MP-1341

LAGOON SYSTEMS for LIVESTOCK WASTE TREATMENT

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Lagoon Systems for Livestock Waste Treatment

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Lagoon systems provide a means of treatment and storage of livestock manure prior to terminal disposal on land. Properly designed and operated, lagoons can reduce organic matter 75 to 95 percent and reduce nitrogen 40 to 80 percent through ammonia volatilization. In addition, lagoons can provide ample storage of manure and wastewater to meet no-discharge requirements of state and federal water pollution control agencies and to fit cropping and labor cycles of the livestock feeding operation.

The recommendations presented in this bulletin apply only to lagoons used to treat liquid manure and wastewater from confinement feeding operations through the creation of carefully controlled, steady state conditions. These recommendations do not apply to feedlot runoff holding ponds which are sometimes improperly called "lagoons."

ADVANTAGES AND DISADVANTAGES

Advantages of lagoon systems for treatment and storage of livestock waste include:

(1) Compatibility with modern hydraulic cleaning methods;

(2) Low cost construction;

(3) Minimum operating costs;

(4) Low labor requirement; and

(5) Reduction or elimination of fly problems.

However, some of the disadvantages of lagoon systems are:

(1) Appreciable loss of manure fertilizer value;

(2) Offensive odor and flies if improperly designed and managed;

(3) The need for periodic sludge removal;

(4) Possible groundwater pollution;

(5) Formation of mosquito habitat; and

(6) The need for terminal disposal of effluent.

Most of these disadvantages can be avoided or minimized through proper design and management of the lagoons.

In the warm climate of Texas, lagoon systems are preferable to storage pit/tank wagon systems when any of the following conditions exist:

(1) Insufficient cropland is available for full utilization of manure as fertilizer;

(2) Large volumes of water are routinely used for manure removal; or

(3) Liquid manure storage pits would create odor nuisance or fly breeding places.

Lagoon systems are also preferable to direct slurry irrigation if land area available is inadequate for direct disposal.

On the other hand, lagoons are not recommended for a site that has a porous subsoil or a high water table, since groundwater pollution problems could result. Lagoons are not advised where the operator wants to (and is able to) realize maximum fertilizer value from the manure. Lagoons also are not recommended where minimum distances to property lines and residences cannot be maintained.

APPLICABLE REGULATIONS

Where groundwater quality may be impaired, the *Texas Department of Water Resources* (formerly Texas Water Quality Board) requires that a soil permeability not exceed 1.0 X 10"' cm/sec (1.24 in/yr). It is necessary to select a site with an impervious subsoil, or to install a 6- to 12-inch compacted clay layer to ensure that

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seepage does not exceed this very low rate. The Texas Department of Water Resources also requires livestock and poultry operations to provide at least 30-day storage capacity for all manure and wastewater. For lagoon systems, however, this requirement has little practical consequence, because much larger storage capacity is inherent in lagoons properly designed for treatment of livestock wastes.

The *Texas Air Control Board* requires that new or expanding confined animal feeding facilities obtain a construction and operating permit any time new construction would provide for more than 1,000 livestock or poultry of any type or size. Therefore, the location and design of lagoons must be approved before a permit will be issued for new or modified operations.

The *Texas Department of Health Resources* and the local milk inspection unit must approve waste management practices for dairies. Dairymen should check with local milk inspectors when planning a lagoon system.

TYPES AND CHARACTERISTICS OF LAGOONS

Livestock waste lagoons act as digestion vessels in which three types of bacteria — aerobic, anaerobic and/or facultative — decompose the manure organic matter. Aerobic bacteria require dissolved oxygen to survive. Anaerobic bacteria cannot survive in free oxygen. Facultative bacteria can grow with or without free oxygen in the liquid waste material.

Anaerobic lagoons are the most common type used for livestock waste treatment. This type of lagoon can handle relatively high loading rates of organic wastes. However, anaerobic decomposition of livestock waste can result in the production of more than 40 different types of odorous gases. Odors can be controlled to reasonable levels with proper design and operation. The lagoon volume and dimensions should be carefully selected. Relatively constant operating conditions for anaerobic decomposition should be provided by maintaining the proper water level and discharging manure into the lagoon daily.

In *aerobic lagoons,* algae generate oxygen through photosynthesis, which takes place where sunlight penetrates the water (upper 4 to 5 feet). Oxygen diffusion also occurs across the surface of the water. Thus, a maximum water depth of 5 feet is recommended. Aerobic bacteria decompose waste more rapidly and completely than anaerobic bacteria, and produce little or no odor. However, a naturally aerobic livestock waste lagoon is generally impractical as the sole means of treatment because of the large surface area required for oxygen transfer. Aerobic lagoons must have about two times as much volume and four times as much surface area as anaerobic lagoons. The large size may also cause difficulty in sludge removal, embankment maintenance and control of aquatic plants. Aerobic lagoons are well suited for secondary treatment and storage of effluent from anaerobic lagoons.

