Review of C&H Hog Farms Application for Arkansas Pollution Control and Ecology Commission Regulation 5, Liquid Animal Waste Management System Permit

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I have been retained by Richard Mays Law Firm, on behalf of the Buffalo River Watershed Alliance to review the C&H Hog Farms Regulation 5 Permit application, submitted to ADEQ in April 2016. My opinions concerning this permit are based on more than 40 years' experience in water quality, agricultural pollution control, and other aspects of watershed management. I have specific expertise in hydrology, water chemistry, animal waste management, crop management, and agricultural production systems. In 1994 I received the EPA Regional Administrator's Environmental Excellence Award for Outstanding Service in Implementing the Requirements of the NPDES Region 6 CAFO General Permit. My C.V. is attached. My analyses in this report are based on a site visit to the Big Creek area, numerous public documents relating to the history of the C&H permit application, C&H Annual Reports to ADEQ, material from the professional literature, and reports of the University of Arkansas Big Creek Research and Extension Team (BCRET).

Background

C&H Hog Farms was approved for a discharge permit under ADEQ Regulation 6 in 2012. The permit specified 2,503 swine over 55 lbs, 4,000 swine under 55 lb. Waste treatment system consisted of two sequential holding ponds, with total capacity 2,735,922 gallons and shallow pits under the houses with additional capacity of 759,542. The holding ponds were designed to contain process water and stormwater from a 25-yr 24-hr storm. The design did not include a spillway.

Description of the Waste Treatment System.

The Animal Waste System, was designed by DeHaan, Grabs & Associates, LLC (DHG) in 2012 for C&H Hog Farm. In 2015, the design was reviewed by Dennis Carmen, P.E. The original design consisted of the following components: (1) concrete tanks under the floor of the farrowing building and the gestation building, (2) Waste Storage Pond #1 (WSP1), Waste Storage Pond #2 (WSP2), and a Nutrient Management Plan (NMP) for application of the wastes to hay fields and grazing land. The floors of the farrowing and gestation buildings have slotted floors under the pens to allow waste to fall into the concrete holding tanks. The contents of the tanks include recharge water, added to keep the wastes moveable, and wash water used in cleaning the animal pens. The tanks have capacity to hold waste and wash water for at least three to five weeks. Periodically, the plug is pulled on each tank allowing the contents to drain by gravity into WSP1. When WSP1 fills up, it spills over through a concrete spillway to WSP2. This arrangement allows most of the solids to settle in WSP1 (biosolids) and supernatant liquid (liquid manure) to reside in WSP2.

During the period between the start of operation and the present, the C&H operator has been working with Karl VanDevender and the University of Arkansas Big Creek Research and Extension Team (BCRET) to modify operations and improve performance of the entire waste handling system. A notable change is the improvement in water handling and distribution installed with assistance from BRCET. This system reduced the quantity of fresh water used by re-using water from WSP2 for washing and pit recharge.

The difference between Waste Storage Ponds and Animal Waste Lagoons.

The ponds at C&H are designed to function strictly for waste storage, i.e. not as animal waste lagoons. An animal waste lagoon would always have water and solids in it (the treatment volume), allowing it to function as a treatment system to reduce organics and nitrogen content. Sludge solids may accumulate in a lagoon for many years, sometime 20 years or more. Lagoon sludge must eventually be removed and disposed as biosolids that are high in organic matter and phosphorus.

A Waste Storage Pond is operated for temporary storage of the waste. The ponds should be mixed thoroughly each time waste is withdrawn, and they should be pumped down to about one-foot of the bottom. The treatment occurs in the field where the contents are applied to cropland or grazing land for nutrient utilization. Operation of a storage pond is simpler than a lagoon because there is no need to retain a treatment volume, giving the operator much more flexibility. As WSP1 accumulates most of the solids, it is particularly important that it be agitated each time it is pumped to get the solids into suspension. This is usually accomplished by recycling the pumped liquids or using a mechanical stirrer. If agitation is not started well ahead of pumping and maintained until solids are in suspension, the solids will build up. Solids and nutrient content of WSP1 is expected to be higher than WSP2, a consideration in developing the nutrient management plan.

The problem of solids accumulation, loss of storage volume, and buildup of nutrients was well established by a 3-year study of 35 hog farms conducted by ADEQ (Sandy Formica, 2002). In this study, ADEQ found Nitrogen content to be three times higher and Phosphorus almost four times higher in ponds that were not maintained by agitation and pumping. The ADEQ study further found storage volume reduced about 40% due to accumulation of solids. Much of the solids had been compacted until they were too dense to be removed by pumping. The ADEQ study underscored the importance of proper maintenance, including agitating and pumping out the storage ponds periodically. In addition to the difficulty encountered in pumping the compacted solids of these ponds, the concentration of nutrients was too high for application to nearby fields.

Evaluation of the Storage Volume Calculations.

In the current application for a Regulation 5 Permit, Dennis Carmen, P. E. reviewed the design calculations of the C&H facility. Carmen's findings affirm that the storage volume of the waste holding structures exceeds the minimum requirement of 180-days storage by more than 40%. We examined the design documents and agree with Carmen's volume calculations.

