

Considerations in Sizing Manure Storage Facilities

Many factors contribute to the volume needed in a manure storage facility. These factors include the type of enterprise (open beef feedlot vs. confined broiler operation), animal numbers and species, climatic characteristics (rainfall and evaporation), type of storage facility (lagoon vs. stackhouse for poultry litter), required storage period, and washwater use. Producers are encouraged to closely evaluate sizing issues to better understand the risks associated with an undersized storage structure. The Environmental Stewardship Assessment for sizing considerations (Appendix A, Lesson 20) assists producers in a critical review.

Storage period

Two primary considerations in selecting a manure storage period are the crop-growing season, and climatic characteristics (rainfall, freezing temperatures) that might influence land application operations. Other considerations might include equipment availability, especially if custom operators are used for land application; labor availability; and management flexibility.

Crop considerations. In the case of row or cultivated crops, land application of manure may not be possible between planting time and harvest. Hence, the minimum storage period would be the growing season of the crop. Forage crops (hay or pasture) may offer greater flexibility for manure application during the growing season. In warm, humid regions with long (or year-round) growing seasons, double or triple cropping may be contemplated for maximum nutrient uptake. However, these practices can reduce the “windows of opportunity” for manure land application, and careful thought and consideration should be given to the potential benefits and problems.

Climatic considerations. In addition to crop considerations, climatic characteristics are an important influence on storage period selection. Most state regulations prohibit or discourage application of manure on frozen or saturated soil. Much of the United States experiences frequent periods between fall and spring when climatic conditions are less than ideal for land application of manure. If irrigation is used for land application, consideration might be given to providing a storage period compatible with the typical irrigation season for a given area. A storage period should be selected so that manure is not land applied during unsuitable climatic and soil conditions.

Equipment and labor availability. If equipment and labor for land application of manure are available only seasonally or at certain times of the year, the manure storage period should be selected accordingly. If custom operators are used, they may be available on a particular schedule.

In general, longer storage periods offer greater flexibility in managing land application operations. Typical storage periods for slurry and liquid

Many regulations may affect the size of your manure storage. Find out what they are before you build.

Cropping schedules and climatic factors, such as rainfall and freezing weather, are primary considerations in determining a suitable manure storage period.

systems range from four months to one year. If crop types and climatic conditions allow, shorter storage periods may be acceptable. Individual states may have specific requirements for manure storage period, and any applicable regulations should be observed. Table 21-1 shows conditions and characteristics associated with different lengths of storage for manure.

Several distinct volume fractions may contribute to the total size of a manure storage facility. These volume fractions may include the following:

1. Manure
2. Bedding
3. Washwater. May include fresh water used for flushing manure, sprinklers or foggers used for cooling, wasted drinking water, and water used in washing down rooms or cleaning milking equipment
4. Open lot runoff due to rainfall
5. Sludge or solids accumulation in the manure storage facility
6. Treatment volume in a lagoon
7. Rainfall on surface of open manure storage facility
8. Evaporation from surface of open manure storage facility
9. 25-year, 24-hour storm

Following is a discussion of these volume fractions and how they might be estimated in sizing a manure storage facility.

Manure

The volume of manure produced during the selected storage period is a primary consideration in sizing a manure storage facility. Manure volume depends upon animal numbers and species, animal weight, and perhaps animal category within a species (gestating sow vs. finishing pig). Manure volume is usually estimated using published values developed from experimental and field measurements. Tables 21C-1 through 21C-9 in

Table 21-1. Conditions and characteristics associated with storage period for manure.

Storage Period	Conditions and Characteristics
Short-term (3 months or less)	Warm climate, no long periods with frozen or saturated soil. Pasture, grass, and hay land available for spreading. Equipment, time, and labor available as needed for frequent spreading.
Mid-term (3 to 6 months)	May accommodate short periods with frozen, snow-covered, or saturated soil. May not be adequate for traditional annual crop rotations. Some pasture, grass, or hay land will likely be needed for spreading.
Long-term (6 months to 1 year)	Provides greatest flexibility for spreading operations. Accommodates longer winter seasons. May best fit timing of cropping operations. Provides storage from one irrigation season to the next. Most flexibility for scheduling custom spreading operations.