Mechanically aerated lagoons combine the odor control advantages of aerobic lagoons with the relatively small size requirement of anaerobic lagoons. They are sometimes used to control odors in sensitive locations, or for nitrogen removal where land disposal areas are severely limited. However, use of floating surface aerators to provide oxygen is much more expensive than normal lagoon operation. For floating aerators, the aeration requirement for odor control is 1 horsepower per 750 to 1,000 square feet of lagoon surface.

LAGOON DESIGN AND OPERATION

Design and operating criteria for primary or first-stage anaerobic lagoons are described in this section. A typical layout and cross-section of an anaerobic or facultative lagoon, are shown in Figures 1 and 2.

Location

Anaerobic lagoons should be located near the source of livestock waste, yet as far from inhabited dwellings as practical (500 feet suggested minimum). They should be at least 100 feet from wells used for human water supply or from milking parlors. Prevailing summer winds should carry odors away from nearby residences. Natural or constructed visual barriers around the lagoon can minimize possible complaints from neighbors. Lagoons should not be constructed in natural drainage paths or gulleys. Runoff from open-lot surfaces or outside drainage areas should be diverted around the lagoon(s) to minimize storage capacity requirements and to avoid upsetting the bio-chemical balance needed for proper digestion.

Water Supply

The water supply must be adequate to maintain full water depth in the anaerobic lagoon. Stock tanks are often used as a temporary source of supplemental dilution water. In West Texas where high evaporation depletes lagoon water and leads to salt buildup, a dependable water supply is essential for proper lagoon operation.

To minimize hydrogen sulfide emissions, water entering the lagoon should contain less than 100 parts per million (ppm) sulfate.

