Chapter 5
THE TECHNICAL FEASIBILITY OF THE SWINE INDUSTRY MEETING A "ZERO DISCHARGE" REQUIREMENT

Joe Zulovich[1], Ph.D., P.E., Amy Millmier[1], M.S., E.I.T.,
John Hoehne[1], M.S., P.E., John Lory[2], Ph.D., Ray Massey[3], Ph.D.
And Chanda Case[3], M.S.

5.1 INDEX

Chapter 5 5-1
5.1 Index 5-1
5.2 Executive Summary 5-3
5.3 Understanding of "Zero Discharge" Requirement 5-5
5.4 Selected Modification Strategies for Anaerobic Lagoons and Earthen Slurry Storages 5-6
5.4.1 Improved Water Management 5-6
5.4.2 Impermeable Covers 5-8
5.4.2.1 General Operation of an Anaerobic Lagoon with an Impermeable Cover 5-8
5.4.2.2 Technical Feasibility of Implementing Impermeable Lagoon Covers 5-9
5.4.2.2.1 General Feasibility Issues for All Impermeable Lagoon Covers 5-9
5.4.2.2.1.1 Lagoon Accessibility for Land Application and Agitation 5-10
5.4.2.2.1.2 Gas Generation and Collection 5-10
5.4.2.2.1.3 Storm Water Collection and Disposal 5-11
5.4.2.2.1.3.1 Collection of storm water (rainwater) to pump 5-11
5.4.2.2.1.3.2 Sampling of collected storm water for possible contamination 5-11
5.4.2.2.1.4 Challenges Related to Size of Cover 5-12
5.4.2.2.1.4.1 Variable Storage Depth 5-12
5.4.2.2.1.4.2 Surface Area of Lagoon and Resulting Cover 5-13
5.4.2.2.1.5 Cover Repair Issues 5-14
5.4.2.2.1.6 Old or Damaged Cover Disposal 5-15
5.4.2.2.1.7 Problems with Decreased Quality of Recycled Effluent 5-15
5.4.2.2.2 Site Specific or Regional Issues Challenging the General Feasibility of Impermeable Lagoon Covers 5-16
5.4.2.2.2.1 Challenges Related to Structural Issues 5-16

[1] Department of Biological Engineering, University of Missouri, Columbia, MO 65211
[2] Department of Agronomy, University of Missouri, Columbia, MO 65211
[3] Department of Agricultural Economics, University of Missouri, Columbia, MO 65211

5.4.2.2.2.1.1 Structural Challenges Due to Gravity Live Loads 5-16
5.4.2.2.2.1.2 Structural Challenges Due to Wind Loads 5-19
5.4.2.2.2.2 Challenges Related to Freezing Conditions 5-20
5.4.3 Additional Storage 5-23
5.4.3.1 Second Storage Cell 5-23
5.4.3.1.1 Second Storage Cell Design Criteria 5-24
5.4.3.1.2 Second Storage Cell Examples 5-24
5.4.3.1.3 Second Storage Cell Implications 5-26
5.4.3.2 Emergency Storage Cell 5-26
5.4.3.2.1 Emergency Storage Cell Design Criteria 5-26
5.4.3.2.2 Emergency Storage Cell Examples 5-27
5.4.3.2.3 Emergency Storage Cell Implications 5-27
5.5 Issues Related to “Zero Discharge” Requirement 5-28
5.5.1 Outside Lots and Pasture Production 5-28
5.5.2 Dry Manure Systems 5-28
5.5.3 Enclosed Treatment Systems 5-29
5.6 Existing Systems Capable of Meeting “Zero Discharge” Requirement 5-30
5.6.1 Outside Covered Slurry Storage 5-30
5.6.2 Under-building Slurry Storage 5-31
5.6.3 Other Systems 5-31

5.2 EXECUTIVE SUMMARY

This chapter addresses issues related to complying with the proposed rule of "*a zero discharge requirement from the production area that does not allow for an overflow under any circumstances*" as presented as "*Option 5*" on page 3060 of the Federal Register (Vol. 66, No. 9, Friday, January 12, 2001). In the proposed rule, EPA suggested the strategies of improved water management, covered storage or additional storage to meet the "zero discharge" criteria. The potential feasibility and limitations of the proposed strategies have been evaluated and discussed for operations that currently use anaerobic lagoon systems. Brief summaries of the various conclusions are presented below.

Improved Water Management: Water reduction strategies in most operational swine production units will not reduce the effluent volumes that flow to earthen manure storages and anaerobic lagoons enough to provide any appreciable increase in the storage period. Only swine operations located in arid regions (where evaporation significantly exceeds rainfall) that are currently using fresh water to remove manure from buildings can benefit from improved water management to meet a "zero discharge" rule by recycling lagoon effluent for manure removal when the earthen storage is becoming full. Many swine operations currently using a slurry manure system are already using appropriate water reduction strategies to minimize the volume of manure to apply.

Covered Storage: Installing floating, impermeable covers on anaerobic lagoons to meet the "zero discharge" criteria has very limited potential due to a number of technical feasibility issues. Some of the main technical issues limiting the feasibility of floating impermeable covers are:

- Floating cover design and installation must allow for varying liquid surface levels in the lagoon. This results in excess cover material which wind can destroy when the lagoon liquid level is near the full level.
- Gas collection and/or removal must be achieved or the cover will "balloon" above the liquid surface and be subject to wind damage.
- Rainwater, sand, soil, ice and snow must be removed regularly from cover surfaces to keep the cover from sinking. Solid materials like sand, soil and snow are typically not easily removed from lagoon covers.
- Freezing weather or a frozen lagoon surface can destroy gas collection equipment, surface water removal equipment, or floatation support structures inherent to lagoon covers.
- Wind speeds below the design wind speeds required for insurance coverage can destroy covers on large lagoons.
- A small hole or rip in the cover will allow rainwater to enter the lagoon or cause the operation to land apply contaminated rainwater collected on surface of cover. If rainwater on the surface of the cover is contaminated, the animal production operation probably cannot maintain a "zero discharge" criterion.
- Worker safety during cover repair, especially near the center of the lagoon, can be difficult to ensure.

- Access for land application equipment, agitator and pump, compromises the integrity of the continuous impermeable lagoon cover.

Additional Storage: The concept of “zero discharge” presents a dilemma for design engineers because design parameters and limits are required to develop satisfactory designs. The suggested scenarios have been developed using defined storms with designated lengths and return frequencies. These, or other reasonable design storms, can be used to develop and design additional earthen manure storage basins and anaerobic lagoon cells. The suggested scenarios do not guarantee a “zero discharge” because the storage may overflow when a rainfall event occurs that is greater than the design storm used to size the structure. The only structures that can be assured to meet a “zero discharge” criterion due to rainfall are covered structures that do not have rainfall or runoff entering the storage structure.

Two additional storage options are evaluated to minimize the frequency of a discharge event due to rainfall. These options are a second storage cell and an emergency storage basin.

A second storage cell is designed with a compacted clay liner to provide long-term storage of effluent. The second cell would provide the extra storage capacity required by the longer storage period. During years when no additional storage capacity was required, the rainwater collected in the second cell would be land applied because the residual effluent that protects the liner would not meet discharge standards.

An emergency cell would have a compacted clay liner; however, the emergency storage cell would not be used for long-term storage. During years when no additional storage was required, any rainwater collected would be discharged unless tests indicated nutrient content levels that would require land application.

Some key conclusions regarding additional storage options of a second storage cell or emergency storage basin are as follows:

- Operations will incur additional costs for constructing the additional storage volumes.
- Operations will not be guaranteed of “zero discharge” from rainfall events that exceed the design storm used to determine the volume of the added earthen cell.
- Operations with additional storage will be more environmentally friendly because the frequency of a discharge event due to rainfall will be reduced.
- Operations will incur added spreading costs from pumping collected rainwater during wet weather periods when above normal rainfall occurs.
- No additional manure nutrients are available to offset the added spreading costs during wet weather.
- The design of the emergency storage cell was based on a 10-year, 10-day storm plus 30 days of manure and wash water.

5.3 UNDERSTANDING OF "ZERO DISCHARGE" REQUIREMENT

This chapter addresses issues related to complying with the proposed rule of "*a zero discharge requirement from the production area that does not allow for an overflow under any circumstances*" as presented as "*Option 5*" on page 3060 of the Federal Register (Vol. 66, No. 9, Friday, January 12, 2001). In the proposed rule, the EPA suggested the strategies of improved water management, covered storage or additional storage to meet the no discharge criteria. The potential feasibility and limitations of the proposed strategies have been evaluated and discussed for operations that currently use anaerobic lagoon systems.

