ALABAMA COOPERATIVE Extension SYSTEM

ANR-973

A L A B A M A  A & M  A N D  A U B U R N  U N I V E R S I T I E S

# Planning and Managing Lagoons for Swine Waste Treatment

## Anaerobic Lagoons

Anaerobic lagoons are earthen structures, which look at first glance like farm ponds. These lagoons are designed to provide biological treatment and long-term storage of animal waste. Anaerobic lagoons are larger than manure storage basins, which do not provide significant biological treatment or long storage periods, but smaller than aerobic lagoons. Even though aerobic lagoons are designed to provide a higher degree of treatment with less odor, anaerobic lagoons decompose more organic matter per unit volume. Because of their treatment and storage capabilities anaerobic lagoons are a good compromise between storage basins and aerobic lagoons.

Anaerobic treatment of waste occurs without free oxygen to liquify or degrade high BOD (biochemical oxygen demand) organic waste. With proper design and management the anaerobic lagoon can function for years. Odor from a well-designed and well-managed lagoon will be only slightly musty; foul odor indicates a malfunction requiring corrective action.

Advantages of anaerobic lagoon systems are:

• Manure can be handled with water flushing systems, sewer lines, pumps, and irrigation equipment.

• The high degree of stabilization reduces odors during land application.

• High nitrogen reduction minimizes the land area required for liquid effluent disposal.

• Long-term storage is provided at low cost.

Disadvantages of anaerobic lagoons include:

• Public perception that a lagoon is an open container of manure.

• Offensive odors if improperly designed and maintained.

• Limited nitrogen availability if manure is used as a fertilizer.

## Location Requirements

Ideally, lagoons should be located downslope from the swine housing unit so that waste can be drained or flushed to the lagoon by gravity. Because recycled lagoon water is generally used to flush waste from buildings, location should be close enough for easy access for the recycle system.

American Society of Agricultural Engineering (ASAE) Engineering Practice 403.3 recommends that lagoons be no less than 300 feet from any water wells to prevent water supply contamination. Natural Resources Conservation Service (NRCS) recommends 500 feet but will accept 150 feet from an upslope well.

Location of lagoons with respect to nonoperator-owned residences is an important consideration. ASAE recommends a minimum of 900 feet downwind. In Alabama, however, recommendations are that lagoons be (1) located at least ¼ mile from property lines and nonoperator-owned residences and (2) screened from view with a natural or constructed screen. In some situations, especially in north Alabama, the location of a lagoon will be controlled by soil and geological considerations.

## Soils Investigation

Although printed county soil survey maps give general guidance, the swine operator planning a treatment lagoon should have an on-site subsurface soils investigation made. Agencies with expertise similar to the NRCS can conduct on-site soils investigations and make appropriate recommendations. Soil borings or backhoe excavations are standard procedures to identify shallow soil over coarse sand and gravel, crevices, limestone, or permeable bedrock. If any of these conditions exist, procedures and materials, such as clay liners, geotextile liners, or concrete, to prevent seepage to ground water must be used in construction.

NRCS currently offers this on-site soils and geologic investigation assistance for animal waste management structures as part of the animal waste management technical assistance program. They should be contacted for assistance. This process will determine the soil suitability for and final location of a swine waste lagoon.

## Lagoon Design—Volume

Proper design of an anaerobic lagoon system requires the calculation of volume that will be needed to accommodate waste accumulation over the desired treatment period. Total lagoon volume of either a single stage or two-stage system is composed of several parts:

- Treatment volume.
- Manure wastewater volume.
- Surface runoff volume.
- Net rainfall (rainfall minus surface evaporation, including the 25-year–24-hour storm).
- Sludge volume.
- Freeboard volume.

**Treatment volume** provides enough dilution volume for the breakdown of volatile solids by bacteria and is not removed from the lagoon during pump-down operations. This volume is based on volatile solids daily loading rate in pounds per day per thousand cubic feet. Typical recommended primary anaerobic lagoon minimum treatment volume for swine waste lagoons in Alabama ranges from 6 to 6.5 pounds of volatile solids per thousand cubic feet per day. This is around 1 cubic foot per pound of average live weight for farrow-to-weanling and farrow-to-feeder operations and up to 1.5 cubic feet of permanent volume per pound of average live weight for weanling-to-feeder, feeder-to-finish, and farrow-to-finish operations.