Carmen computed total manure and wastewater production to be 1.6 million gallons in 180 days. Our estimate was 1.76 million gallons. Total storage in WSP1 and WSP2 is 2.33 million gallons. A 25-yr, 24-hr storm for the area would produce an additional 259,000 gallons. These calculations indicate that with careful management, the operator should not have a problem keeping water level in a safe zone, for rainfall up to and including the design storm.

The safety associated with the excess storage in the waste pond design depends, however, on managing the water level in WSP2 and retaining enough freeboard at all times. The design calls for maintaining volume for the 25-year, 24-hr design storm (about 7 inches), plus one foot of freeboard, a total of about 20 inches. Considering the lack of an emergency spillway and the experience of unusually high rainfall in the Ozarks, the operator should be required to maintain more than the minimum storage at all times. A picture from the ADEQ inspection report from 12/30/2015 (see Figure 1), shows that WSP2 is operated close to the maximum level with about three months to go before a significant pumpdown was expected.

Photographer:	**Jason Bolenbaugh**	Date:	**12/30/2015**	Time:	
Witness:	**Keith Waters**			Photo #:	**2**
Description:	**WPS #2 showing adequate amount of freeboard and the depth gauge which marks (red line) the Must Pump Down level.**				

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FIGURE 1 VIEW OF WASTE POND 2 DURING DECEMBER 2015, FROM ADEQ INSPECTION

The water level management specified in the Regulation 5 permit is based on ***no discharge***, but the design guidance from the NRCS Waste Management Field Handbook is based on allowing discharge from a storm greater than the 25-yr 24-hr storm. If no discharge is allowed, a different design criterion, such as “Probable Maximum Precipitation” (PMP) (see Figure 2) should be used for design and management. Estimates of PMP were developed by the National Oceanic and Atmospheric Administration (NOAA) According to the NOAA analysis, the PMP for this area in Arkansas would be about 40 to 42 inches, about twice the volume currently reserved for the design storm and freeboard.

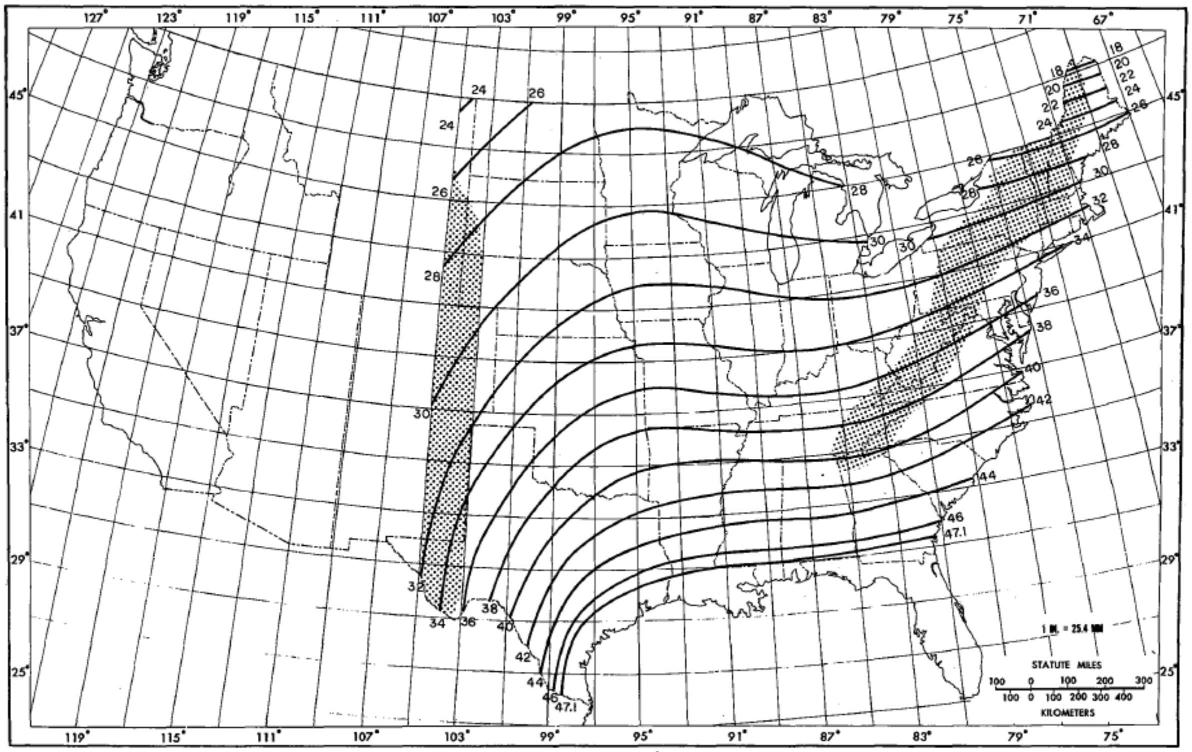

FIGURE 2 ALL-SEASON PMP (IN.) FOR 24-HR 10 SQUARE MILE AREA EAST OF THE 105 DEGREE MERIDIAN

The original design (2012) called for installation of a pump with a pipeline and sprinklers. The pump and sprinklers were never installed, and the current permit application allows use of tanker equipment for application of wastes to all designated fields. Although a pump and sprinkler system would be more efficient for reducing the water level in WSP2, it would also concentrate the application of waste to a few nearby fields. In my opinion concentrating applications to a few nearby fields would be more problematic than distributing it more evenly to many of the 40 fields as currently proposed.