The implementation of the proposed "zero discharge" rule has resulted in a design dilemma. The design dilemma, from an engineering perspective, is how to design for conditions that essentially have no limits. The proposed "zero discharge" rule implies that storm water (rainwater) entering a manure storage and/or treatment structure cannot result in a discharge from the structure. A structure can be designed to store the amount of rainwater that would enter the given structure for a given design storm or rainfall event. However, the return frequency and duration of the design storm event for a given location must be known in order to determine the volume of rainwater that will enter a structure at the given location. The EPA does not provide the return frequency and duration for a design storm in the proposed rule. This design volume is essential for an engineer to determine the size of the structure. The other option is a design that assures that no rainwater will enter the manure storage structure. Rainwater can be excluded from the manure storage structure or system by constructing the entire swine production system under roof. This includes the swine housing and all manure storage and treatment structures to be buildings with roofs. By not defining the return frequency and duration of design storms, and by explicitly stating no "upset and bypass" in the permit for swine operations, the EPA implies that the entire swine production system must be placed under roof in order to comply with the proposed "zero discharge" rule.

The proposed "zero discharge" rule makes it clear that all lagoons would require some technology modification to be in compliance. First, the requirement that existing lagoons comply with the "zero discharge" rule indicates that no "grand fathering" is envisioned. Existing lagoons would need to have technology added to guarantee zero discharge. Any lagoons built after the Rule goes into effect would need added technology to guarantee "zero discharge."

Secondly, the fact that the frequency factor for lagoon compliance with "zero discharge" is set at 0% (Cost Methodology p 61) and that no specific characteristics warrant a cover (as sandy soils, high ground water table and karst topography are factors that are said to warrant lagoon liners), it can be implied that the EPA considers all lagoons in need of covering or some type of compliance effort. While the EPA might not mandate covers, the fact that all lagoons require some compliance cost in their cost analysis implies that all lagoons (including those designed to contain 12 months of manure storage, a 25-year, 24-hour storm event plus one foot of freeboard) currently do not comply with the proposed rule.

Other technologies, such as secondary containment, may satisfy permit requirements, but it is clear that current lagoon standards, even 12-month storage lagoons, are insufficient to obtain a permit. However, without the return frequency and duration for a design storm, no open structures can be designed to assure, without exception, that a "zero discharge" criterion can be met. If the EPA sets the return frequency and duration for a design storm, an "upset and bypass" provision in a permit must be allowed for any systems with open structures as a rainfall event that will exceed the design storm rainfall is possible for almost any location. Otherwise, all portions of the swine production and manure storage system must be "under roof" to comply with an absolute "zero discharge" rule. Later sections in this chapter provide examples and additional discussion related to rainfall amounts and absolute "zero discharge" compliance.

5.4 SELECTED MODIFICATION STRATEGIES FOR ANAEROBIC LAGOONS AND EARTHEN SLURRY STORAGES

The selected strategies discussed in this section are three strategies expressed by the EPA as potential methods for swine operations to meet the proposed "zero discharge" requirement. The EPA discusses these selected strategies on page 3060 of the Federal Register (Vol. 66, No. 9, Friday, January 12, 2001). The potential of the swine industry to adopt the strategies and implication of adopting the strategies are presented below.

5.4.1 Improved Water Management

The EPA indicates in the "Option 5 section" that fresh water reduction strategies can be implemented to help swine operations comply with a "zero discharge" criterion. The EPA implies that reducing the amount of fresh water used as part of the manure handling activities on swine operations will result in significant reduction in the amount of effluent to be stored and then land-applied.

Water reduction strategies in most operational swine production units will not reduce the effluent volumes that flow to earthen manure storage and anaerobic lagoons enough to provide any appreciable increase in the storage period. Anaerobic lagoon effluent is presently recycled in most flush and pit-recharge manure collection units. Swine operations exist in arid areas of the country where groundwater is used for manure collection without recycling. Swine operations using fresh water for manure handling have irrigated cropland and have found an economic advantage to pumping groundwater at lower flow rates and storing the water, rather than directly pumping the groundwater at the high flow rates needed to supply adequate flow to a center pivot irrigation system. These swine operations use the pumped groundwater to remove manure from their swine facilities to an earthen storage, and then to irrigate the water containing manure nutrients on crops at rates needed by crops. Additional groundwater is typically pumped directly to irrigation systems to provide the total water needs of the growing crop. When the earthen storage structures on swine operations in arid areas are close to full liquid level, the operation will switch to using recycled water from the storage to remove manure from the swine facilities.

Wet-dry feeders and several cup or bowl type drinking water systems will reduce wastewater flows. These devices can make an appreciable difference in manure volume in manure tank storages that have limited or no rainfall volume contributions. These more concentrated manure nutrients are often transported and land applied with tank wagons or trucks. Because of the additional effluent volumes that are the result of rainfall and runoff that flow to earthen manure storage basins and anaerobic lagoons, adopting these water reducing systems will not significantly increase the storage volume period for these types of structures. The major portions of the annual pumping volume for anaerobic lagoon systems include the manure volume and added rainwater unless the lagoon is located in an arid region. Table 5.1 gives the annual pumpdown volume, manure volume, added water and rainwater for anaerobic lagoons from surveyed farms. The added water portion, which an operation can control, is typically the smallest portion of the annual pumpdown volume.

Table 5-1. Liquid volumes composing annual average pumpdown volume of anaerobic lagoons on surveyed farms.

Presentation Code	Annual Pumpdown Volume (gallons)	Annual Manure Volume (gallons)	Added Water[1] (gallons)	Average Rainwater Added (gallons)
MO-1	342,916	207,222	41,969	93,725
MO-4	1,787,886	1,352,444	186,125	249,317
MO-5	1,324,556	758,699	231,885	333,982
MO-6	3,564,137	2,498,263	39,032	1,026,842
NC-1	851,444	273,894	273,754	303,796
NC-2	1,236,928	630,676	56,932	549,320
NC-3	2,833,339	1,177,808	602,170	1,053,361
NC-4	3,076,788	1,115,708	99,996	1,861,084
NC-5	4,176,314	2,710,104	218,972	1,247,238
NC-6	4,680,769	3,283,180	219,701	1,177,888
OK-1	2,988,239	366,178	2,481,688	140,393
OK-2	2,081,130	1,569,182	9,671,208	-7,749,260
OK-3	800,507	469,586	564,214	-233,293
OK-4	318,511	255,274	912,378	-849,141
OK-5	378,977	432,314	929,397	-982,734
OK-6	1,797,356	495,532	3,831,988	-2,530,164
OK-7	4,924,327	2,807,198	5,693,239	-3,576,110
OK-8	604,033	558,599	1,094,854	-1,079,420
PA-8	697,437	464,258	75,180	157,999

[1] Added water includes any runoff from open lots.
Note: OK farms are in an arid region where evaporation significantly exceeds rainfall.

5.4.2 Impermeable Covers

The use of impermeable covers is recommended as a method by the EPA (page 3060, bottom of 2nd column) to meet "Option 5, zero discharge" from swine lagoons. Impermeable covers are promoted as having the ability to keep rainwater from entering the anaerobic lagoon or the earthen manure storage structure. However, in order to implement the use of impermeable covers for lagoons or earthen manure storage structures, several operational issues must be addressed to assure the cover will function correctly. The comments below include the challenges that impermeable cover manufactures and suppliers will need to fully address in order for the swine industry to widely adopt impermeable cover technology. Cited examples of the successful application of impermeable cover technology may not have needed to address all challenges presented below because of their geographic location or may have yet to experience or be exposed to any one of the challenges presented below. Some background information is initially presented to better understand the importance of the challenges that minimize the technical feasibility of implementing impermeable covers.

5.4.2.1 General Operation of an Anaerobic Lagoon with an Impermeable Cover

An anaerobic lagoon, by design, will produce bubbles containing biogas (about 70% methane and 30% carbon dioxide). As the bubbles are created, an impermeable cover will trap the gas under the cover. The trapped gas must be removed from under the cover and be either flared or collected and used as an energy source. When the biogas is used as an energy source, the gas collection system, in conjunction with the cover, must collect and remove gas from anywhere on the lagoon surface. The collection system must be gas tight to avoid diluting the biogas with air from the atmosphere.

The liquid surface level in an anaerobic lagoon will vary from a lower level at the treatment volume to an upper level when pumping should begin. The variation in depth will depend upon the specific design of the system. This variation in depth is typically three to four feet but can easily be six feet or more at specific sites.