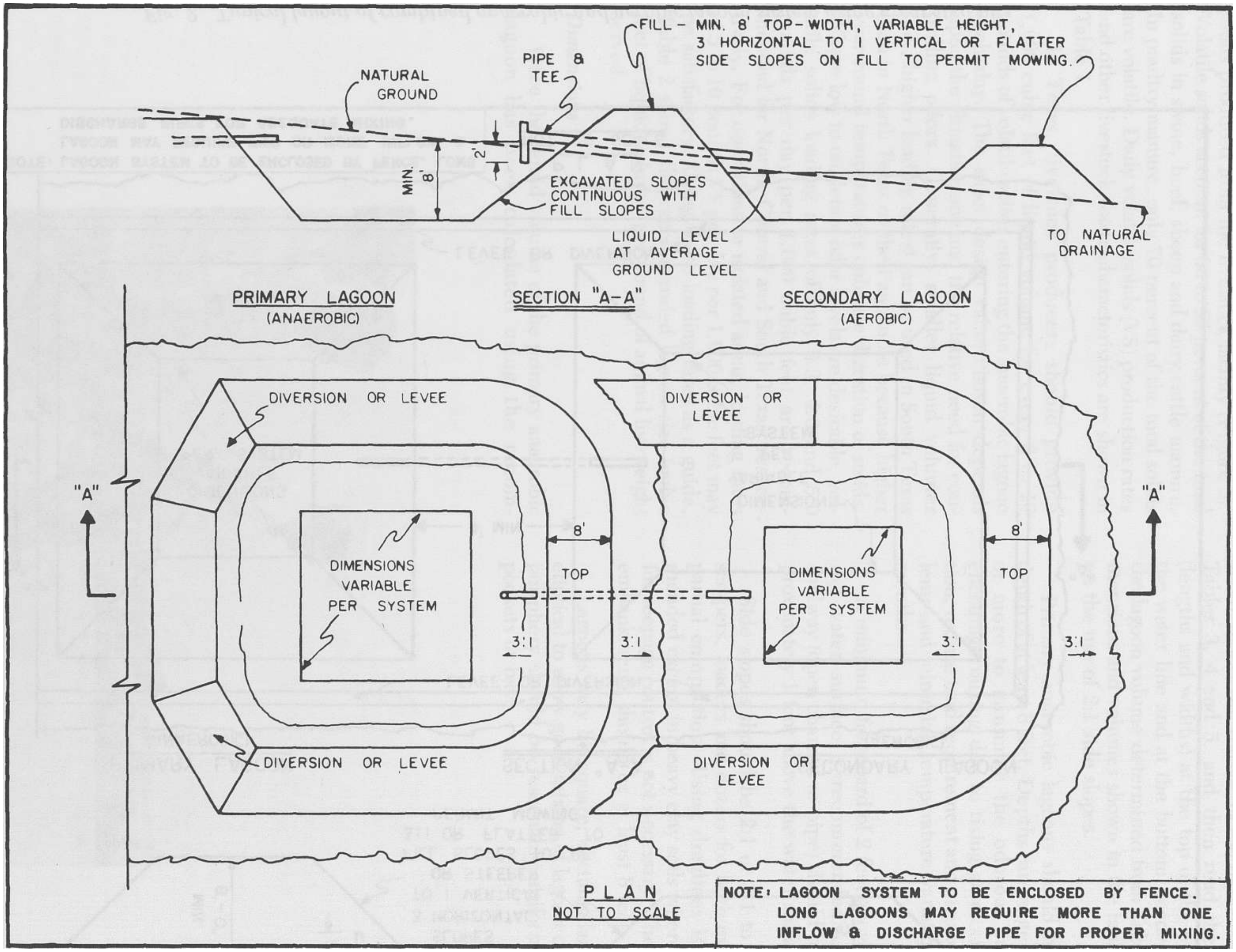

Fig. 1. Typical layout of combined anaerobic and aerobic lagoon system using combination of excavated pits and embankments.

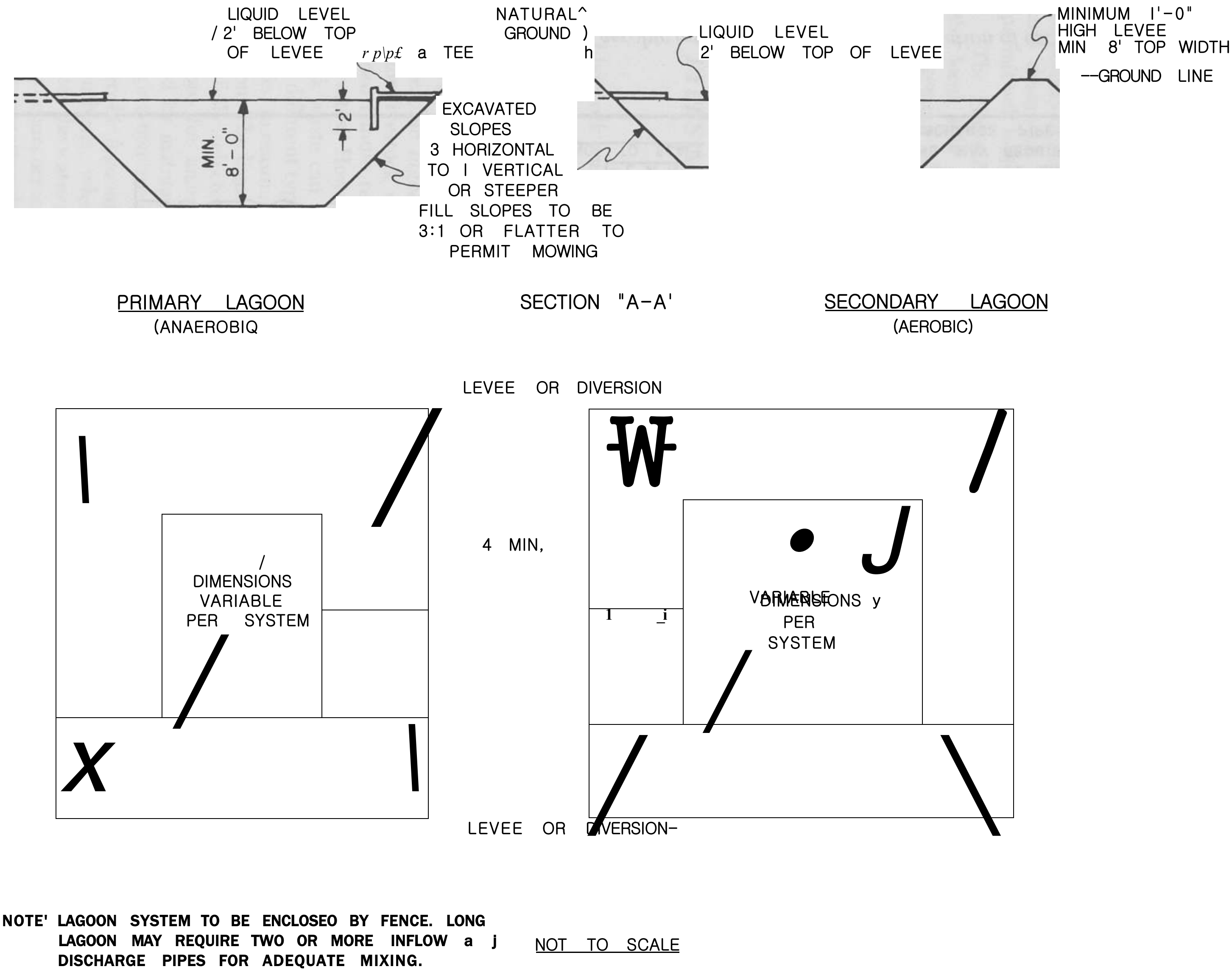

Fig. 2. Typical layout of combined anaerobic and aerobic lagoon system using excavated pits.