**Manure wastewater volume** provides for wastewater storage equal to the accumulated manure volume over the designed treatment period. Pump-down interval and manure treatment period are the same and should be 180 days in Alabama. Storage volume per pound of average live weight is 0.5 cubic foot for 6 months. Longer treatment time offers greater flexibility in scheduling pumping operations.

**Surface runoff volume** provides storage for rainfall runoff plus any wash water or other freshwater that may be used for cleaning buildings or lot areas. This volume is removed from the lagoon during pumping operations. Manure-free runoff from open areas, unless needed for filling or dilution, should be diverted away from the lagoon. Generally the amount of rainfall and runoff to be collected and stored in the lagoon is figured on the wettest 10 years for net rainfall less evaporation on lagoon surface and berm runoff.

**Net rainfall.** The lagoon must provide storage for the net gain of rainfall minus lagoon surface evaporation plus the berm area runoff plus the 25-year–24-hour storm. In Alabama, typical annual rainfall is at least 12 inches more than evaporates from a free water surface. Surface area and berm runoff can add as much as 4 feet per year. This volume from rainfall less evaporation is held in the second stage of a two-stage lagoon and removed when the lagoon is pumped.

**Sludge volume** results from manure solids entering a swine lagoon and a portion remaining in the first stage as bottom sludge. Recent research on feeder-finish units in North Carolina indicates that approximately 0.034 cubic feet of sludge accumulates per year per pound of average swine live weight. Solids separation with a properly operating settling tank can cut sludge accumulation in half. The sludge accumulation rate can be used to determine volume necessary for sludge over any particular chosen design time, up to 12 to 15 years by some designers. Recommended sludge volume is 0.5 cubic foot per pound of average swine live weight.

**Freeboard volume** is the minimum extra depth above total full pool level, usually 1 foot, after all other volume requirements are met. Figures 1 and 2 show a cross section of one- and two-stage lagoon designs, which may be used throughout Alabama. Surface area will vary with depth.

## Two-Stage Lagoons

Where space is available, a two-stage lagoon should be constructed to improve wastewater treatment and management flexibility. For swine operations where lagoon liquid is recycled for open gutter flushing and animals have direct access to flush water a second stage lagoon provides some insurance against disease organisms being returned from the first stage lagoon before a reasonable die-off period. In addition to further treatment, the second stage lagoon also stores treated wastewater for irrigation to further treatment. This treated wastewater can be irrigated through small diameter sprinkler nozzles.

A second stage lagoon should allow for a permanent volume that cannot be pumped (2-foot minimum), wastewater volume for the desired treatment period (180 days minimum), surface runoff volume for the desired treatment period, net rain on both stages, and space for the 25-year–24 hour storm for both stages (see Figure 2). The first stage will contain only the treatment (permanent) volume and sludge volume.

## Lagoon Design—Geometry

Swine waste lagoons can be designed in a variety of shapes. However, circular or square la-