The impermeable cover is located on the lagoon surface and inside the berms completely covering the lagoon. As a result, all storm water that falls on the surface of the lagoon and within the berms that slope to the lagoon surface will collect on the surface of the cover. This storm water must be removed from the surface of the cover. The system to remove the trapped water must be able to collect and remove ponded water from anywhere on the surface of the lagoon without compromising the integrity of the cover.

Figure 5-1 shows a picture of an impermeable cover on a swine anaerobic lagoon. Both storm water removal and gas collection challenges exist. If the storm water challenge is not addressed satisfactorily, the cover may sink. If the gas collection challenge is not addressed, wind will damage the cover and may result in total failure of the cover. These challenges are discussed in greater detail later in this chapter.

Figure 5-1. Picture of an impermeable cover showing trapped gas “bubbling” the cover and pools of storm water not pumped from surface.

5.4.2.2 Technical Feasibility of Implementing Impermeable Lagoon Covers

This section addresses the challenges that currently exist with the implementation of impermeable covers. If the current challenges cannot be fully addressed, the number of locations able to implement impermeable lagoon covers will be very limited due to technical feasibility challenges.

5.4.2.2.1 General Feasibility Issues for All Impermeable Lagoon Covers

This section addresses the general feasibility issues for all impermeable lagoon covers installed anywhere in the country. The general feasibility issues discussed in this section are for anaerobic lagoon structures (either single cell or multi-cell systems) that include both manure storage and treatment volumes and that must be accessed with pumping and agitation equipment to transport effluent to cropland. Satisfactorily addressing the challenges listed in this section does not insure the technical feasibility of impermeable lagoon covers for a given location. Other site specific, technical issues can render an impermeable lagoon cover infeasible and will be discussed in section 5.4.2.2.2 of this chapter.

5.4.2.2.1.1 Lagoon Accessibility for Land Application and Agitation

Lagoon effluent is typically pumped from an anaerobic lagoon using a pump placed on the berm of the lagoon with an intake hose suspended below the liquid surface by a float. Pumping access to a lagoon that is covered with an impermeable cover will require a portion of the cover to be removed. Removing a portion of the cover for access to the effluent may lead to contamination of storm water collected on the cover surface. This scenario would require the storm water to be handled as a manure product. Further discussion of this issue can be found in section 5.4.2.2.1.3 of this chapter.

Accessing the lagoon for agitation prior to pumping is another issue relating to land application of effluent from a covered lagoon. Many producers choose to agitate their lagoon prior to land application of lagoon liquids in order to reduce solids build-up in the lagoon. In order to properly agitate some lagoons, the lagoon must be accessed at several points around the lagoon perimeter. Use of an impermeable lagoon cover will limit access to the lagoon for agitation. The proposed rule (Federal Register, page 3061) states that the EPA considers agitation of lagoons every three years to be appropriate management. Lagoons covers are incompatible with this agitation management recommendation.

Any opening provided in the lagoon cover for access of land application activities must be maintained watertight. An underlying assumption of impermeable lagoon covers is defined as “a structural addition to earthen storages and anaerobic lagoons that is capable of keeping storm water out of the effluent stored in the structure.” If the access provided is not watertight, storm water will enter the structure. This storm water issue is discussed further in section 5.4.2.2.1.3 of this chapter.

5.4.2.2.1.2 Gas Generation and Collection

Gaseous emissions from a properly operated anaerobic lagoon can provide for buoyancy of an impermeable lagoon cover. The gas production capability of a lagoon is highly dependent upon the temperature of the lagoon liquids. During cooler months (November through May each year in some regions), lagoon liquid temperature can drop a significant number of degrees compared to liquid temperatures during warmer months. This reduced seasonal liquid temperature results in less microbial activity in the lagoon and, consequently, in reduced gas production. This minimal gas production could contribute to problems with cover buoyancy, and may be of particular concern since snow and ice loads on the cover’s surface are greater during this period. Foam blocks or some other type of flotation aid can be used to provide for buoyancy. However, other problems with freezing can occur and will be discussed later. The effluent under the cover can support the cover by allowing the cover to sink down an amount equal to the weight of the water or material on the cover. Uneven loading of the cover will result and lead to gas bubbles trapped under the cover. This uneven loading and resulting trapped gas bubbles are visible in the picture of Figure 5-1.

The gas generated by the anaerobic lagoon must be collected from under the cover. The gas will constantly be generated and must be removed from underneath the cover, or the cover will “bubble-up” as can be seen in Figure 5-1. When the cover is “bubbled up” from trapped gas, wind forces can easily damage the cover, as opposed to when the cover is on the lagoon surface. Anaerobic lagoons with larger surface areas will have greater challenges than those with smaller surface areas when addressing gas collection.

5.4.2.2.1.3 Storm Water Collection and Disposal

A key underlying assumption of the proposed “zero discharge” rule is that storm water will not enter manure storage and treatment systems used for swine operations. The collection and removal of storm water from the surface of an impermeable cover must be implemented in order to meet the objective assumption of the proposed rule.

5.4.2.2.1.3.1 Collection of storm water (rainwater) to pump

The collection and removal of storm water from the surface on an impermeable cover must be successfully accomplished in order to meet the objective of the “zero discharge” rule. As shown in Figure 5-1, collecting storm water from the surface of a large cover is not automatic and may not be a simple task. Water must be collected from the entire surface by allowing the water to pool in one or several locations and then be pumped from the cover surface. To facilitate pooling of surface water, the cover must be systematically sloped to form water pools at pre-determined locations. If surface water is not systematically pooled, a pump or a pump intake will have to be moved to different locations around the lagoon cover to pump water from the cover surface. Multiple pump locations can be used to remove storm water from covers surfaces, but they increase the time and cost of sampling the water for nutrient content.

5.4.2.2.1.3.2 Sampling of collected storm water for possible contamination

Storm water that is collected from the surface of the impermeable cover will need to be disposed of once it is pumped off of the cover. The collected storm water will likely have to be tested for nitrogen in the same fashion as storm water collected in secondary containments before it can be discharged to waters of the state. In some states, ammonia-nitrogen concentrations greater than 2.5 ppm in the storm water require that the water be land-applied at agronomic rates or pumped into the manure storage system. If lagoon effluent collects on the cover due to a hole in the cover, spillage during access to the lagoon liquid, or other means; then all water on top of the cover becomes contaminated and must be managed as a manure effluent. If water on the cover is treated as effluent, the cover serves no purpose as related to the “zero discharge” issue because the volume of water entering the manure management system has not been reduced.

5.4.2.2.1.4 Challenges Related to Size of Cover

Single cell and two cell anaerobic lagoons used by swine operations can be large compared to most treatment lagoons or structures for municipal systems. Table 5-2 gives example lagoon surface areas for different sizes of swine operations. Since the lagoon surfaces are relatively large, the cover needed to keep storm water from entering the lagoon will be relatively large.

Earthen manure storages can also be large as seen in Table 5-3. Many of the same challenges will exist for earthen manure storage basins as exist for anaerobic lagoons. The challenges include but are not limited to: 1) storm water collection, removal, and disposal issues, 2) access for agitation and pumping, 3) removal of trapped gas (although the generation rate will be significantly lower than for anaerobic lagoons).

5.4.2.2.1.4.1 Variable Storage Depth

Because an impermeable cover is relatively inelastic, the cover must be sized to cover the lagoon liquid surface and exposed inside berms during maximum pump down of the lagoon (when the liquid level is lowest). Covers sized for this condition will have excess material present when the lagoon liquid level is at its maximum. A typical lagoon, with a 3:1 inside slope, will have a 0.17-foot per foot of depth variation in coverable surface area on each side between the minimum and maximum pump down levels. This excess material that is present when the lagoon is near maximum liquid level will make the cover more susceptible to lifting during high winds. In addition, this is the time when the lagoon berms protect the liquid surface from wind the least.

Earthen manure storages will usually have greater variation in liquid depth than lagoons. Excess cover material will be greater for earthen manure storage basins than for anaerobic lagoons. The greatest danger for wind damage to the cover on an earthen basin occurs when the earthen manure storage is almost full because the amount of extra material will be greatest when storage is almost full.

Table 5-2. Geometric characteristics of anaerobic lagoons on surveyed farms.