Capacity and Loading Rates

The liquid volume of anaerobic lagoons should be based on the amount of volatile (or biodegradeable) solids produced from the livestock facility (Figure 3). Volatile solids account for 80 to 85 percent of the total solids in swine, beef, sheep and dairy cattle manure. In poultry manure, only 70 percent of the total solids are volatile. Daily volatile solids (VS) production rates and other livestock waste characteristics are shown in Table 1.

In Texas, livestock producers should provide 1,000 cubic feet of liquid volume for every 3 to 10 pounds of volatile solids entering the anaerobic lagoon each day. The exact design value chosen depends upon the climatic zone and the relative need for controlling odors. Generally, smaller liquid volumes (i.e., higher loading rates) can be used in South Texas than in North Texas or the Panhandle because higher year-round temperatures enhance digestion of solids. Where low to moderate odor levels are desirable, volatile solids loading rates of only 3.3, 4.0 and 5.0 pounds per day per 1,000 cubic feet are recommended for North, Central and South Texas, respectively. For operations in isolated areas, loading rates of 5 to 10 pounds VS per day per 1,000 cubic feet may be satisfactory. Using these loading rates as a guide, Table 2 shows the recommended lagoon size (cubic feet of liquid volume) per pound of animal liveweight served.

Dimensions

Once the liquid volume of the primary anaerobic lagoon has been calculated using the recommendations in Table 2, the actual dimensions of the lagoon can be computed. Various combinations of lengths, widths and depths are given in Tables 3, 4 and 5. Select the volume in the right-hand column of Tables 3, 4 and 5, and then read the dimensions (lengths and widths) at the top of the excavation, at the water line and at the bottom needed to provide the lagoon volume determined from Table 2. The dimensions and volumes shown in the tables are based on the use of 2:1 side slopes.

Primary anaerobic lagoons should have a liquid depth of at least 8 feet. Depths can range up to 20 feet or more to minimize the odorous surface area, encourage mixing due to rising gases of decomposition, reduce land requirement and maintenance problems and minimize temperature variations in winter months.

A minimum freeboard of 2 feet above the operating water surface is recommended. A protective spillway (open channel or pipe) should be located approximately 1 foot above the water surface.

Side slopes should be 2:1 or 3:1 to allow use of scrapers, loaders and dozers for both excavation and partial compaction. Using draglines is not recommended except in heavy clay soils where compaction for seepage control is not necessary. The top width of embankments should be at least 8 feet.

Lagoons may be square, rectangular, circular or eliptical to allow good mixing of lagoon contents. The periphery should be reasonably uniform and free of pockets or bays.

Fig. 3. Lagoon operating volume depends on the amount of manure produced from the confinement livestock facility (a function of animal type, number and size), climate and location relative to neighbors.

Table 1. Average waste production rates for livestock and poultry (Per 1000 lbs. liveweight). *

Parameter		Dairy cow	Beef feeder	Swine	Poultry Layer	Poultry Broiler	Sheep feeder	Horse
1. Raw manure (RM) feces and urine	lbs./day	82	60	65	53	71	40	45
2. Total solids (TS)	lbs./day	10.4	6.9	6.0	13.4	17.1	10	9.4
	%RM	12.7	11.6	9.2	25.2	25.2	25	20.9
3. Volatile solids (VS)	lbs./day	8.6	5.9	4.8	9.4	12.0	8.5	7.5
	%TS	82.5	85	80	70	70	85	80
4. ROD_5	lbs./day	1.7	1.6	2.0	3.5	–	0.9	–
	%TS	16.5	23	33	27	–	9.0	–
5. Nitrogen (N)	lbs./day	0.41	0.34	0.45	0.72	1.16	0.45	0.27
	%TS	3.9	4.9	7.5	5.4	6.8	4.5	2.9
6. Phosphorus (P)	lbs./day	0.073	0.11	0.15	0.23	0.26	0.066	0.046
	%TS	0.7	1.6	2.5	2.1	1.5	0.66	.49
7. Potassium (K)	lbs./day	0.27	0.24	0.30	0.31	0.36	0.32	0.17
	%TS	2.6	3.6	4.9	2.3	2.1	3.2	3.2

*Source: Reproduced with permission from Livestock Waste Facilities Handbook MWPS-18, Midwest Plan Service, Ames, Iowa 50011.

Table 2. Recommended liquid capacities of primary anaerobic lagoons (Cubic feet per pound liveweight). *

Location	Dairy cattle	Swine, beef or horses	Poultry (layers) or sheep
Texas Panhandle and North Texas	2.0	1.8	2.3
Central and West Texas	1.6	1.5	1.9
South Texas	1.3	1.2	1.5

*Values in this table assume all manure production enters the lagoon. Reduce according to fraction of time animals are not in confinement. Liquid capacity can be reduced by 25 percent if fibrous fraction is removed by settling or screening.