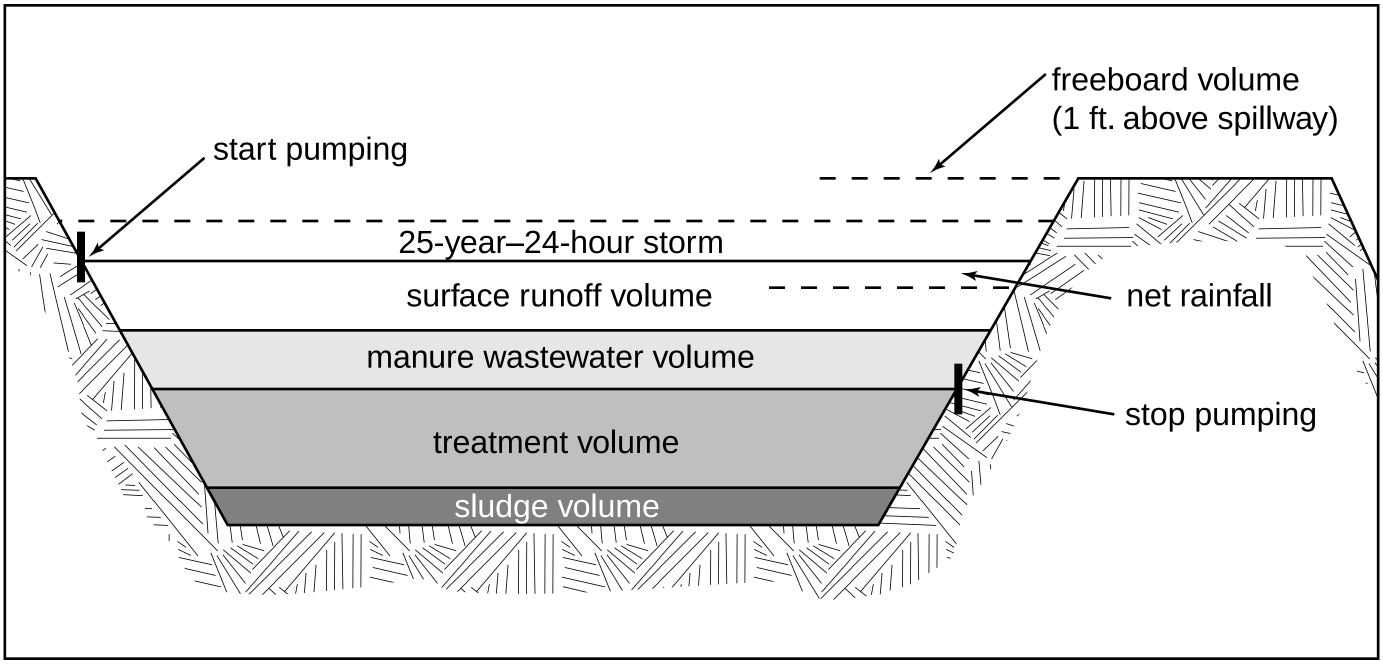


Figure 1. Capacity of single-stage anaerobic lagoon.