Presentation Code	Area for Berm Centerlines (ft^2)[1]	Full Water Surface Area (ft^2)[2]	Length:Width Ratio	Inside Slope
MO-1	44,967	37,828	2.5:1	3:1
MO-4	86,933	77,254	2:1	3:1
MO-5	132,653	120,100	2.5:1	3:1
MO-6	319,790	301,949	1:1	3:1
NC-1	39,933	33,600	1.7:1	3:1
NC-2	62,546	50,600	1.9:1	2.5:1
NC-3	165,150	147,900	1.76:1	3:1
NC-4	186,624	160,000	1:1	3:1
NC-5	142,848	126,888	1.6:1	3:1
NC-6	192,219	179,010	1.5:1	3:1
OK-1	45,579	38,844	1.6:1	2:1
OK-2	350,529	320,420	2.3:1	3.5:1
OK-3	36,481	28,561	1:1	3:1
OK-4	48,054	37,950	2.1:1	3:1
OK-5	66,764	55,672	2.78:1	3:1
OK-6	105,779	89,543	1.02:1	4:1
OK-7	161,122	142,129	1:1	3:1
OK-8	76,388	62,376	1.6:1	4:1
PA-8	21,881	16,744	1.7:1	2:1

[1]This area has the perimeter of the centerline of the berms surrounding the lagoon.
[2]This area is the area of the water surface when lagoon is filled to design depth.

Table 5-3. Geometric characteristics of earthen slurry storages on surveyed farms.

Presentation Code	Area for Berm Centerlines (ft^2)[1]	Full Water Surface Area (ft^2)[2]	Length:Width Ratio	Inside Slope
IA-2	90,699	80,000	1.5:1	2:1
MO-3	14,654	10,731	2.5:1	3:1
PA-7	110,400	96,800	2:1	2.5:1

[1]This area has the perimeter of the centerline of the berms surrounding the storage.
[2]This area is the area of the water surface when storage is filled to design depth.

5.4.2.2.1.4.2 Surface Area of Lagoon and Resulting Cover

Design criterion for permitted lagoons in some states require a 3:1 inside slope on the lagoon berm. The EPA's proposed regulations reference 2:1 inside slopes for lagoon berms. The increase in side slopes to 3:1 results in the need for an extra foot of cover material along each side of the lagoon berm for each foot of lagoon depth. Table 5-4 shows several examples of the increased surface area resulting from the flatter inside slope of lagoon. Flatter inside slopes as very common as seen from the survey data in Table 5-2. The EPA's proposed regulations reference length:width ratios of 1:1. As seen in Table 5.2, larger length:width ratios are more common indicting a more rectangular shape. Increased length:width ratios results in increased surface areas as seen in Tables 5-4 and 5-5. The EPA's selection of a 2:1 inside slope and a 1:1 length:width ratio actually minimizes lagoon surface area. The larger actual surface areas will result in an increase (over the EPA's estimates) in material needed to cover a given lagoon. The increased material need will increase the cost for covering lagoons and affect the economic analysis conducted.

Table 5-4. Surface areas of a five million gallon anaerobic lagoon designed using different geometric characteristics.

Example Configuration	Length:Width Ratio	Inside Slope	Full Water Surface Area (ft^2)
1	1:1	3:1	64,778
2	2:1	3:1	66,479
3	1:1	2:1	57,791
4	2:1	2:1	58,792

Table 5-5. Surface area and volume of an anaerobic lagoon for a given operation using different geometric characteristics.

Example Configuration	Length:Width Ratio	Inside Slope	Liquid Volume (gallons)	Full Water Surface Area (ft^2)
1	1:1	3:1	5,000,946	64,778
2	1.5:1	3:1	5,012,102	65,475
3	2:1	3:1	5,034,061	66,848
4	1:1	2:1	4,905,029	56,819
5	1.5:1	2:1	4,912,816	57,237
6	2:1	2:1	4,928,085	58,056

5.4.2.2.1.5 Cover Repair Issues

The watertight integrity of the impermeable cover must be maintained to meet the objective of the "zero discharge" proposed rule. Storm water that enters the lagoon through the cover or becomes contaminated with lagoon effluent will have to be land applied. In these cases, no storm water management benefit has been gained from the use of an impermeable cover. The cover must be maintained watertight to realize a storm water management benefit.

Damage to an impermeable cover can occur along the berm of the lagoon where the cover is attached. Locating and repairing this type of damage along the perimeter of the lagoon can be accomplished with relative ease. The worker doing the repairs can probably remain on the berm of the lagoon and be safe.

Finding and repairing cover damage located away from the berm is a more challenging repair activity. Repairs implemented while the lagoon cover is kept in place require the workers to be on the cover. If a worker were to fall into a lagoon due to cover failure, the danger from drowning would be similar to someone falling through the ice-covered surface of a water body. The damaged cover could be removed and repaired while the cover was temporarily located on the berm. For small lagoons, removing the cover may not be a significant issue. However, for larger lagoons, removing, repairing and replacing the cover without causing additional damage would present a significant challenge and additional cost to the producer.

Repairing damage located away from the berm remains a significant challenge regardless of whether the repair is done on the lagoon surface or on the berm. If portions of the cover have sunk due to holes in the cover, the cover must be cut into strips to be removed because of the water weight on top of the cover. In these cases, a small tear or hole in the cover will require total replacement of the cover.

5.4.2.2.1.6 Old or Damaged Cover Disposal

Disposal of old and damaged covers can be a significant problem for some locations. The disposal challenges of old cover material are similar to challenges for old plastic silage and hay bags and old tires. Present technology limits disposal options to either sanitary landfills or recycling the material for some other use. If sanitary landfills do accept old cover material, charges can range from $12 per ton to over $100 per ton of material. Many sanitary landfills will not accept tires, plastic silage and hay bags. This would indicate non-acceptance of used lagoon cover material. A recycling program or reuse effort will be needed. Some existing recycling programs require that used plastic silage and hay bags be cleaned before the material will be accepted for recycling. Cleaning an old lagoon cover before recycling may be required in certain locations and result in additional expense for disposal of the old cover material. If impermeable lagoon covers are to be implemented on an industry-wide basis, the disposal of old cover material will need to be addressed and the cost of cover disposal incorporated into the overall cost analyses.

5.4.2.2.1.7 Problems with Decreased Quality of Recycled Effluent

The EPA recommends the use of recycled lagoon effluent rather than fresh water for barn flushing purposes to reduce the volume of effluent that ultimately must be land applied. Many production systems are currently using recycled lagoon water (effluent from approximately 12-24” below the lagoon surface) for flushing in production barns. With properly operating uncovered anaerobic lagoons, odor is minimal during flushing with the recycled water. When an impermeable lagoon cover is installed, the recycled flush water will have elevated dissolved gas concentration levels because the cover will reduce the emissions from the anaerobic lagoon. Higher dissolved gas concentrations can result in elevated gas concentrations within the production facilities. Higher gas concentrations might be irritating for animals and production workers in the barns, and might result in increased odor emissions from the production facilities.

Recycled water from a covered anaerobic lagoon will tend to contain a higher level of dissolved and suspended solids due to a decrease in dilution of the effluent from storm water. The increased level of dissolved and suspended solids in the recycled flush water may cause solids to build up in the recycle system within the production units and result in less effective manure removal.

5.4.2.2.2 Site Specific or Regional Issues Challenging the General Feasibility of Impermeable Lagoon Covers

The technical challenges presented in this section may only affect the technical feasibility of an impermeable cover installed at a specific location for a given operation. However, depending upon the location of the swine operation, one or more of the following technical challenges may cause installation of an impermeable lagoon cover to be infeasible.

5.4.2.2.2.1 Challenges Related to Structural Issues

Impermeable covers, as installed, will have to withstand various structural loads. The two types of structural loads discussed in this section include gravity live loads and wind loads. Other types of structural loads may be exposed to impermeable covers; however, if a lagoon cover system can withstand the two load conditions discussed in this section, the cover probably will not fail due to structural loads.

A structure that can repeatedly withstand various loads is considered to be reliable. Two important concepts related to structural loads and structural failures must be understood when evaluating the reliability of a structure. First, the concept of design loads must be understood when evaluating structural reliability. Design loads are defined as the required largest loads that a structure will be expected to withstand. Design loads are determined either from engineering calculations and judgment or from minimum requirements specified by code or regulatory authorities. Second, an understanding of the concept of exposure when evaluating structural reliability is also necessary. Exposure is defined as whether, or how often, a structural load near or equal to the design load is actually experienced by a given structure. A structure never exposed to a design load will not fail due to the design load. A structure is considered reliable when it withstands a given design load or when the structure is shown capable of withstanding the required design load.

When a structural failure occurs, the load the structure experienced is estimated. If the structural failure was caused by exposure to a load that exceeded the design load, no fault is assessed. Insurance coverage from the financial losses possible from a structural failure due to “acts of God” is collected. Loads less than those specified by code causing a structural failure usually negate the owner’s insurance protection. Owners may attempt financial loss recovery from the material manufacturer(s), the engineer or the builder of the structure when structural failures occur at loads less than specified by code. Structures must be designed and constructed to withstand at least the minimum design loads specified by codes in order to obtain insurance protection from a structural failure.