The disadvantage of relying on tank and sprayer equipment is that each pumping event will take longer, making it more difficult to keep the wastewater mixed, resulting in less uniform application of waste and less predictability in assessing the waste nutrient content. In addition, in an emergency, it would be very difficult to operate tank sprayer equipment.

Conclusion concerning pond sizing.

Our estimate of annual waste production is consistent with that of the permit design engineers, DeHaan, Grabs, & Associates and with the review of Carmen. Our analysis confirms the following points:

- The waste holding ponds should be designed and operated to a higher standard than the NRCS Agricultural Waste Management Field Handbook (AWMFH) because Regulation 5 requires “no discharge.” The 25-yr 24-hr storm would be acceptable under a discharge permit like the Regulation 6 NPDES permit, but Regulation 5 is a “No Discharge Permit” and should require a higher standard such as NOAA’s Probable Maximum Precipitation.

- The high recreational value of the Buffalo River should also be a basis for designing to a higher standard, such as the PMP, or at least 40 inches of stormwater and freeboard combined.
- As the waste ponds have no emergency spillway, any discharge could erode the embankment, increasing the risk of catastrophic failure.

Review of Pond Siting, Liner Design, and Leakage

Siting and liner design of the waste storage ponds were based on the United States Department of Agriculture Natural Resource Conservation Service (NRCS) Chapter 10 of the AWMFH (USDA-NRCS, 2009). The NRCS AWFMH suggests that the first consideration for siting and designing a liquid waste storage facility is to recognize features such as “high vulnerability,” due to karst geology (Table 10-4 from the NRCS AWMFH, See Appendix). The documented presence of karst geology at C&H, triggers criteria for High Vulnerability and High Risk, suggesting the designer “evaluate other storage alternatives” or at least require installation of a synthetic liner. Considering the value of the Buffalo River, I recommend installing a synthetic liner with leak detection or using above ground steel tanks. The C&H waste ponds were designed based on Moderate Risk and Moderate Vulnerability.

The 2012 NOI shows soil profiles from 3 borings, and indicates that soil from the 7 ft to 11 ft zone in two of three borings was selected for use in constructing a compacted clay liner. It was not clear how much clay was available for use in the zone selected. Two samples were analyzed for plasticity, and one was analyzed for hydraulic conductivity (2012 QA-QC report). The permeability was shown to be 5 x 10^{-7-} cm/sec and Plasticity Index (PI) was greater than 30, values suitable for use in a pond liner with compaction. The handbook notes that soils with high PI typically have a tendency to crack when dried, resulting in a chance of substantial leakage. The AWMFH recommends (NRCS AWMFH, Chapter 10) covering high plasticity clay with a lower PI soil layer or a geomembrane to prevent drying. Such protection was not provided in this installation, and cracks are visible in photographs from ADEQ inspection (1/23/2014) and EPA inspection (4/15/2014.) See Figure 3.

FIGURE 3 LINER CRACKS (FROM INSPECTION REPORT BY ADEQ, TONY MORRIS 7/23/2013

Leakage rate from the waste ponds.
The design specified in the 2012 NOI and approved by Carmen (2016) is based on a single recompacted sample of clay, reported in the 2012 QA-QC Report as having permeability of 5 x 10-7 cm/sec. If this permeability is correct for the entire clay liner, the leakage rate from Pond 1 would be 1,175 gal/day when the pond is full and 2,153 gallons/day from Pond 2 when it is full. The NRCS AWMH recommends, "In the absence of a more restrictive State regulation, assume an acceptable specific discharge of 5,000 gallons per acre per day." The leakage rate allowed in this design is generally acceptable to NRCS, in the absence of more restrictive rules. I would suggest that a leakage rate of 2,000 to 3,000 gallons/day is very high considering the karstic nature of the geology of the area. Note this leakage rate would be about one-half the daily manure production rate (4,2790 gal/day based on Carmen review of waste pond design).

Comparison of leakage rate with the rate allowed in other states.
The leakage rate allowed in Arkansas is higher than many other states. I reviewed eight state standards, and the "10-State Standard" for comparison. This analysis (see Appendix) showed that most states in this comparison hold animal waste structures to a higher standard than Arkansas. In this comparison I looked at leakage rate based on a 6-foot depth. Ohio's standard generally allows a leakage rate of 277 gal/ac/day, but restricts leakage further in a karst area. Missouri restricts leakage to 500 gal/ac/day in a basin where potable groundwater might become contaminated, Oklahoma restricts leakage to 462 gal/ac/day and requires installation of monitoring wells. The **10-state standard** restricts leakage to 500 gal/ac/day.