*Table 3. Water volume of anaerobic lagoons of various sizes (total depth 10 feet — water depth 8 feet).**

Top Length (feet)	Top Width (feet)	Waterline Length (feet)	Waterline Width (feet)	Bottom Length (feet)	Bottom Width (feet)	Volume to waterline (cubic feet)
70	70	58	58	26	26	14,700
80	80	68	68	36	36	22,300
90	90	78	78	46	46	31,400
100	100	88	88	56	56	42,100
150	100	138	88	106	56	70,900
200	100	188	88	156	56	99,700
150	150	138	138	106	106	119,700
250	100	238	88	206	56	128,500
300	100	288	88	256	56	157,300
200	200	188	188	156	156	237,300
250	250	238	238	206	206	394,900
300	300	288	288	256	256	592,500

*An anaerobic lagoon should be at least 8 feet deep and may be 12 feet or more. Dikes around the lagoon should be high enough to provide 2 feet of freeboard above the waterline.

Table 4. Water volume of anaerobic lagoons of various sizes (total depth 12 feet — water depth 10 feet).

Top		Waterline		Bottom		Volume to waterline
Length (feet)	Width (feet)	Length (feet)	Width (feet)	Length (feet)	Width (feet)	(cubic feet)
70	70	58	58	18	18	15,700
80	80	68	68	28	28	24,300
90	90	78	78	38	38	34,900
100	100	88	88	48	48	47,500
150	100	138	88	98	48	81,500
200	100	188	88	148	48	115,500
150	150	138	138	98	98	140,500
250	100	238	88	198	48	149,500
300	100	288	88	248	48	183,500
200	200	188	188	148	148	283,500
250	250	238	238	198	198	476,500
300	300	288	288	248	248	719,500

Table 5. Water volume of anaerobic lagoons of various sizes (total depth 14 feet — water depth 12 feet).

Top		Waterline		Bottom		Volume to waterline
Length (feet)	Width (feet)	Length (feet)	Width (feet)	Length (feet)	Width (feet)	(cubic feet)
70	70	58	58	10	10	16,100
80	80	68	68	20	20	25,500
90	90	78	78	30	30	37,200
100	100	88	88	40	40	51,400
150	100	138	88	90	40	89,800
200	100	188	88	140	40	128,200
150	150	138	138	90	90	158,200
250	100	238	88	190	40	166,600
300	100	288	88	240	40	205,000
200	200	188	188	140	140	325,000
250	250	238	238	190	190	551,800
300	300	288	288	240	240	838,600

Table 6. Surface area requirements for naturally aerobic lagoons.

	BOD_5 load lbs./day/1000 lbs. liveweight	Surface area requirement, sq. ft. per lb. animal liveweight	
		First stage*	Second stage**
Dairy cow	1.7	1.0	0.4
Beef feeder	1.6	0.9	0.4
Swine	2.0	1.2	0.5
Poultry (layer)	3.5	2.0	0.8
Sheep	0.9	0.5	0.2

*Based on a loading rate of 75 lbs. BOD_g per acre per day. Assumes entire manure production enters lagoon and should be adjusted in proportion to time actually spent in confinement.

**Assumes 60 percent BOD reduction in primary anaerobic lagoon.

DESIGN OF SECONDARY LAGOONS

Second-stage lagoons, though not required, give the operator certain flexibility in managing effluent and improve treatment efficiency. The main function of second-stage lagoons may be storage, rather than treatment. Effluent can be recirculated for use as flush water in hydraulic manure removal systems. Effluent from a second-stage lagoon is still not of acceptable quality to allow discharge. Effluent disposal on land is eventually necessary.

The size and capacity of second-stage lagoons usually are not as critical as first-stage lagoons because the entering waste is less concentrated. In designing second-stage aerobic lagoons, one can assume that 20 to 40 percent of the 5-day biochemical oxygen demand (BOD_5) and volatile solids remain after first-stage lagoon treatment. The most common design criteria is the minimum surface area needed to achieve aerobic activity. The recommended surface area for oxygen transfer can be computed by multiplying the total liveweight of animals on feed by the values in the right hand column of Table 6. The water depth should be approximately 5 feet.

CONSTRUCTION DETAILS

Seepage Control

Lagoons should be located in soils of low permeability, or in soils that can be adequately sealed to prevent groundwater contamination. Avoid sandy or gravelly soils and locations with a high intersecting water table. The Texas Department of Water Resources allows a maximum seepage of only 0.1 foot per year, or a soil permeability of 1.0 X 10 ' cm/sec. Research shows that bacteria on the lagoon bottom clog soil pores and reduce seepage by 90 to 99 percent. But in most cases, self-sealing action alone is not adequate to meet the state requirement. A 6- to 12-inch layer of compacted clay may be required for seepage control. The cost of installing a compacted clay lining increases sharply with haul distance.

Inlet/Outlet Devices

Lagoon inlets should be constructed of smooth steel or plastic pipe at least 6 inches in diameter and laid on a minimum slope of 2 percent (1/4 inch per foot). Cantilevered pipe sections should not exceed 5 feet without a supporting member. The discharge end of lagoon inlets can be either below or above the water line of the primary lagoon. Above-water inlets help the operator detect pipe stoppage and take samples for analytical purposes. Lagoon inlets below the water line are more susceptible to stoppage, and should have an access port for cleanout.