5.4.2.2.2.1.1 Structural Challenges Due to Gravity Live Loads

Gravity live loads are defined herein as the weight experienced by a cover due to any storm water, snow, ice, sand or soil that collects on the surface of the cover. Gravity loads will cause the cover to be displaced downward into the effluent. Equilibrium is reached when the amount of load above the cover is equal to the weight of water displaced under the cover.

One of the problems of gravity loads on covers relates to the displacement of the cover material when a load occurs on the top of the cover. As indicated earlier in this chapter, excess cover material usually exists. However, when the lagoon liquid level is at its lowest point, no excess cover material will be available to sink into the liquid when a gravity load occurs on the top of the cover. The cover may be strong enough to support the material on top of the cover without significant displacement into the lagoon liquid if the gravity load is small. A heavy gravity load will tear the cover resulting in cover failure. Lagoon management recommends pumping the effluent level down to provide a winter storage volume. Gravity loads resulting from winter snow and ice can result in a failed cover unless the snow and ice load is removed in a timely manner.

The distribution of gravity live loads on top of impermeable lagoon covers causes a second problem. Gravity loads, particularly storm water, will be unevenly spread over the top of the cover. Storm water will usually pool in different areas of the cover. The pooling of storm water on an impermeable lagoon cover is seen in Figure 5-1. The uneven distribution of storm water on the cover contributes to the formation of trapped gas that "balloons" the excess cover material. Removal of the pooled storm water presents challenges. Wind forces, discussed later in this report, can easily damage the "bubbled up" cover. Figure 5-2, contributed by a cover vendor, shows installation details that minimize storm water pooling on lagoon cover surfaces. If storm water pools between the foam logs, similar problems as described above can arise.

Soil and sand that is blown onto the cover surface results in a live gravity load. These solid materials are usually unevenly distributed over the cover surface. Gravity live loads introduce by workers removing sand, soil, snow or ice from the cover must be addressed prior to at most potential lagoon cover installations. The impermeable lagoon cover will require the structural load capabilities to support workers doing cover maintenance and repair. The same worker safety issues exist for debris removal as exist for repairing damaged covers.

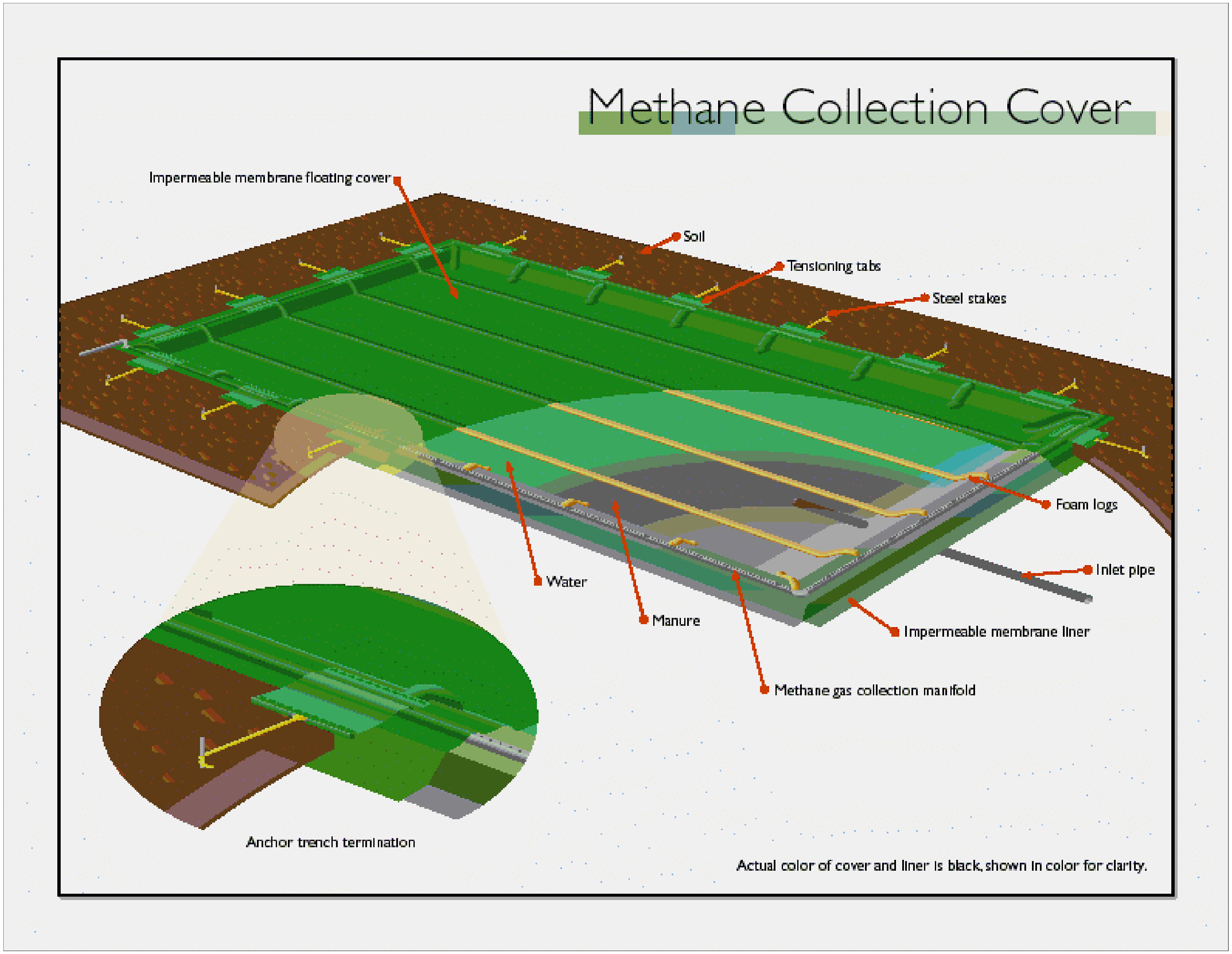

Figure 5-2 Diagram showing installation details for an impermeable cover. Source: Colorado Lining International. www.coloradolining.com

5.4.2.2.2.1.2 Structural Challenges Due to Wind Loads

Wind loads will damage impermeable covers. The reliability of a given cover with respect to wind loads should be evaluated based on a minimum design wind load for the geographic location utilizing those design parameters that affect the entire surface of the cover. Wind exposure factors on covers can be quite variable. Understanding wind exposure factors and how these factors change between specific sites is critical in the evaluation of wind load design. Impermeable lagoon covers have to be capable of withstanding the wind forces to which the cover is exposed. Lagoon cover reliability is determined by evaluating whether the cover can withstand a given design wind load.

Design wind loads for various structures can be determined by using procedures presented in the design standard ANSI/ASCE 7-98 entitled Minimum Design Loads for Buildings and Other Structures. This Standard specifies how to calculate various design loads for buildings and building components and documents the minimum design loads that buildings or components must be capable of withstanding. Wind load calculation methods and the minimum wind load recommendation are presented in Standard ANSI/ASCE 7-98. The minimum wind load recommendation given in Section 6.1.4.2 of ANSI/ASEC 7-98 states the following: "*The design wind pressure for components and cladding of buildings shall be not less than a net pressure of 10 lb/ft^2 (0.48 kN/m^2) acting in either direction normal to the surface.*" Based on this minimum load recommendation, an impermeable cover on an anaerobic lagoon or earthen manure storage should be capable of withstanding 10 lb/ft^2 of uplift force acting over the entire surface of the cover. Resulting tensile forces the edge of a cover must withstand are tabulated for various cover sizes and geometric configurations in Table 5-6. The force that the cover material must withstand increases as the cover size increases. The largest size of cover for a given cover material is determined by finding the largest tensile force the cover material can withstand from Table 5-6. If the required tensile force is equal to or less than the strength of the cover material, that cover will withstand the specified minimum wind load. If the required tensile force is greater than the strength of the cover material, the cover is too large for the given material. Insurance coverage to protect against the financial losses resulting from a cover failure due to wind damage is usually dependent on accurate wind design of the lagoon cover. A reliable cover should be capable of withstanding the minimum design wind load acting over the entire surface of the cover.