A recent electrical resistance study by Halihan and Fields (2015) suggested, and follow-up drilling by Harbor Environmental (2016) confirmed, that the ponds and the application fields are all underlain by Boone Formation limestone. This limestone, clay, and chert geology is noted for fractures and karstic groundwater features. Although leakage from the ponds was not confirmed, any seepage or direct leakage from the ponds would eventually be transmitted to groundwater and to the Buffalo River. The fact that Harbor Environmental did not confirm any ground water contamination is not conclusive because they only drilled one hole.

In 2015, the C&H permit was modified to allow installation of a synthetic liner and sub-liner gas collection system. This system should be installed along with a system for leakage detection. Installation of a synthetic liner would also reduce the concern for drying and cracking of the high plasticity clay that currently lines the ponds. Note these ponds are designed to be pumped down to one-foot depth periodically, allowing long periods where drying and cracking could occur.

Opinion concerning pond liner
It is my opinion that a synthetic pond liner with sub-liner gas collection and leak detection should be required as a term of the permit considering the valuable nature of the receiving water and the karstic geology identified under the facility. The liner and leak detection should not be optional.

Nutrient Management and Waste Disposal
The C &H Hog Farms nutrient management plan (NMP) is based on Nitrogen as fertilizer, resulting in excess Phosphorus application. This amounts to disposal of Phosphorus as most of the fields already have medium to very high soil test P levels. Table 1 shows the P-status of each field in the Permit Application with its most recent Soil Test Phosphorous (STP) and the Phosphorus (P2O5) fertilizer recommendation from the Arkansas Cooperative Extension Service. According to these recommendations these fields need very little if any P2O5. Note virtually all the fields included in the NMP, particularly those that were used previously have "Above Optimum" P-status.

TABLE 1 SOIL P-STATUS, FERTILITY RECOMMENDATION, AND SUITABILITY FOR WASTE APPLICATION BASED ON STEEPNESS AND SHAPE OF APPLICATION AREA

Field	spread-able ac	STP	P-Nutrient Status	Recommendation P2O5 lb/ac	Suitability for waste application
Field 1	8.4	95	Above Optimum	0	Fair – contorted
Field 2	6	108	Above Optimum	0	Poor – Steep, contorted
Field 3	15	89	Above Optimum	0	Good
Field 4	7.2	75	Above Optimum	0	Poor – steep, contorted
Field 5*	9.7	63	Above Optimum	0	Good
Field 6*	5.6	116	Above Optimum	0	Good
Field 7	64	89	Above Optimum	0	Good
Field 8	7.2	82	Above Optimum	0	Good
Field 9	25	82	Above Optimum	0	Good
Field 10	14	72	Above Optimum	0	Good
Field 11	14	62	Above Optimum	0	Poor - contorted
Field 12	11	88	Above Optimum	0	Good
Field 13	12	86	Above Optimum	0	Good
Field 14	8.1	75	Above Optimum	0	Fair - steep
Field 15	23	72	Above Optimum	0	Good
Field 16	15	66	Above Optimum	0	Good
Field 17	32	86	Above Optimum	0	Good
Field 6A*	7.9	111	Above Optimum	0	Poor - contorted
Field 7A**	28	38	Optimum	45	Good
Field 8a**	1.4	82	Above Optimum	0	Good
Field 9a**	10	57	Above Optimum	0	Good
Field 10A**	16	100	Above Optimum	0	Good
Field 13A**	31	75	Above Optimum	0	Good

Field 13B*	8.5	61	Above Optimum	0	Poor – steep, contorted
Field 15A*	10	18	Low	80	Fair - contorted
Field 15B*	15	66	Above Optimum	0	Poor – contorted, steep
Field 18*	23	42	Optimum	45	Good
Field 19*	11	66	Above Optimum	0	Good
Field 20*	22	63	Above Optimum	0	Good
Field 21*	20	12	Very Low	120	Very Poor – contorted, steep
Field 21A*	6	21	Low	80	Fair - steep
Field 21B*	6	38	Optimum	45	Very Poor - contorted
Field 22*	36	38	Optimum	60	Good - steep
Field 23*	28	56	Above Optimum	0	Good
Field 24*	8	45	Optimum	45	Good
Field 32*	10	57	Above Optimum	0	Good
Field 33*	4	52	Above Optimum	0	Good
Field 34*	14	56	Above Optimum	0	Good
Field 35*	18	40	Optimum	45	Good - contorted
Field36*	9.3	20	Low	110	Fair - contorted

*Fields newly designated in this plan
**Fields created by subdividing fields used in previous plans

In my opinion, application of wastes to fields with P-Status higher than “Above Optimal” should be considered waste disposal, making them subject to stormwater rules. If wastes were applied at agronomic rates, the number of fields at Optimal or Above Optimal STP would preclude use of most of these fields. This would severely reduce the amount of land available for waste application without additional BMPs.