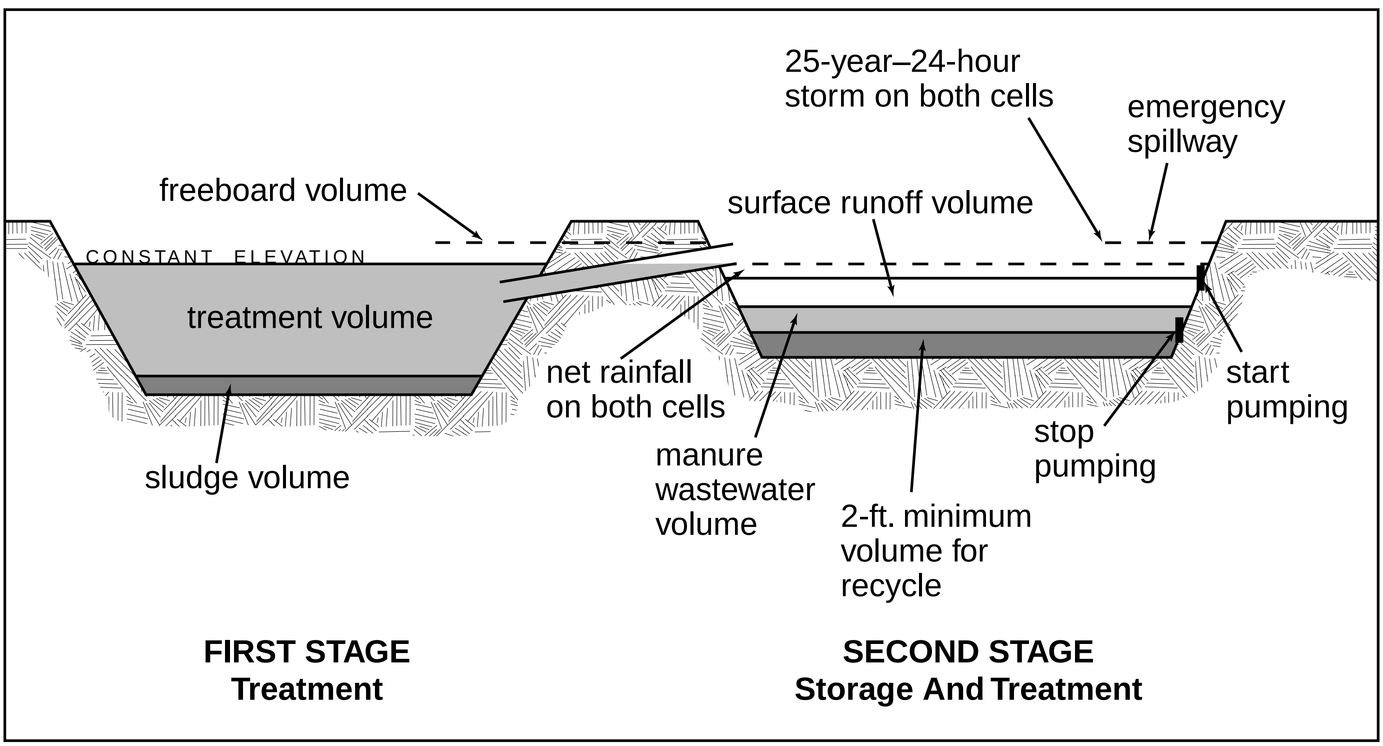


Figure 2. Capacity of two-stage anaerobic lagoon.

goons allow easier mixing with propeller or pump type agitators and are usually less expensive to construct. When rectangular lagoons are constructed, a 4:1 length to width ratio should not be exceeded to encourage even distribution of manure.

Typical lagoon depths range from 8 to 20 feet, with a minimum depth of 8 feet. The specific footage depends on animal numbers, runoff area slope, and underground geology. Deeper lagoons offer several advantages, including less land needed because of smaller surface area requirement, more thorough mixing of lagoon contents by rising gas bubbles, efficient mechanical aeration, and minimum odor.

The dike for a lagoon must be a minimum of 8 feet wide. Slopes on earthen dikes and banks generally range between 2:1 and 3:1. To establish good grass covers and for safe mowing, slopes of 3:1 or better are recommended. Generally, slopes below the waterline are 2:1 though this depends on soil type and structure design.

An emergency spillway must be provided in the second stage of a two-stage system to protect the dam from extreme flooding. The spillway should be placed a minimum of 1 foot below the top of the berm with allowance for settling. It should be located as close to natural ground as possible and as far as possible from a corner location. The spillway is intended for use in flood conditions and is not to be used as a drain instead of pumping down the lagoon.

## Construction Techniques

Proper lagoon construction is essential to ensure protection of ground water resources as well as to provide a system that will operate effectively for many years. Most guidelines for accepted lagoon construction techniques include:

- Site preparation.
- Excavation.
- Embankments
- Cutoff trench.
- Sealing.

**Site preparation** requires that all trees, grass, and organic material be removed. Topsoil should be stockpiled close to the construction site for later placement on the top and exposed sides to allow good establishment of grass. After stripping, the foundation area should be prepared to bond with the fill. Loose dry material should be removed and the foundation area scarified, disked, adjusted for moisture, and compacted as necessary.

**Excavation** requires the removal of rocks, sand pockets, gravel, and other materials not suitable for sealing. The excavation should be deep enough for both proper volume and seal construction.

**Lagoon embankments** should be constructed to allow for usual settling of 5 percent. The embankment should be planted with a cover grass to prevent erosion and must be large enough to accommodate mowers. Suitable fill materials should be free of sand, roots, stones more than 6 inches in diameter, and other objectionable material. The minimum moisture content of the fill material and foundation should allow the formation of a ball that will not separate when squeezed by hand. Experience has shown that with suitable soil material (with enough clay content) three passes of a sheepsfoot roller per 6-inch fill lift on the embankment or bottom seal will provide adequate compaction for sealing.

**A cutoff trench** may be required to remove sand, gravel, or other water-conducting materials to prevent leakage under the embankment.

**Sealing** is required on the bottom and sides of the lagoon to protect ground water. Seal construction guidelines generally call for overexcavation and then backfilling and recompaction of seal materials in thicknesses not exceeding 6 inches compacted depth (not more than 9 inches deep for compaction).