The exposure of wind forces greater than a cover will withstand will result in the failure of the cover due to wind. If, or how frequently, such wind forces occur at a given location defines the foundation for understanding wind force exposure. Using calculation methods presented in Standard ANSI/ASCE 7-98 for various scenarios, the wind load forces acting upon a cover can be estimated. The minimum design wind load of 10 lb/ft^2 can result from approximately a 70 mile per hour (mph) wind speed. Whether an entire cover will be exposed to forces resulting winds greater than 70 mph is the basic exposure question. Some geographic locations in the country may never experience 70 mph wind speeds. Structures in these locations will not be damaged by wind regardless of whether they were designed to withstand design wind loads or not. Other geographic locations experience winds speeds significantly greater than 70 mph, and structures must be designed to withstand the increased design wind forces associated with the greater wind speeds. Structures not designed or constructed to withstand design wind loads will probably be denied insurance coverage for the structure. Insurance coverage is usually available at locations where documented tornado damage has occurred. Lagoon covers should be designed to withstand design wind loads to minimize the potential for cover failure from wind. Covers that are not capable of withstanding design wind loads as specified by code may never fail if the cover is not exposed to design wind loads due to geographic location or local site conditions. These covers should not be considered reliable or structurally adequate for other specific sites. Recommending the use of structures not capable of withstanding minimum design loads is a questionable, if not unethical, engineering practice.

5.4.2.2.2.2 Challenges Related to Freezing Conditions

Freezing conditions will create significant challenges for the implementation of impermeable lagoon covers. These challenges include the potential formation of ice and snow loads, freezing of the lagoon surface, and damage to the cover from storm water collection, gas collection and/or floatation systems used with the cover. Freezing problems will become significant when winter design temperatures reach 25 °F or less. Areas of the country where winter design temperatures can reach 25 °F or less can be seen in Figure 5-3. Minor damage to storm water collection components and gas collection equipment can be expected when temperatures reach 25 °F for short time periods.

The formation of ice and snow loads will create the same challenges as the sand and soil gravity live loads discussed in section 5.4.2.2.2.1.1. The formation of ice and snow loads on the surface will often coincide with pumped down storages going into the winter. The challenge of the ice or snow load is from the deflection of the cover to compensate for the load. Loads that cause large cover material deflections may tear the cover. Physical removal of the ice and snow from the cover has the same worker safety issues as previously discussed.

Freezing of the lagoon surface can be expected to occur in areas where frost penetration exceeds five inches. The areas of the country where frost penetration exceeds five inches can be seen in Figure 5-4. Ice formation will probably damage any floatation aids, as shown in Figure 5-2, along with any other components floating or penetrating the effluent surface when the lagoon surface freezes. Storm water collection components, such as pipes and pumps, not drained between freezing weather uses will be significantly damaged at locations where frost penetration exceeds five inches.

Table 5-6. Tensile force[1] on edge of impermeable cover to withstand minimum design wind load.

	Lagoon Length											
Lagoon Width	50 ft	75 ft	100 ft	125 ft	150 ft	175 ft	200 ft	225 ft	250 ft	300 ft	400 ft	500 ft
50 ft	42	42	42	42	42	42	42	42	42	42	42	42
75 ft		63	63	63	63	63	63	63	63	63	63	63
100 ft			83	83	83	83	83	83	83	83	83	83
125 ft				104	104	104	104	104	104	104	104	104
150 ft					125	125	125	125	125	125	125	125
175 ft						146	146	146	146	146	146	146
200 ft							167	167	167	167	167	167
225 ft								188	188	188	188	188
250 ft									208	208	208	208

[1] Tensile force has units of pounds per inch of cover perimeter length.

Note: Minimum design wind load used is 10 pounds per ft^2.

Example: If cover material has tensile tear strength of 100 lbs per inch of cover width, cover size is limited to lagoons with a width less than 125 feet.

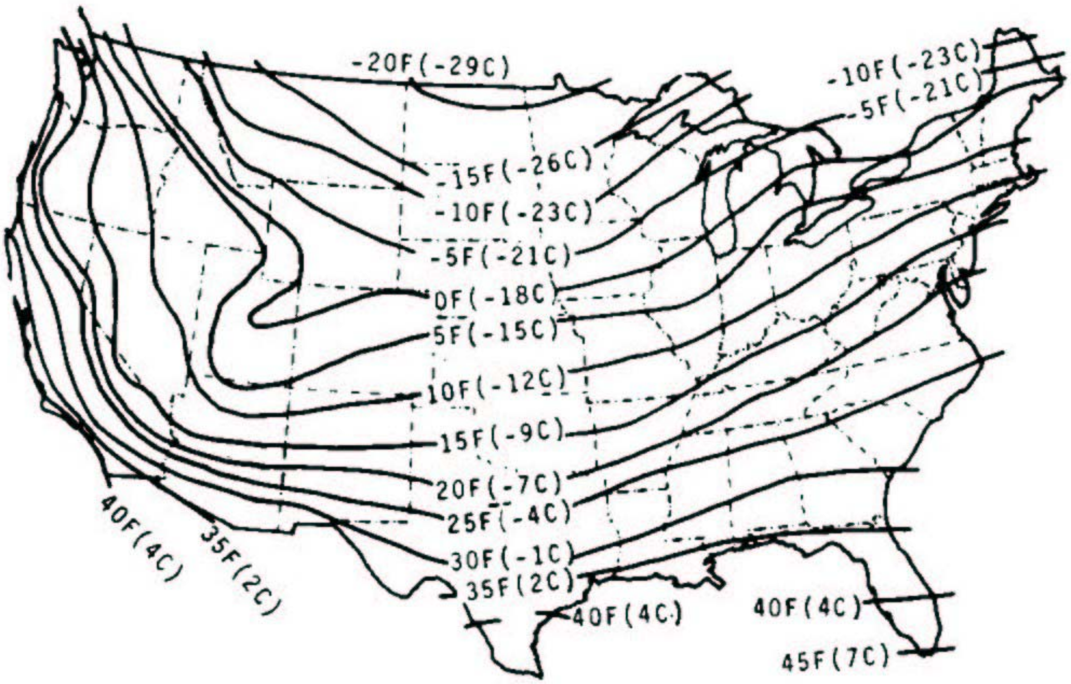

Figure 5-3. Map showing winter design temperatures for US. Source: ASAE EP270.5.

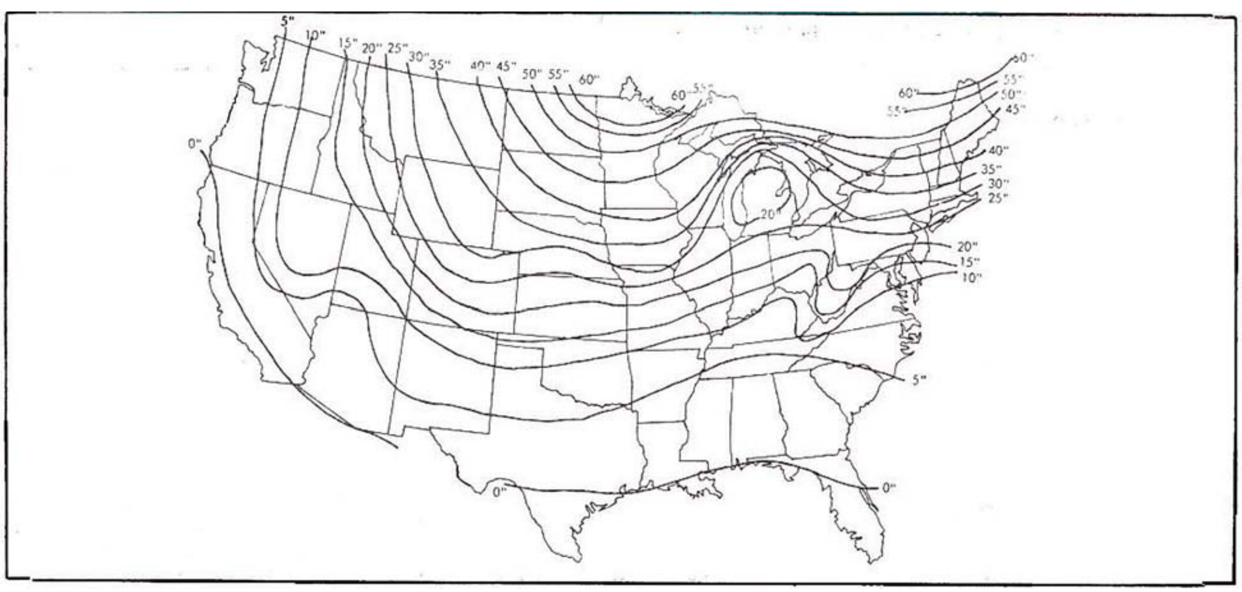

Figure 5-4. Map showing average frost penetration for US. Source: MWPS-1

5.4.3 Additional Storage

The concept of “zero discharge” presents a dilemma for design engineers because design parameters and limits are required to develop satisfactory designs. The scenarios suggested by the EPA are presented below, and have defined storms with designated lengths and return frequencies. These, or other reasonable design storms, can be used to develop and design additional earthen manure storage basins and anaerobic lagoon cells.