Suitability of Fields for Waste Application

The last column of Table 1 also shows my assessment of each field’s suitability for waste application based on shape and steepness. Most fields in the NMP have reasonably good shape, with large open areas where a spray rig could maneuver easily to follow boundaries of buffer zones. Some, however, have few restricted areas, or at least areas that are easy to identify. Several fields, however, are so contorted, with odd shaped buffer areas and steep slopes, it would be difficult or even impossible to follow. Examples of fields with severe limitations include fields 2, 4, 6A, 11, 13B, 20, 21A, and 21B. Figure

4 shows the example of Field 21A , where an operator would have difficulty. These six fields include 71.5 acres that should be removed from the permitted application area.

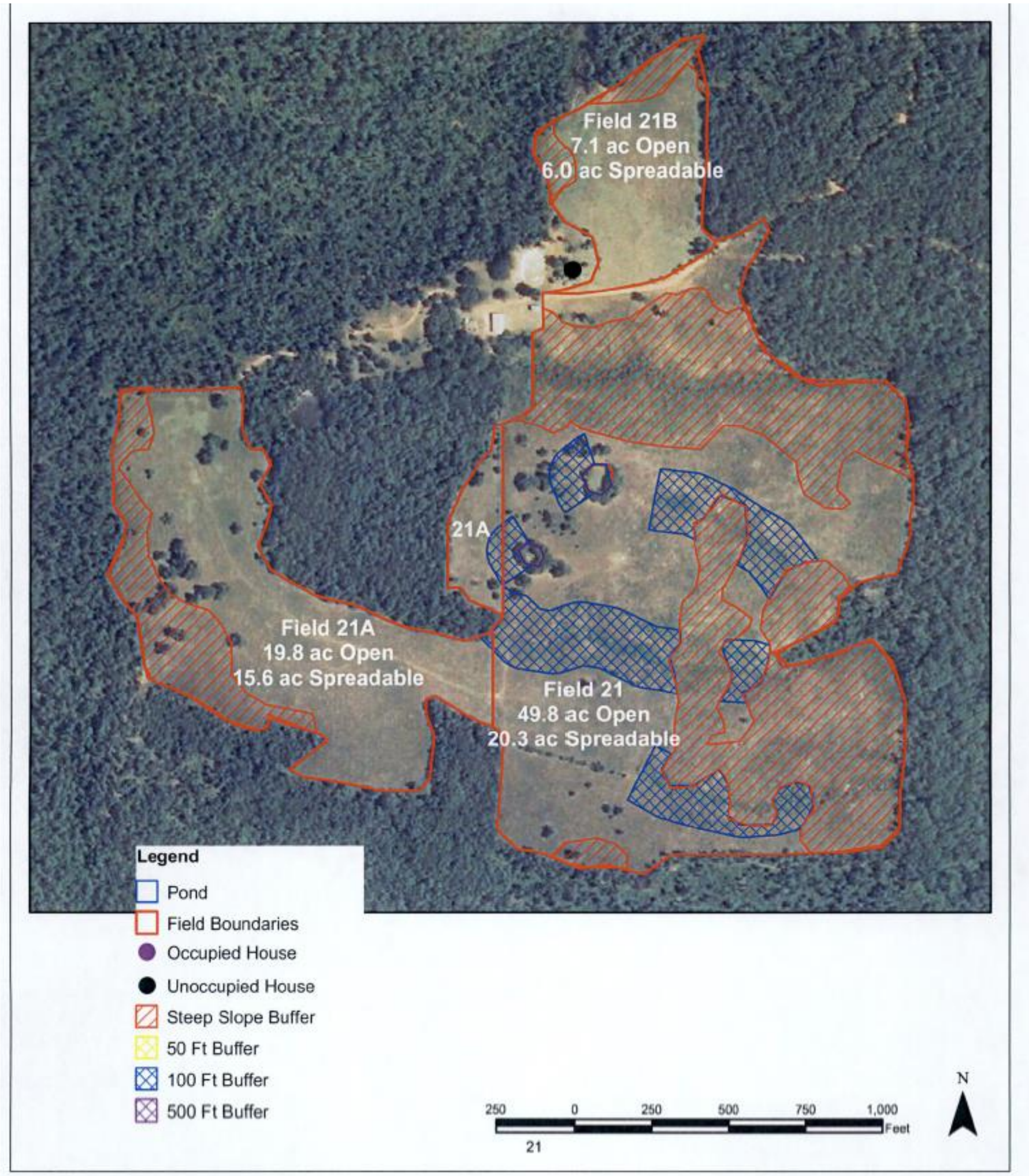

FIGURE 4 EXAMPLE OF A FIELD 21A, WHICH IS CONTORTED AND INAPPROPRIATE FOR WASTE APPLICATION

Evaluation of Risk Due to Excess P Application

The Arkansas P-index. The approved Nutrient Management Plan indicates that virtually all fields are intended to receive waste applications greater than the crop P-requirements, and some will exceed both the Nitrogen and Phosphorus requirements of the crop. To stay in compliance with the Waste Regulations, the Nutrient Management Plan (NMP) used the Arkansas Nutrient Management Planner 2009 PI (Beta draft ver 022512106) to evaluate Phosphorus Index (PI). I requested a copy of this Beta version from Karl VanDevender (UA Cooperative Extension) to evaluate their result and was told by VanDevender, it is not publicly available, but that the version I use (2009 PI (ver 6/25/2013) is still the recommended version.