Appendix C (adapted from the NRCS Agricultural Waste Management Field Handbook) list characteristics of manure produced by different livestock species. This data can be used to calculate the volume of manure produced during a given storage period. The term “Kwt” refers to thousand pounds of live animal weight.

Bedding

In some cases, bedding used in livestock production contributes to the final volume of material to be stored. Typical bedding materials include hay, straw, sawdust, wood shavings, and sand. Bedding is used in such operations as dairy freestall or loafing barns, poultry raised on litter systems, and hoop structures for swine. In estimating the volume of a bedding/manure mixture, consideration must be given to the amount of bedding used, moisture conditions, and density of the bedding/manure mixture. The volume contributed by bedding to a manure/bedding mixture depends upon the amount of bedding used. If minimal bedding is used (just enough to make the manure/bedding mixture behave as a solid or semi-solid), then the volume contribution of the bedding may be in the range of one-third to one-half the bedding volume, because manure tends to fill the void spaces between bedding particles. If greater fractions of bedding are used (such as providing a sleeping area in a horse stall), then the volume contribution of the bedding may be much greater. Experience with similar systems and management is usually the best way to estimate the volume of manure/bedding mixtures.

Table 21-2 shows common types of bedding materials and their physical characteristics.

Table 21-2. Characteristics of common bedding materials.

Material	Loose, lb/ft ³	Chopped, lb/ft ³
Legume hay	4.25	6.50
Non-legume hay	4.00	6.00
Straw	2.50	7.00
Wood shavings, dry	9.00	
Sawdust, dry	12.00	
Sand	105.00	
Ground limestone	95.00	

Adapted from NRCS Agricultural Waste Management Field Handbook 1996.

EXAMPLE 1

Calculate the volume of manure produced by 1,000 finishing swine whose average weight is 150 lbs. Assume a storage period of 6 months.

Use data in Table 21C-1.

$$1 \text{ ft}^3/\text{d-Kwt} \ 150 \text{ lb}/\text{hd} \times 1,000 \text{ hd} \times 1 \text{ Kwt}/1,000 \text{ lb} \times 180 \text{ d} = 27,000 \text{ ft}^3$$

The volume of manure and bedding produced depends upon the amount of bedding used and the type and size of animals.

To calculate the volume of a manure/bedding mixture, the volume of bedding used must be estimated. Bedding use in animal production systems is highly variable and often depends upon such diverse factors as availability and operator preference. Table 21-3 shows estimates of bedding use in dairy and swine housing systems.

Table 21-3. Daily bedding use in dairy and swine housing systems, lbs bedding material per day per thousand pounds live animal weight.

Material	Dairy stanchion	Dairy freestall	Dairy housing	Swine structure
Loose hay/straw	5.4		9.3	15.0
Chopped hay/straw	5.7	2.7	11.0	--
Wood shavings, sawdust	--	3.1	--	18.0
Sand, limestone	--	20.0 - 35.0	--	--

Adapted from NRCS Agricultural Waste Management Field Handbook 1996 and AED-41, Hoop Structures for Grow-Finish Swine 1997.

EXAMPLE 2

Estimate the volume of manure/bedding mixture generated in growing out a group of hogs in a swine hoop structure. There are 150 pigs in the structure for 16 weeks, and their average weight during the growout period is 150 lbs. Assume that sawdust will be used for bedding.

Using data in Table 21C-1, calculate the manure volume.

$$1 \text{ ft}^3/\text{d-Kwt} \times 150 \text{ lb}/\text{hd} \times 150 \text{ hd} \times 1 \text{ Kwt}/1,000 \text{ lb} \times 16 \text{ wk} \times 7 \text{ d}/\text{wk} = 2,520 \text{ ft}^3$$

Using data in Tables 21-2 and 21-3, estimate the bedding volume.

$$150 \text{ lb}/\text{hd} \times 150 \text{ hd} \times 1 \text{ Kwt}/1,000 \text{ lb} \times 18 \text{ lb}/\text{Kwt-d} \times 16 \text{ wk} \times 7 \text{ d}/\text{wk} \times 1 \text{ ft}^3/12 \text{ lb} = 3,780 \text{ ft}^3$$