The construction of additional manure and wastewater storage is proposed as one alternative to attain “zero discharge” from open earthen manure storage basins and anaerobic lagoons that provide manure storage for Concentrated Animal Feeding Operations (CAFOs). Several concepts may be used to set the design criteria for the added storage. Two concepts presented in this analysis are:

1. Select a longer storage period and construct additional earthen storage to provide storage for manure produced, wastewater, additional lot and berm runoff, and rainfall minus evaporation volumes that occur on the liquid surface during the selected storage period. (Second Storage Cell)

2. Select some frequency and duration of storm and construct an earthen containment basin that would provide secondary storage for manure produced, wastewater, additional lot and berm runoff, and rainfall volumes that would overflow the full primary manure storage during the selected storm. Rainfall collected in the secondary containment basin during periods when manure and wastewater were contained in the primary manure storage would be tested to ensure non-contamination and discharged. (Emergency Storage Cell)

These approaches provide additional manure and wastewater storage for periods when weather related events do not allow scheduled land application of effluent or when rainfall events exceed the present 25-year, 24-hour design storm (catastrophic event) or a 10-year, 10-day design storm (chronic storm). Events that occur in nature are somewhat predictable; however, criteria that specify design limits are required to complete a design. Natural “Acts of God” occasionally exceed design limits. Selection of rainfall frequencies and durations are necessary to design manure storages that will effectively comply with the “zero discharge” concept.

5.4.3.1 Second Storage Cell

A second lagoon storage cell is defined as an earthen structure that is constructed according to federal, state and local regulations, and which can serve as a long-term manure effluent storage basin. The second lagoon storage cell can be located near the primary cell or be sited at a remote location to allow easier effluent pumping access to land application areas. When the second cell is located near the primary cell, effluent from primary cell can usually flow by gravity into the second cell. When the second cell is sited at a remote location, effluent will probably have to be pumped from the primary cell to the second cell. Pumping capacity and operational management design is needed so that the primary cell will not overflow except when design rainfall frequency and/or duration conditions are exceeded. Effluent from the second storage cell would be land applied each year regardless of whether the second cell had received effluent from the primary cell or whether only rainwater had entered the second cell. Annual pumping is required to maintain the designed additional storage capacity. In years when evaporation exceeds rainfall (drought), fresh water may need to be added to the second cell to maintain the volume required by the operating permit to maintain a water cover over the clay liner.

5.4.3.1.1 Second Storage Cell Design Criteria

Selection of a longer storage period is the initial step in the design of a second earthen manure storage cell that has the capacity to collect and store all inflow for the selected storage period. Construction and operational management of second cells must provide additional storage volume. The second cell cannot be used as a substitute for incompetent pumping and land application management of effluent. Design criteria studied are:

- Increase effluent storage periods to 12 and 18 months depending on the length of the present storage period design.

- Design the second cell to store net rainfall amounts from both cells that would be expected during the wettest year in 10 years.

- The second cell would have volume available to store the 25-year, 24-hour frequency storm at anytime during the increased storage period.

5.4.3.1.2 Second Storage Cell Examples

For this study, swine operations located in Missouri, Oklahoma, and North Carolina were examined since anaerobic lagoons are the predominant manure storage systems used in these states. Secondary storage cell structures were designed based on the above criteria. Using the secondary cell designs, additional pumpdown volumes were calculated for 12 or 18-month periods based on the above criteria. Construction costs were estimated for the second cell. Results for secondary cell analysis are presented in Tables 5-7 and 5-8.

Table 5-7. Existing lagoon volumes and additional storage sizes needed to expand storage capability to 12 and 18 months.

Presentation Code	Existing Storage Period	Existing Lagoon: Liquid Lagoon Volume (gallons)	Existing Lagoon: Total Lagoon Volume (gallons)	Increasing to 12 Month Capability: Liquid Volume (gallons)	Increasing to 12 Month Capability: Total Volume (gallons)	Increasing to 18 Month Capability: Liquid Volume (gallons)	Increasing to 18 Month Capability: Total Volume (gallons)
MO-4	12 mo.	5,993,847	6,585,025	NA	NA	4,356,175	4,925,249
MO-6	12 mo.	19,136,028	21,419,358	NA	NA	9,850,238	11,032,456
NC-1	6 mo.	1,769,144	2,029,079	1,816,003	2,086,150	6,205,693	6,995,115
NC-4	6 mo.	6,718,302	9,184,428	6,320,165	7,111,524	24,320,612	27,058,489
OK-1	6 mo.	2,728,419	3,025,072	3,321,651	3,771,414	10,112,580	11,372,611
OK-8	12 mo.	4,158,310	5,154,171	NA	NA	1,596,921	1,845,410

Table 5-8. Pumpdown volumes and costs associated with adding additional storage to existing operations.

Presentation Code	Increasing to 12 Month Capability: Average Annual Additional Pumpdown Volume (gallons)	Increasing to 12 Month Capability: Construction Cost	Increasing to 18 Month Capability: Average Annual Additional Pumpdown Volume (gallons)	Increasing to 18 Month Capability: Construction Cost
MO-4	NA	NA	242,955	$36,581
MO-6	NA	NA	472,847	$81,940
NC-1	316,088	$15,494	726,243	$51,954
NC-4	1,030,199	$52,819	3,073,420	$200,969
OK-1	132,298	$28,011	96,193	$84,467
OK-8	NA	NA	(-508,196)[1]	$13,706

[1]Note: This negative annual pumpdown is assumed to be zero for analysis. This operation is located in an arid region. If this operation was to build a second storage cell, the cell should be lined with a synthetic liner instead of a clay liner because keeping water in the cell to protect a clay liner will be difficult.

5.4.3.1.3 Second Storage Cell Implications

Construction of additional earthen cells to store manure and wastewater for longer storage periods also requires added storage volumes to be constructed to contain the additional rainfall and runoff volumes. Especially in humid areas, these additional effluent volumes may cause hydraulic loading problems during land application. Effluent pumping management problems will increase and application of the increased effluent volume may not be feasible on the existing land application area or with the irrigation equipment that is presently used.

Second storage cell volume calculations were based on local rainfall data and the stocking rate of the case study farm. Construction costs were estimated by assuming that 75% of total volume of the cell required soil excavation. The excavation yardage or cut yards were assumed to cost of $2.00 per cut yard.

5.4.3.2 Emergency Storage Cell

Emergency storage is defined as an earthen structure that is constructed to serve only as a short-term earthen manure storage basin. An emergency storage basin is assumed to be located down stream from the primary lagoon structure. The emergency storage would be designed such that any stored storm water could be discharged from the structure. If overflow from the primary lagoon or earthen manure storage was to occur during a storm event, the emergency storage would store the storm water and overflow effluent. The overflow and any other water stored in the cell that was not acceptable for discharge would have to be land applied. Emergency storage cells are designed to be short-term water storage structures. The advantage of the emergency storage is that when the stored water (presumably only rain water) is acceptable for discharge, the stored water can be released to waters of the state. No land application costs would be incurred by the swine operation when the stored rainwater could be discharged.

5.4.3.2.1 Emergency Storage Cell Design Criteria

Selection of an extended duration design storm is the initial step in the design of an emergency storage cell. The emergency storage cell must be designed to provide a volume that will store the design storm plus storage for manure and wastewater during a longer design period so that land application can be accomplished in an environmentally satisfactory manner. Proposed emergency storage cell design criteria are:

- Provide additional storage volume to contain the 10-year, 10-day design storm and runoff from that storm that would be generated in the primary lagoon cell or earthen manure storage basin. Design volumes would be based on the geographic area rainfall data.

- Provide storage volume for an additional 30-days (one month) of manure and facility wastewater production.

- Rainfall collected during periods when manure and effluent is contained in the primary would be tested and, if not contaminated, would be discharged.

The emergency storage cell is sized based on the assumption that all manure, wash water, net precipitation, and lot and berm runoff is contained within the primary manure storage system unless a rainfall event occurs that exceeds storage design parameters. The occurrence of such a rainfall event requires the emergency storage cell to be of sufficient size to collect all overflows from the primary storage system, as well as precipitation falling directly into the emergency cell and runoff from the emergency cell berm.

Emergency cell volume is determined by calculating the maximum volume of flow that would need to be contained in any one-month period. This flow volume is comprised of the 10-year, 10-day frequency storm, and production system wash water volume and manure volume for a 30-day period. As long as the primary manure storage system is capable of containing all inflow, the emergency storage cell would be drained following storm events if the tested water is found to be free of ammonia nitrogen or other easily measured prediction compound.

