Water Commission, Missouri Department of Natural Resources, Jefferson City, Mo. 65102.

USDA-EPA, *Unified National Strategy for Animal Feeding Operations*. March 9, 1999.

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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*

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