Assume that the bedding will contribute 50% of its volume to the mixture due to manure filling bedding void spaces. The volume of the manure/bedding mixture is then estimated as follows:

$$2,520 \text{ ft}^3 \text{ manure} + (3,780 \times 0.5) \text{ ft}^3 \text{ bedding} = 4,410 \text{ ft}^3 \text{ manure/bedding mixture}$$

Washwater and other wastewater

Water used in cleaning animal production facilities is a volume component in manure storage facilities. Examples include fresh water (not recycled) used for flushing, water used to clean milking systems and cow udder preparation, and water used to wash down confinement rooms in swine operations. The amount of water used for a given activity or operation is usually specific to that operation and management scheme, and thus must be determined specifically in each case. Often a comparison of systems similar in size and management is the best way to estimate the amount of washwater used. Experience has shown that water use is often significantly greater than anticipated, and a water meter can be a useful tool in determining actual water use patterns. Table 21-4 outlines typical water usage for cleaning swine and dairy facilities.

Table 21-4. Typical water usage rates for cleaning milking center facilities and swine production areas.

Production Area	Typical Water Usage
Milking center	8-12 gallons per cow per day
Swine breeding/gestation	0.1 gallons per head per day
Swine farrowing	1.0 gallons per crate per day
Swine nursery	0.05 gallons per head per day
Swine grow/finish	0.1 gallons per head per day

Adapted from MWPS-7, Dairy Freestall Housing and Equipment 2000, and University of Missouri CLEAN Program.

Water used to clean and wash livestock facilities can require significant volume in a manure storage structure. Minimize your use of fresh water by making cleaning operations as efficient as possible.

EXAMPLE 3

Estimate the annual volume of washwater used in a 500-sow farrowing/nursery operation. Assume there are 80 farrowing crates and 1,800 nursery pig spaces. Use data in Table 21-4.

Breeding/Gestation

$0.1 \text{ gal/6hd-d} \times 420 \text{ hd} \times 365 \text{ d} = 15,330 \text{ gallons}$

Farrowing

$1.0 \text{ gal/crate-d} \times 80 \text{ crate} \times 365 \text{ d} = 29,200 \text{ gallons}$

Nursery

$0.05 \text{ gal/hd-d} \times 1,800 \text{ hd} \times 365 \text{ d} = 32,850 \text{ gallons}$
 Total gallons = $15,330 + 29,200 + 32,850 = 77,380 \text{ gallons}$
 Total cubic feet = $77,380 \text{ gal} / 7.48 \text{ gal/ft}^3 = 10,345 \text{ ft}^3$

Lot runoff can require significant storage volume. Limit lot size and runoff area as much as possible.

Lot runoff

Contaminated runoff from open lots and production areas must be handled in a controlled fashion. Such runoff is usually directed into manure storage facilities so it can be ultimately used for land application. A very important concept in livestock production, especially in humid areas with significant rainfall, is to minimize the amount of rainfall and surface water coming into contact with manure. Open lot areas should be minimized to the extent reasonably possible, and terraces or berms should be used to divert surface water around or away from lot areas. Consideration should be given to guttering roofs that would otherwise shed clean water into lot areas and thus increase the amount of contaminated runoff.

The volume of runoff water to be handled in any system depends primarily upon the types of surfaces involved (unsurfaced, concrete, roof), the area of surfaces exposed to rainfall, and the amount of rainfall. Figures 21B-1 and -2 in Appendix B (adapted from the NRCS Agricultural Waste Management Field Handbook) show runoff from unpaved and concrete lots as a percentage of mean annual precipitation. Figures 21B-3a and -3b also in Appendix B (adapted from MWPS-18, Livestock Waste Facilities Handbook) show mean annual precipitation for the continental United States. This information can be used to estimate the amount of runoff that might occur for an enterprise with production areas exposed to rainfall.

Some states may require manure storage facilities to be designed using rainfall data with a greater return frequency (for example, the wettest year in 10 years) rather than mean rainfall. When storage periods less than 12 months are used, local rainfall data should be used in the calculation (for example, the wettest six-month period of the year).