For each geographic location, the 10-year, 10-day storm event was determined from Midwest Plan Service Publication No. 18. The states of Missouri, Oklahoma and North Carolina used in this study basically have a 10-year, 10-day storm event equaling ten inches of precipitation.

5.4.3.2.2 Emergency Storage Cell Examples

Based on the above criteria, emergency storage cell structures were designed for example operations from Missouri, Oklahoma, and North Carolina where anaerobic lagoons are the predominant manure storage systems. Additional pumpdown volumes from the emergency cells and construction costs were estimated. Results of emergency cell analysis are presented in Table 5-9.

Emergency storage cell volume calculations were based on local rainfall data and the stocking rate of the case study farm. Construction costs were estimated by assuming that 75% of total volume of the cell required soil excavation. The excavation yardage or cut yards were assumed to cost of $2.00 per cut yard.

5.4.3.2.3 Emergency Storage Cell Implications

Management of the emergency secondary containment cell requires that the cell be equipped with a manually operated “draw-down” device. This manually operated device would be normally closed so that any rainfall or runoff water would be collected in the cell. This water would be field tested for ammonia level or other indicative field test to insure that no manure flow from the primary storage had occurred. When the testing confirmed that the water in the emergency secondary containment was below some determined ammonia level (probably 2.5 to 5 ppm) or other acceptable test, it would be discharged. The secondary containment cell would then be available to collect any outfall flow from the primary lagoon cell or earthen manure storage basin. The proposed “zero discharge” rules specify no overflow of the primary manure storage structure. The proposed rules would have to be modified for this proposal to comply with the proposed “zero discharge” rule.

Table 5-9. Pumpdown volumes and costs associated with adding emergency storage to existing operations.

Facility Code	Existing Storage Period	Emergency Cell Liquid Volume (gallons)	Emergency Cell Total Volume (gallons)	Emergency Storage Construction Cost
MO-4	12 mo.	1,325,688	1,534,860	$11,400
MO-6	12 mo.	3,991,631	4,520,549	$33,575
NC-1	6 mo.	703,769	831,820	$6,178
NC-4	6 mo.	2,780,067	3,166,053	$23,515
OK-1	6 mo.	1,047,661	1,221,284	$9,071
OK-8	12 mo.	1,279,948	1,484,677	$11,027

5.5 ISSUES RELATED TO “ZERO DISCHARGE” REQUIREMENT

The comments in this section discuss issues that have indirectly risen if the “zero discharge” rule is implemented as presented in the Federal Register.

5.5.1 Outside Lots and Pasture Production

The EPA states “animals are not considered to be stabled or confined when they are in areas such as pastures or rangeland that sustain crops or forage growth during the entire time that animals are present (Federal Register, page 3135).”

The EPA defines the production area under control of the CAFO owner or operator as a point source. Consequently, any operation with a confined area that is not under roof must collect, store, and properly dispose of all discharge storm water that has come in contact with animals or manure. Some swine operations utilize “Cargill” floors or open concrete feeding areas. For these types of open swine confinement systems, it is impossible to contain all discharge storm water and to meet the zero discharge requirements being proposed. The only option is to move the animals into confined housing under roof.

5.5.2 Dry Manure Systems

The EPA in the Federal Register promotes housing systems capable of using dry manure systems (pages 3061 & 3068). Dry manure system facilities include hoop housing, deep litter barns and "High-Rise" facilities. A carbon source is required for bedding or to be blended with the manure. Hoop barns use a significant amount of bedding because the facility is not designed to moderate inside temperatures. A deep litter swine barn is similar in function to a poultry litter barn. Less bedding is required as compared to a hoop barn because the inside temperature can be moderated for aid with pig comfort. A "High-Rise" facility uses a carbon source to blend with swine manure in a facility similar to a deep pit swine barn that uses a ventilation system similar to a high-rise layer facility.

For hoop house systems, an estimate of one pound of bedding material is required for each pound of gain by pigs housed in facility. For example, if 200 pigs were housed in a hoop barn and each pig gained 200 pounds while in facility, approximately 40,000 pounds of bedding would be required to raise the 200 pigs. For these 200 pigs, the 40,000 pounds of bedding must be gathered and hauled to facility and then the bedding must be hauled away from the facility with the incorporated swine manure. Bedding availability, in the quantities required for an operation, can be a challenge. In some locations, crop residue must be left on the fields to maintain soil conservation practices to minimize soil erosion. In these locations, bedding availability at a reasonable low may be a problem. If bedding costs become significant for an operation using hoop barns, this operation will be placed at an economic disadvantage because of high bedding costs.

5.5.3 Enclosed Treatment Systems

Enclosed manure treatment systems can be used in some situations to reduce the contact between manure and storm water. Several alternative technologies are being designed and operated to improve the handling characteristics of manure and to reduce manure storage volumes. Most alternative treatment systems implement some type of solid separation to divide the liquids and solids into two separate streams. Often there is additional treatment of the solids.

Solids can be digested to create methane for use as an energy source or composted to create a stable organic fertilizer that is more easily transported than manure in a liquid or slurry form. Processing of solids to produce an inert product suitable for packaging as a fertilizer is being examined as well. These systems are commonly contained within a covered structure so that storm water does not come into contact with the separated solids. This reduces the risk of contact between manure and storm water for the solid portion of the manure treatment system.

Although these methods of treatment are generally successful for processing and utilizing solids, the liquid portion of the waste stream must still be utilized. The most economical and practical use of the liquid stream is land application as a soil amendment. The nutrient content of the liquid fraction is lower than manure from traditional manure storage systems due to removal of the solids. Commonly, the liquid is stored in a lagoon where the water can be naturally treated by sunlight and anaerobic bacteria, or mechanically treated with aeration. However, the storage of the liquid portions of the manure stream does not comply with the "zero discharge" rule since contact with storm water is still possible. Advanced treatment of the liquid stream could merit re-use of the water for animal consumption. If treated to suitable nutrient levels for receiving streams, discharge permits similar to those for municipal treatment systems would need to be approved to make the treatment system a desirable option for producers.

5.6 EXISTING SYSTEMS CAPABLE OF MEETING "ZERO DISCHARGE" REQUIREMENT

This section describes the few existing systems that can currently meet the "zero discharge" rule. Any operation that is not using one of the systems below will need to invest in additional equipment or a technology to meet a "zero discharge" rule.

5.6.1 Outside Covered Slurry Storage

Concrete and metal storage structures that store manure as a slurry are capable of meeting the "zero discharge" requirement. Whereas lagoons are designed to treat the manure by sustaining microbes that break down and utilize the solids and nutrients in the manure, slurry storage structures are simply designed to store the manure until it can be utilized. Therefore, the volume and surface area of a fabricated slurry tank is much less than for a lagoon at the same operation. The smaller surface area makes an impermeable cover much more feasible than for an anaerobic lagoon or earthen slurry storage.

Operations that currently utilize a lagoon could meet the "zero discharge" requirement by converting their existing manure storage system to a covered slurry structure. This change in manure storage would drastically change the nutrient value of the manure being utilized for land application. A more in-depth discussion of the impacts of converting from a lagoon system to a slurry system for manure handing and storage is presented in Chapter 6 of this series of documents. In brief, the number of additional acres an operation would need for land application of manure if converting from a lagoon to a slurry system could increase by a couple of magnitudes.

The cost of converting from a lagoon system to a covered slurry storage system must also be considered. A slurry storage structure would not be capable of supplying recycled flush water to the barns as many lagoons currently do. This could potentially cause a need for using fresh water to flush barns. In addition to the cost of constructing the new slurry storage structure, the existing lagoon would need to be emptied and properly closed.

Operations currently applying lagoon effluent would likely also need to invest in new equipment capable of handling the slurry. Many operations with lagoons are presently using center pivot irrigation and traveling guns, which are not capable of handling slurry manure.

5.6.2 Under-building Slurry Storage

Confinement buildings that retain the manure in a deep pit beneath the animals will be capable of complying with a "zero discharge" requirement. Manure drops through a slotted floor on which the animals stand and is collected and stored in a pit until it is utilized for land application. A very high cost is associated with converting a current operation with a flush system to a deep pit system.

5.6.3 Other Systems

Any system where the animals are completely confined under roof and manure is collected and stored under roof will be capable of complying with the "zero discharge" rule. Hoop structures, high-rise buildings, and deep bedding systems all use a carbon source such as straw, sawdust, or cornstalks to combine with animals manure for easier handling and treatment of the manure. Most often, the manure and bedding material mixture is composted and land applied as a soil amendment.