I compared results from the two versions and noted the Beta version seems to use the same algorithm as the 2013 version but has increased complexity, allowing the user to include application of waste from different sources and application in different seasons all in the same spread sheet. My testing of the Beta version was not exhaustive, however.

The Beta version sums the PIs from separate seasons to give a single value for the year, whereas the older version considers each season-source combination separately. I further noted that the estimate of PI in either version is dependent primarily on waste characteristics (P-content and Water Extractable P-content) and application rate, slope and pasture use combinations, and season of application). Soil test phosphorus (STP) status has a small effect on PI, but when PI changes drastically, this impact is clear.

Note neither the API in the 2009 version nor the current Beta version considers the additional risk due to karst, proximity to streams, or the presence of gravel bars or other conduits that would transmit waste directly to the stream through a groundwater pathway.

In writing the NMP, the planner used the API to set waste application rates that keep the PI in the Low to Medium range for each field. They analyzed only summer and spring seasons, although some winter application was reported each year under the previous permit, and winter application is the most Risk-prone season for waste application. The planner considered each field separately to set a maximum application rate for that field. This seems an acceptable approach to set upper limits for each field, but is not really a plan for distribution of waste.

The API analysis presented in the Permit Application is based on the most recent waste analyses and the most recent soil tests (about 2 years ago). The planner assumed in the API that all fields would be managed as rotational grazing at the highest possible forage yield and the best ground cover condition possible for the area. Many of these assumptions are not correct and certainly do not represent a worst-case assessment.

Arkansas PI Shortcomings (API). The API, as used in planning the NMP, has several severe shortcomings. First, although it purports to address risk of degrading water quality, it does not address some important factors affecting transport to the receiving waters. In reality it only compares the source term of the Index not the risk of polluting the receiving waterbody. The PI was derived from a series of rainfall simulator studies of runoff produced from application of a synthetic rainstorm on a small area of soil. This makes it very sensitive to application rate and characteristics of the waste, but not to many other physical factors such as karst, surface drainage, gravel bars, or management factors that affect delivery to the stream.

To the extent that different soil types have been evaluated, the PI may account for the effect of varying soil type. Because it was developed from very short-term, micro-studies, it cannot address the larger-scale effects of season, groundwater pathways, or weathering, leaching, or eroding of enriched soils.

The API does not address the risk due to increased runoff due to soil compaction from livestock hoofs or increased drainage efficiency due to subsurface gravel bars, karst geology, or increased drainage efficiency through surface or subsurface features.

Another limitation is the API's treatment of erosion. Erosion is a very important mechanism for transporting Phosphorus. The P-content of eroded soil can be so high it can far exceed that predicted by the API. This is particularly important when assessing risk due to poor grazing management or overstocking.

Conclusions Regarding Overall Planning of NMP

The assessment of an upper limits for waste application rates from each source on each field in two seasons of the year is a reasonable approach to setting guidelines for each field, but some of the choices for parameters are not correct. For example, under Regulation 5 soil testing is only required once in five years, but STP it is likely to increase drastically in that time. A glaring error is the designation of "Rotational Grazing" as the use of each pasture. This assumption is based on a very high level of grazing management, where cattle are moved frequently from paddock to paddock to assure the forage is harvested uniformly and has ample opportunity for regrowth before cattle are returned. It gives the lowest PI of all options in the PI spread sheet. Observations by local residents (Figure 5) indicate some fields are overstocked from time to time, and grass cover is not maintained in the most healthy, protective state at all times. An aerial view of Fields 2 and 3 (Figure 6) shows the eroded condition of these fields in mid-March 2016. In this case, Field 2 is among those that should not be included in the Permit.

Waste Application History

The history of waste applications taken from C&H annual reports to ADEQ is shown in Table 2 and

Table 3. Approximately 79 percent of all the waste in three years was applied to six fields, and Field 7 received the most waste even though it was not used in 2016. Application rates on a per-acre basis are shown in

Table 3 Note the highest rates were applied in fields 1, 7, 9, 10, 12, 15, and 17.