EXAMPLE 4

A dairy in southern Missouri has a 1.5-acre unsurfaced exercise lot, 20,000 ft² of concrete lot, and 12,000 ft² of unguttered roofed area exposed to rainfall. Estimate the volume of runoff expected annually. Assume that runoff from roofed areas and concrete areas is similar.

Unsurfaced lot: Runoff is 28% (Figure 21B-1, Appendix B) of mean annual precipitation, 42 in (Figure 21B-3b, Appendix B).
 $1.5 \text{ acre} \times 43,560 \text{ ft}^2/\text{acre} \times 42 \text{ in} \times 1 \text{ ft}/12 \text{ in} \times 0.28$
 $= 64,033 \text{ ft}^3$

Concrete lot and roofs: Runoff is 60% of mean annual precipitation (Figure 21B-2, Appendix B).
 $(20,000 \text{ ft}^2 + 12,000 \text{ ft}^2) \times 42 \text{ in} \times 1 \text{ ft}/12 \text{ in} \times 0.60$
 $= 67,200 \text{ ft}^3$

Total runoff
 $= 64,033 \text{ ft}^3 + 67,200 \text{ ft}^3 = 131,233 \text{ ft}^3$

EXAMPLE 5

Estimate the annual sludge accumulation volume for a 1,000-head swine-finishing unit. Assume average pig weight is 150 lbs.

Total solids (TS) production (Table 21C-1):

$$6.34 \text{ lbTS/Kwt-d} \times 1 \text{ Kwt/1,000 lb} \times 1,000 \text{ hd} \times 150 \text{ lb/hd} \times 365 \text{ d/yr} \\ = 347,115 \text{ lbs solids}$$

From Table 21C-10, the sludge accumulation ratio for swine is 0.0485 ft³ sludge/lb solids.

$$347,115 \text{ lbs solids} \times 0.0485 \text{ ft}^3 \text{ sludge/lb solids} \\ = 16,835 \text{ ft}^3 \text{ sludge accumulation.}$$

Sludge accumulation

Manure storage facilities that combine treatment and storage in the same unit (anaerobic lagoons) typically experience an accumulation of nonbiodegradable material in the bottom of the impoundment. If the lagoon is not agitated when pumped, the accumulated sludge can eventually displace sufficient volume to impair lagoon performance. Hence, consideration of sludge accumulation should be included in lagoon design. The amount of sludge accumulation is related to the amount and biodegradability of manure solids and/or bedding entering the lagoon. Table 21C-10 (adapted from the NRCS Agricultural Waste Management Field Handbook) gives estimates of the ratio of sludge accumulation (cubic feet) to the weight (pounds) of solids (dry matter or TS) entering the lagoon. Long-term experience with lagoons in some states indicates that sludge accumulation may be overpredicted by values in the table. Sludge accumulation volume is estimated using values in Table 21C-10, and the appropriate manure solids production value from Tables 21C-1 through 21C-9.

Treatment volume

Some manure storage facilities, such as anaerobic lagoons, perform the dual function of storing and treating the manure. This treatment feature requires that a permanent volume be included in the design. This permanent volume provides dilution and capacity for a bacterial population to become established and functional in breaking down and degrading manure solids. For anaerobic lagoons, the treatment volume is based on temperature and volatile solids (VS) that the animals produce. Volatile solids are that fraction of total solids that is potentially subject to breakdown by lagoon bacteria. Temperature is important because bacteria are more active in areas of higher temperature. Figure 21B-5 in Appendix B (adapted from the NRCS Agricultural Waste Management Field Handbook) shows VS design loading rates for anaerobic lagoons in the United States. Loading rate

Monitor sludge buildup to ensure that it does not significantly decrease available volume in a manure storage facility.

Treatment volume depends on number of animals and average local temperatures.

When rainfall exceeds evaporation, the excess water must be accumulated in the manure storage facility.

Federal regulations require that manure storage facilities have the minimum capability of holding the lot runoff and direct rainfall resulting from the 25-year, 24-hour storm.

varies from 0.003 lb VS/ft³-d in the cold northern regions to 0.007 lb VS/ft³-d in the warmer southern regions. The treatment volume for a lagoon can be calculated using VS data from Tables 21C-1 through 21C-9 along with the data in Figure 21B-5 in Appendix B.