The lower 6 inches of the bottom seal may be scarified and compacted in place to eliminate removal and replacement. In general, a minimum of 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 or beyond 4 feet for a water depth of 25 feet.

Some soils require soil amendments such as bentonite, soda ash, or artificial liners to obtain a proper seal. Most properly planned swine waste lagoons receiving raw manure eventually seal, limiting soil permeability to as little as $10^{-6}$ cm/sec. Immediately after construction, the lagoon seal should be covered with water (at least 2 feet deep above the highest bottom elevation) to prevent drying and cracking.

## Solids Exclusion And Agitation

Some manure solids break down very slowly or not at all in a lagoon. This nondegradable material leads to sludge buildup, which interferes with the pumpout procedure. As much of these solids as possible should be separated from the manure waste stream and kept from entering the lagoon. Over time the accumulated solids will reduce waste treatment volume and cause “overloading” of the lagoon. This “overloading” causes increased odor and reduced waste treatment function.

As solids accumulate into the waste treatment volume, they should be removed to prevent overloading by a special pump-out procedure called **lagoon renovation.** This requires continuous agitation with specially designed propeller or chopper pump agitators during the pump-out procedure. For further information on this see Extension Circular ANR-953, “Renovating Livestock Lagoons Using Irrigation.”

## Management Procedure

Proper management is essential to ensure that a lagoon functions effectively and efficiently during its expected lifetime. Good design and well-executed construction are worthless if the lagoon is not properly managed.

For a lagoon system to operate successfully, start-up procedures must be followed carefully. A new lagoon should be filled with water to 60 percent of treatment volume before manure is introduced. This assures sufficient dilution for the establishment of bacterial activity and will also minimize start-up odors. Starting a lagoon in late spring or early summer will allow a good bacterial population to be established during the warm season.

After initial start-up, lagoons perform best when they are loaded continuously. Flushing systems provide ideal loading conditions for lagoons.

If foul odors develop in an anaerobic lagoon, the pH level should be checked. A pH reading can be made using soil testing equipment or litmus paper. The addition of hydrated lime will increase a pH that is too low (less than 6.5). A higher pH will increase the activity of methane bacteria and decrease the acid concentration. If this treatment does not greatly reduce and control foul odors, the lagoon is probably overloaded.

Lagoons usually fill to design capacity within 2 to 3 years of start-up with the accumulation of wastes and rainfall on the open lagoon surface. To prevent lagoon overflow, excess lagoon liquid should be applied to grassland, cropland, or woodland at rates within the soil infiltration capacity and the fertilizer requirement of the vegetation. Lagoons should be pumped during the growing season to allow enough storage space for wastewater accumulation through winter when crop growth and nutrient requirements are low.

The lagoon liquid should be sampled and analyzed to determine its nutrient content. Table 1 gives information on average feeder-to-finish lagoon liquid accumulation rates and estimated available nutrient contents. Table 2 estimates application rates and minimum land areas needed for feeder-to-finish lagoon liquid irrigation application for different crops.

Wastewater irrigation using regular irrigation equipment is the easiest and most cost-effective way to apply lagoon liquid to land. Lagoon liquid should be irrigated on days with low humidity and when winds are not blowing toward neighboring residences. Irrigating in the early morning and early in the week will reduce offensive odors.

For more information on land applying swine waste from lagoons refer to Extension Circular ANR-925, “Calibrating Traveling Guns For Slurry Irrigation.” Procedures described apply to wastewater irrigation from lagoons.

As lagoons age, salt concentrations may increase to levels that can inhibit bacterial activity. Salt buildup in lagoons should

**Table 1. Fertilizer Nutrients In Swine Feeder-To-Finish Lagoon Liquid.**

| Total Anaerobic Lagoon Liquid Capacity, $Ft^3$/Animal | | Total Lagoon Liquid To Be Irrigated[a]/ Animal/ Year | | Plant Nutrient | Total Nutrients | Plant Available Nutrients[b] | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Irrigated | | Soil Incorporated | |
| One Stage | Two-stage 1st + 2nd | Gallons | Acre-Inch | | Lbs./ Acre-Inch | Lbs./ Acre-Inch | Lbs./ Animal/ Year | Lbs./ Acre-Inch | Lbs./ Animal/ Year |
| 270 | 200 + 70 | 927 | 0.034 | N | 136 | 68 | 2.3 | 96 | 3.3 |
| | | | | $P_2O_5$ | 53 | 37 | 1.3 | 40 | 1.4 |
| | | | | $K_2O$ | 133 | 93 | 3.2 | 100 | 3.4 |