Outlets connecting the primary lagoon with a secondary lagoon should be T-shaped as shown in Figures 1 and 2. They should be designed to remove effluent at a depth of 1 to 2 feet below the lagoon surface. For each acre of lagoon surface, one outlet pipe with a diameter of 4 to 6 inches (for West and East Texas, respectively) will be sufficient to remove heavy rainfall on the primary lagoon surface. A concrete channel or spillway may be suitable for this purpose also.

Embankment Lagoon Construction

Provide a cutoff wall of relatively impervious material in the embankment to prevent seepage. The cutoff should extend along the centerline of the embankment. Excavate the cutoff trench to a relatively impervious layer, using a bottom width and side slopes adequate to accommodate the equipment used for excavation, backfill and compaction operations. Continue the cut-off wall, using relatively impervious material, to a height equal to maximum water level in the lagoon.

The minimum top width of the embankment should be 8 feet. The top of the embankment should slope away from the lagoon.

Side slopes of the settled embankment (both inside and outside the lagoon) should not be flatter than 3 horizontal to 1 vertical. Slopes of the excavation pit portion of the embankment lagoon should match slopes of the embankment portion of the lagoon.

The freeboard should be at least 2 feet. Increase the design height of the embankment by the amount needed to ensure that the design top elevation will be maintained after all settlement has taken place. This increase should be as follows:

Embankments constructed with	Height allowance, percent
Bulldozer and bulldozer-dragline combinations	10
Carry-alls and scrapers	5

The use of draglines alone for embankment construction is not recommended. To ensure an impermeable embankment, draglines may be used where the embankment is compacted in layers of 12 inches or less by bulldozers, scrapers or similar equipment.

Actual allowance for shrinkage (in excess of the minimum listed) should be determined for the individual site, based on soil, moisture conditions, contractor and experience in the area.

The entire outside slope of the fill and the inside slope above the water line should be seeded or sodded in perennial grasses adapted to the area.

Excavated Pit Construction

Side slopes of excavated pit lagoons should be constructed on a stable slope. They should not be steeper than 1 horizontal to 1 vertical, nor flatter than 3 horizontal to 1 vertical. The maximum elevation of the water level in the lagoon should be 1 foot below normal ground level at the delivery pipe inlet.

Diversion of Outside Runoff

Construct a levee or diversion around the periphery of lagoons as needed to prevent entrance of any outside runoff. Levees or diversions should have a minimum settled height above normal ground level of 1 foot with a minimum top width of 8 feet and side slopes not steeper than 3 horizontal to 1 vertical. The top of the diversion or levee should slope away from the lagoon. Construct the levee or diversion adjacent to the excavated pit. The slope toe of the levee should blend with the top of the slope of the excavated pit.

LAGOON OPERATION AND *MAINTENANCE*

Start-up Procedure

A new anaerobic lagoon should be filled to at least 50 percent of the design depth before loading begins. Start-up should take place during warm weather so that maximum bacterial reproduction, digestion and stabilization can be achieved.

Anaerobic decomposition is a two-phase process. First, manure organic matter is liquefied to organic acids, thus lowering the pH. These intermediate organic acids are then converted by "methane bacteria" into stable end products such as carbon dioxide, methane, water and numerous inorganic or stable organic compounds. The first or liquefaction phase of anaerobic decomposition is relatively easy to achieve, but the second phase is sometimes sluggish.

As a result, the pH in new lagoons (or in overloaded lagoons) can be reduced to 6.5 or less (slightly acidic), thereby creating odor problems. This can be corrected by applying hydrated lime to the lagoon surface at the rate of 1 pound per 1,000 square feet. An anaerobic lagoon in proper balance will have a pH of approximately 7.5 (slightly basic).

Operating Procedure

It is important to maintain the design liquid level of the lagoon by adding water as needed. Insofar as possible, bedding material, straw, oil, plastic sheeting and other foreign material should be kept out of lagoons. Rapid buildup of floating fibrous material and bottom sludge accumulation often occurs in lagoons serving dairy cattle. Fibrous material comes from high roughage rations and from bedding in free-stall dairy barns. In most cases, these solids should be separated from liquid dairy manure since they are difficult to digest in lagoons. The principal methods of solids separation are: (a) a settling pit or basin; or (b) mechanical screen (stationary or vibrating).

Anaerobic lagoons should be loaded with manure at least once daily. Research shows that intermittent loading can cause as much odor production as 50 percent under-design of the lagoon. In areas of high evaporation, the inflow should contain dilution water in the ratio of at least 5 parts water to 1 part wet manure. Hydraulic flush systems normally add ample dilution water. If manual washdown is used, liberal use of washwater is encouraged.