Table 2 History of waste application in fields 1 – 17 and the percent of waste applied

	Area	2014	2015	2016	
Field	acres	Gallons Applied x1000			% of waste
1	7.3	46	48	78	2.1%
2	6	23	51	48	1.5%
3	15.2	118	60	108	3.4%
4	6.8	29	39	57	1.5%
7	64.3	396	985	0	16.5%
8	8.6	25	48	84	1.9%
9	35.5	104	216	480	9.6%
10	29.3	249	483	303	12.4%
11	14.2	51	15	132	2.4%
12	11.4	48	93	156	3.6%
13	50.9	454	429	354	14.8%
14	8.1	73	60	75	2.5%
15	37.5	401	187	339	11.1%
16	15.2	56	63	93	2.5%
17	31.9	295	448	462	14.4%
Average		2367.4	3225.0	2769.0	100.0%

Table 3 Application rates to fields 2014 through 2016

Field	2014	2015	2016	Av rate
1	6.30	6.58	10.68	7.85
2	3.77	8.50	8.00	6.76
3	7.77	3.95	7.11	6.27
4	4.24	5.74	8.38	6.12
7	6.16	15.32		10.74
8	2.91	5.58	9.77	6.09
9	2.92	6.08	13.52	7.51
10	8.51	16.48	10.34	11.78
11	3.59	1.06	9.30	4.65
12	4.21	8.16	13.68	8.68
13	8.91	8.43	6.95	8.10
14	9.01	7.41	9.26	8.56
15	10.70	4.99	9.04	8.24
16	3.68	4.14	6.12	4.65
17	9.24	14.04	14.48	12.59
Average	6.13	7.76	9.76	

FIGURE 5 PHOTOGRAPH OF FIELD 2 SHOWING POOR MANAGEMENT OF FORAGE PRODUCTION AND GRAZING. PHOTO BY BRWA TAKEN FEBRUARY 17, 2017.

FIGURE 6 AERIAL VIEW OF FIELDS 2 AND 3 SHOWING COW TRAILS AND OTHER EVIDENCE OF ERODIBLE CONDITIONS.

The Problem of Nutrient Imbalance from applying Hog Waste to Agricultural Fields

The final stage of treatment of manure wastes is the application of waste to the land as fertilizer to utilize the nutrients in an actively growing crop. Hog manure is rich in Nitrogen, Phosphorus, and Potassium, which are all essential plant nutrients, and organic matter that is beneficial to the soil. There may be as much as 60% loss of soluble Nitrogen during storage in the pond due to volatilization of ammonia and denitrification (Chastain, 1999). Consequently, when the waste is applied to a hay crop, the waste is relatively high in phosphorus and low in nitrogen relative to crop needs.

Because a hay crop needs fertilizer in a ratio of 8: 1: 1 (N: P: K), but the hog manure has a ratio of about 1: 1: 1, the crop leaves behind most of the P that is applied. With continued application of manure, the soil test P (STP) will increase rapidly. Studies have shown that on average STP increases about 20 lb for every 100 lb of excess fertilizer. Finally, it has been well documented that the concentration of P in runoff increases with STP, although the actual rate of increase depends on the soil (Vadas, 2005).

TABLE 4 SOIL TEST P (STP) IN FIELDS 1 THROUGH 17 AND PERCENT INCREASE.

Field	2012	2014	2015	increase
1	83	45	95	14%
2	72	67	108	50%
3	42	79	89	112%
4	50	46	75	50%
7	178	94	89	---
8	46	80	82	78%
9	52	53	82	58%
10	69	31	72	5%
11	57	27	62	9%
12	19	72	88	363%
13	48	23	86	78%
14	52	15	75	63%
15	15	29	72	380%
16	48	50	68	42%
17	50	21	86	72%
Average	58.7	48.8	81.9	

The effect of continued application of P-rich waste from 2012 through 2015 can be seen in the buildup of soil P in the C&H fields shown in Table 4 and in Figure 2 of the Appendix. In a three-year period, STP increased as much as 380%. The P-enriched soils will continue to be a source of P to the river for many years. This is an important reason to require annual soil testing.

The problem of Soil-P-buildup is virtually assured in these fields because the crop is only harvested by grazing, which removes very little P. Most of this nutrient is consumed by cattle then redeposited in shady lounging areas and riparian areas. This exacerbates the water quality issues, first because much of the manure is deposited in environmentally sensitive areas and second because the P distribution is not optimal for tor the crop. As can be seen by the STP results in Table 4, these fields have more than enough P for grazing.

Use of the API to show risk due to excessive grazing and increases in STP

When the planner prepares the NMP for waste application each year, he/she takes the most recent waste analysis and uses that in the planner spread sheet. This seems logical, but the procedure has a few pitfalls. Most important is that the most recent single value for waste nutrient content may not be the most accurate. Obtaining a good, representative sample is difficult because it requires either mixing the contents of the pond or sampling at multiple locations and depths. Such guidance has not been presented to the typical waste system operator. Another approach would be to sample the waste during application by sampling directly from the effluent from the waste pump. This is not practical because the waste analysis typically takes a week or more, time that is not available with this procedure.

A better procedure would be to keep a record of all waste analyses conducted through the years of operation and average them, dropping any outliers. The record of analyses for Waste Ponds 1 and 2 are shown in Table 5 and Table 6.Table 5. Note the relatively stable results after the pond was in operation for a full year. Subsequent analyses using API in this section assume average concentrations of waste nutrients, from Table 5 and Table 6.