[a]Estimated total lagoon liquid includes total liquid manure plus average lagoon surface rainfall surplus; does not account for seepage.
[b]Irrigated: sprinkler irrigated liquid, uncovered for 1 month or longer.
Soil incorporated: sprinkler irrigated liquid, plowed or disked into soil within 2 days.

| Table 2. Land Application Rate For Irrigated Swine Feeder-To-Finish Lagoon Liquid. | | | | | | |
|---|---|---|---|---|---|---|
| Rate-Limiting Nutrient | Cereal Grain | Corn | Fescue[b] | Tifton44[b] | Tifton44 Bermuda[c] | Bermuda Hay |
| Maximum Pounds Per Acre Per Year | | | | | | |
| N | 100 | 150 | 200 | 275 | 325 | 400 |
| $P_2O_5$ | 50 | 60 | 75 | 75 | 85 | 100 |
| $K_2O$ | 80 | 100 | 100 | 225 | 260 | 300 |
| Inches Per Acre Per Year | | | | | | |
| N | 1.50 | 2.2 | 2.9 | 4.0 | 4.8 | 5.9 |
| $P_2O_5$ | 1.30 | 1.6 | 2.0 | 1.0 | 2.3 | 2.7 |
| $K_2O$ | 0.86 | 1.1 | 1.1 | 2.4 | 2.8 | 3.2 |
| Minimum Acres Per Animal | | | | | | |
| N | 0.023 | 0.015 | 0.012 | 0.0085 | 0.0072 | 0.0058 |
| $P_2O_5$ | 0.025 | 0.021 | 0.017 | 0.0170 | 0.0150 | 0.0130 |
| $K_2O$ | 0.040 | 0.032 | 0.032 | 0.0140 | 0.0120 | 0.0110 |

[a]N leaching and denitrification and P205 soil immobilization unaccounted for.
[b]Open grazing.
[c]Controlled grazing.

be monitored yearly to ensure a safe level. Electrical conductivity (EC) is a convenient field measurement that indicates salt content. Before the salt content reaches 2,000 to 3,000 milligrams per liter (electrical conductivity of 3 to 5 millimhos per centimeter), the lagoon should be pumped down and fresh water added. This will reduce the chance of bacterial inhibition and formation of magnesium ammonium phosphate or struvite. This struvite may form on the inside of pipes and pump impellers in the recycled flush system, eventually causing breakdown. For information on addressing this situation see Extension Circular ANR-860, “Controlling Salt Buildup In Wastewater Recycling Systems.”

Pumping operations should be started before the lagoon is full to assure space (safety volume) is always available to hold a 25-year–24-hour storm. Good management guidelines call for pumping the lagoon when the water level reaches 1 foot below the design water level (usually marked by a treated post on the inside slope of the last stage).

In a single-stage lagoon, permanent markers should be installed (1) at a mark 1 foot below design water level to show when to initiate pumping the lagoon and (2) at the lagoon treatment level to indicate when to stop pumping (see Figure 1). In a two-stage lagoon, a permanent marker is needed only in the second stage to indicate when to initiate pumping. Pumping out too much effluent is not a problem in the second stage if the 2-foot minimum depth remains to allow recycle pump operation (see Figure 2). The first stage is pumped only to remove accumulated solids which reduce the permanent treatment volume (lagoon renovation, once every 5 to 20 years, depending on design).

## Appearance And Safety

Efforts should be made to make a swine waste lagoon as aesthetically pleasing as possible. Berms and embankments should have good grass cover for appearance and erosion control and be mowed and maintained on a regular basis. A well-maintained lagoon is less likely to attract attention and cause controversy.

The lagoon should be fenced to prevent access of children, trespassers, and livestock. Warning signs (SEWAGE TREATMENT FACILITY—KEEP OUT) should be posted and any access gate locked.

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