Maintenance

Lagoons should be inspected periodically to ensure that inlet devices are operational and that floating debris, odors and flies are at a minimum. Grass and weeds around the embankment should be closely mowed, as they make inspection difficult, increase the likelihood of accidental slippage into the lagoon, add to the organic loading rate and increase attractiveness to flies and mosquitoes.

Operators should plan adequate roads to provide access to the lagoons and appurtenances. If the fill is also used as a road, adequate access ramps and an area for turning should be provided.

To prevent accidental drownings, lagoons should be fenced and warning signs posted.

Sludge and Effluent Removal

From 15 to 30 percent of the manure solids entering the lagoon are non-biodegradeable (Table 1). These solids, plus slowly-biodegradeable organic compounds such as lignin and cellulose, will accumulate as sludge on the bottom of the lagoon and eventually will require cleanout. Even with good bacterial digestion, as much as 1/3 to 1/2 of the total solids inflow may remain as sludge.

The rate of sludge buildup depends upon many variables such as type of animal, ration, temperature, loading rate and chemical balance. For instance, sludge can accumulate in properly designed dairy lagoons at the rate of 15 percent of lagoon volume per year.

Sludge accumulation rates as high as 0.5 to 1 cubic foot per day (or 160 to 350 cubic feet per year) per 1,000 pounds liveweight have been observed with dairy cattle manure. This is mainly attributable to the high-fiber ration and bedding material, most of which can be removed from the waste stream by screening or gravity settling. Sludge will accumulate much more slowly in swine or poultry lagoons, averaging about 0.1 to 0.2 cubic foot per day (or 35 to 75 cubic feet per year) per 1,000 pounds of liveweight. Maintaining the current water level will result in maximum sludge digestion and compaction.

The solids concentration of lagoon sludge ranges from 4 to 10 percent. Nutrient content of lagoon

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sludge can be appreciable because phosphorous and organic nitrogen compounds accumulate in the sludge. Phosphorous concentrations are 5 to 25 times higher in lagoon sludge than in lagoon effluent. Nitrogen concentrations in lagoon sludge may be up to 100 percent higher than in lagoon effluent.

In general, it is recommended that sludge be removed every 5 years or when buildup becomes apparent. Annual removal of sludge near the inflow pipe will increase the performance and effective life of a lagoon.

Types of equipment available for lagoon sludge removal include (Figure 4):

(1) Sludge pumps
- — Centrifugal; long hitch trailer mounted; PTO drive
- — Chopper-agitator; 3-point hitch mounted; PTO drive
- — Diaphragm suction; electric or gasoline engine drive

(2) Agitation
- — Long shaft propeller; 3-point hitch mounted
- — By-pass valve for recirculation from centrifugal or chopper-agitator pumps

(3) Tank wagons — vacuum loaded

(4) Hydraulic dredge

(5) Dragline

Sludge can be disposed of with surface or large bore sprinkler irrigation systems if ample dilution water is used. For small lagoons, liquid manure spreading with a tank wagon will suffice.

When the concentration of soluble salts exceeds approximately 4,000 ppm, bacterial action is inhibited. Salt buildup is especially likely in high evaporation areas or where the water supply has a high salt content. Up to one-half of the lagoon contents should be disposed of by irrigation whenever the total salt concentration exceeds 3,000 ppm. After pumping, the lagoon should be filled with fresh water.

Lagoon Effluent Disposal

Lagoon effluent can provide substantial amounts of nutrients to pasture and cropland. The concentration of nutrients, salts and pollutants in effluent from primary and secondary lagoons varies widely, depending upon many factors. Nutrient concentrations appear to be closely related to the solids content. Typical nutrient concentrations of primary lagoon effluent are recorded in Table 7. Lagoon effluent contains live salmonella and other disease organisms; therefore, direct contact with humans or animals should be avoided. However, it is safe to use lagoon effluent on non-food crops and pastures because these organisms are rapidly destroyed in the soil and on plant surfaces.

Soil application rates usually are based on the nitrogen concentration in the lagoon effluent and on soil test results. The salt content may also be a limiting factor. Contact the local county Extention agent for guidance on land disposal.

Effluent from second-stage lagoons can be applied using conventional sprinkler irrigation equipment with 1/4- to 3/8-inch nozzles. Effluent from primary swine and poultry lagoons can normally be disposed of through 3/8- to 1/2-inch nozzles. Larger nozzle sizes (from 3/4 inch to 1 inch) should be used for pumping anaerobic lagoon effluent from dairies. Protective screening of the intake pipe should be provided. Pump power requirements for disposal of lagoon effluent are the same as for irrigation water at equiva-

Fig. 4. Lagoon sludge can be removed periodically using trailer-mounted centrifugal pumps, vacuum-loaded tank wagons or other devices.