Rainfall-evaporation

Manure storage facilities exposed to rainfall, whether structured or earthen, should be designed to hold the rainwater that falls on the surface. Some of this rainfall, however, will be lost through evaporation, and the net effect is called “rainfall minus evaporation (R-E).” While rainfall data is usually readily available, many factors influence evaporation, which sometimes results in a scarcity of meaningful data. For example, crusting on the surface of a manure storage facility can significantly reduce evaporation. Also, evaporation tends to be much higher during summer than during winter months; hence, local data based on the storage period in question is needed when designing manure storage facilities with less than a 1-year storage period. R-E on an annual basis is usually calculated by subtracting annual lake evaporation from annual rainfall at the same location. Figure 21B-4 in Appendix B (adapted from MWPS-18, Livestock Waste Facilities Handbook) shows mean lake evaporation for the United States.

Some states may require that R-E be calculated using rainfall data with a greater return frequency (for example, the wettest year in 10 years) rather than mean rainfall. When R-E is calculated for shorter storage periods, monthly rainfall and evaporation data should be examined to determine the monthly sequence with the highest R-E value. Check local or state requirements for the cases in which evaporation exceeds rainfall for the design storage period and climatic return period. Some states may or may not allow a deficit to be used in sizing a manure storage facility.

25-year, 24-hour storm

Federal regulations require that manure storage facilities have the minimum capability of holding the lot runoff and direct rainfall resulting from the 25-year, 24-hour storm. Furthermore, many states require that this volume be available in addition to any other storage components such as manure/wastewater volume, or treatment volume. The volume resulting from a 25-year, 24-hour storm is equal to the storm itself (inches of rain falling in 24 hours), plus runoff from the lot area exposed to the rainfall. For a manure storage facility exposed to rainfall, the depth required to store the 25-year, 24-hour storm is simply the depth, or inches of rainfall, represented by the storm itself. Figure 21B-6 in Appendix B (from MWPS-18, Livestock Waste Facilities Handbook) shows the depth of rainfall for the 25-year, 24-hour storm for the United States. Runoff resulting from the 25-year, 24-hour storm is usually calculated based on this depth also, with no infiltration or retention assumed because of the high intensity and short duration of the rainfall event. However, some states may allow modification for infiltration and retention. Check local and state requirements.

EXAMPLE 6

Calculate the treatment volume for an anaerobic lagoon serving 1,000 finishing swine (average weight = 150 lbs) in central Indiana.

VS produced (from Table 21C-1):

$$5.4 \text{ lb VS/Kwt-d} \times 1 \text{ Kwt/1,000 lb} \times 1,000 \text{ hd} \times 150 \text{ lb/hd} \\ = 810 \text{ lb VS/d}$$

VS loading rate for central Indiana is 0.0044 lb VS/ft³-d:

$$\text{Treatment volume} \\ = (810 \text{ lb VS/d}) / (0.0044 \text{ lb VS/ft}^3\text{-d}) = 184,090 \text{ ft}^3$$

EXAMPLE 7

Calculate the annual R-E for a lagoon in central Alabama.

Annual rainfall in central Alabama (Figure 21B-3b, Appendix B)
= 52 in

Annual lake evaporation in central Alabama (Figure 21B-4, Appendix B)
= 43 in

$$\text{R-E} = 52 \text{ in} - 43 \text{ in} = 9 \text{ in}$$

EXAMPLE 8

Calculate the storage volume required for the 25-year, 24-hour storm for a dairy in central Pennsylvania. Exposed dirt lot, concrete, and unguttered roofed area is 1 acre.

From Figure 21B-6 in Appendix B, the 25-year, 24-hour storm is 5 inches in central Pennsylvania.

$$5 \text{ in} \times 1 \text{ ft}/12 \text{ in} \times 1 \text{ acre} \times 43,560 \text{ ft}^2/\text{acre} \\ = 18,150 \text{ ft}^3$$

In addition to this volume, the manure storage facility should be designed to hold the 5 inches falling directly on its surface.