*Table 7. Typical nutrient content of anaerobic lagoon effluent (Percent).**

Parameter	Dairy	Swine	Beef
Solids content	**0.2-0.5**	**0.5-1.1**	**0.2-2.5**
Nitrogen	**0.01-0.03**	**0.06-0.2**	**0.02-0.20**
Phosphorus	**0.0005-0.01**	**0.006-0.01**	**0.002-0.04**
Potassium	-	**0.04**	**0.01-0.12**

•Conversion factors — multiply values shown by 2265 to get pounds per acre-inch, or by 83.4 to get pounds per 1000 gallons.

lent pressure-discharge combinations, provided the solids content is less than 2 percent.

Insect Control

Mosquito production in livestock waste lagoons varies inversely with the loading rate. Maximum mosquito production occurs in lightly loaded lagoons (3 to 5 cubic feet per pound liveweight). Heavily loaded lagoons (0.8 cubic feet per pound liveweight) result in little or no mosquito production. Several chemicals have proved effective for mosquito control in lagoons. Lagoon performance is not impaired by use of pesticides at the recommended dosages. Mosquito breeding is enhanced in lightly-loaded lagoons by bank sloughing or floating herbage which tends to form shallow pockets unruffled by wave action.

Fly breeding in lagoons may occur whenever a partially dry floating crust develops during the warm months, or whenever bank sludge remains exposed for several days or weeks after effluent pumping. Floating crusts can be controlled by providing the proper lagoon liquid volume, or by separating the fibrous manure solids through settling or screening. Fly breeding along the banks can be controlled by refilling with water after pumping and by mowing and removing excess vegetation along the banks.

APPENDIX

EXAMPLES — DETERMINING LAGOON SIZES

Example 1 — Anaerobic Lagoon Volume

A Central Texas dairyman wants to construct an anaerobic lagoon for 100 dairy cattle with an average weight of 1200 pounds. From Table 2, he finds that the lagoon volume should be 1.6 cubic feet per pound of liveweight. Thus, the lagoon liquid volume should be:

Lagoon volume = 100 cows X 1200 lbs/cow
X 1.6 cubic feet/pound
= 192,000 cubic feet

But, since his cattle are confined in milking parlors and holding pens only 6 hours per day, the volume can be reduced by 75 percent. Thus,

Lagoon volume = 48,000 cubic feet

Example 2 — Anaerobic Lagoon Dimensions

Dimensions of the lagoon for the 100-cow dairy herd in Central Texas (Example 1) are determined from Table 5. A lagoon 14 feet deep, 100 feet wide and 100 feet long (top dimensions) will be adequate because it has a liquid capacity (at 12 feet of water depth) of 51,400 cubic feet.

Example 3 — Second Stage Lagoon

The dairyman with a 100-co*W herd in Central Texas wants to construct an aerobic second-stage lagoon to store and treat effluent from the primary anaerobic lagoon (Examples 1 and 2). From Table 6, the required surface area is: 0.4 square foot per pound liveweight X 120,000 pounds liveweight = 48,000 square feet. Reducing this by 75 percent because cattle are confined just 6 hours per day gives a surface area of 12,000 square feet, or 110 feet X 110 feet water line dimensions. The water depth should be 5 feet. Using 3:1 side slopes, the bottom dimension would be 80 feet X 80 feet, while the top dimensions would be 130 feet X 130 feet, assuming a 2-foot freeboard.

Example 4 — Calculating Liquid and Excavated Volumes

To calculate the volume of a lagoon with selected dimensions, use the formula:

$$V = T(A_T + 4A_M + A_B)$$

where V = volume or capacity in cubic feet
D = depth in feet
Ay = area at the top in square feet
A_m = area at one-half the depth in square feet
Ag = area at the bottom in square feet

For example, the *liquid volume* of the aerobic lagoon in Example 3 can be calculated as follows:

A_t = 110 X 110 = 12,100 square feet (water line)
A_b = 80 X 80 = 6,400 square feet (bottom)
A_m = 1/2(80 + 110) x 1/2(80 + 110)
= 95 x 95 = 9025 square feet (one-half depth)

Thus, the liquid volume is:

V = 5/6(12,000 + 4[9025] + 6400)
V = 45,500 cubic feet

The *excavated volume* is calculated as follows:

A_t = 130 X 130 = 16,900 square feet
A_b = 80 X 80 = 6,400 square feet
A_m = 1/2(80 + 130) x 1/2(80 + 130)
= 105 X 105 = 11,025 square feet

Thus, the excavated volume of the lagoon is:

V = 7/6(16,900 + 4[11,025] + 6,400)
V = 78,630 cubic feet
= 2,910 cubic yards

Example 5 — Solids Separation (Screening)

Solids separation to remove fibrous solids by stationary screening will reduce lagoon capacity requirements by 25 percent. If the dairy manure in the previous example is first screened, the anaerobic lagoon size can be reduced to 36,000 cubic feet. Thus, the size selected from Table 5 will have top dimensions of 90 feet X 90 feet and a liquid volume of 37,200 cubic feet. A comparable adjustment can be made for screening in determining the size of the second stage lagoon.

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