TABLE 5 WASTE POND 1 ANALYSES FOR WASTE NUTRIENTS

	Waste Pond 1 lb per 1000 gal				
Date	N	K2O	P2O5	WEP	EC
	--------- pounds per 1000 gallons -------------				μS/cm^2
9/24/2013	12.6*	10.6*	10.54*	1.15*	
4/10/2014	22.4	14.4	18.1	1.6	
4/17/2015	20.1	13.6	4.8*	1.4	13580
1/5/2016	26.5	13.2	32.1	1.7	11840
5/27/2016	21.6	14.1	15.7	1.2	12780
Average	22.65	13.83	21.97	1.48	12733
***Outlier not included in average**					

TABLE 6 WASTE POND 2 ANALYSES FOR WASTE NUTRIENTS

	N	**K2O**	**P2O5**	**WEP**	**EC**
	--------- pounds per 1000 gallons ----------				μS/cm^2
9/24/2013					
4/10/2014	11.6	12.3	3	0.7	
4/17/2015	15.2	10.4	7.9	0.7	8710
1/5/2016	8.7	7.9	1.8	0.5	6710
5/27/2016	11.8	10.7	3.1	0.76	8100
Average	11.83	10.33	3.95	0.67	7840

I used the API Planner to show the effect of continued use of these fields for waste application and the impact of minor variations in management. Table 7 shows these effects. The ***base scenario*** is the same as used by the planner for API, based on March – June applications from Waste Pond 1, with rotational grazing and 95-100% grass cover. In the Permit Application, the planner assumed either 5,000 gallons/acre or 9,500 gallons/acre on specific fields.

Results of my analysis are shown in Table 7. Analysis of the ***base management scenario*** gave PI values varying from 17 (Low) to 46 (medium). Changing the management from the ***base*** (Rotational Grazing) to ***base + Conventional High Rate Grazing*** (stocking rate > 0.75 au/acre) increased the PI to a range of 27 (low) to 61 (Medium). Increasing STP by 50%, a scenario that is likely within the next few years, increased the range to 34 (medium) to 103 (very high). This effect is probably underestimated by API.

Increasing application rates, not shown here, has even more effect than that of stocking rate or STP because PI is very sensitive to application rate.

TABLE 7 IMPACT OF GRAZING MANAGEMENT AND STP INCREASE ON PHOSPHORUS INDEX

Field	Base gal/ac x1000	Base + (Rotional grazing)	BASE + conv. grazing	BASE +50% increase STP and conv. grazing
Field 1	5	17	27	34
Field 2	5	20	44	56
Field 3	9.5	47	49	69
Field 4	5	17	38	50
Field 5 new	9.5	43	45	65
Field 6 new	5	19	30	38
Field 7	9.5	47	49	69
Field 8	9.5	25	27	38
Field 9	9.5	46	48	68
Field 10	9.5	24	26	37
Field 11	5	16	36	47
Field 12	9.5	47	49	69
Field 13	9.5	28	61	86
Field 14	9.5	27	59	84
Field 15	9.5	26	59	83
Field 16	9.5	44	46	65
Field 17	9.5	28	61	86
Field 6a new	5	19	29	37
Field 7a	9.5	40	41	61
Field 8a	9.5	46	48	68
Field 9a	9.5	42	44	64
Field 10a	9.5	49	51	70
Field 13a	9.5	27	59	84
Field 13b	9.5	25	57	81
Field 15a	5	27	36	36
Field 15b	9.5	26	57	82
Field 18	9.5	22	35	51
Field 19	9.5	24	38	54
Field 20	9.5	26	57	82
Field 21	5	17	35	51
Field 21a	5	18	37	53
Field 21b	9.5	23	52	77
Field 22	5	14	31	43
Field 23	9.5	34	70	103
Field 24	9.5	42	44	64
Field 32	9.5	41	42	62
Field 33	5	26	27	37
Field 34	9.5	42	43	63
Field 35	9.5	22	34	51
Field36	9.5	49	65	99

Results of the API analysis are summarized in Table 8. Using the base scenario taken from the C&H Regulation 5 Application, 26 fields are in the Low-Risk category. Just changing to Conventional grazing increases the number of medium fields to 32, and moves one field into the High Risk zone. Increasing STP by 50% moves 16 more fields in to the High Risk zone and one field into the Very High Risk zone.

TABLE 8 INCREASE IN API (RISK) DUE TO GRAZING AND STP INCREASE

Scenario	Rotational Grazing	Conventional Grazing	STP Increase 50%
Number of fields in Low Risk	26	7	1
Number of fields in Medium Risk	14	32	21
Number of fields in High Risk	0	1	17
Number of Fields in Very High Risk	0	0	1

Conclusions concerning API

Use of the API spreadsheet shows the effect of grazing management, application rate and increase in STP. The effects are probably understated, but clearly the fields that have high gradient are most susceptible to these factors. API does not recognize the impact of erosion as well as it should, and therefore, underestimates the impact of poor grazing management.

Overall Conclusions

1. Design capacity of holding pond is adequate for a discharge permit. Management changes would be necessary to achieve a “no discharge” capability. Freeboard and stormwater capacity should be increased to contain Probable Maximum Precipitation.

3. A synthetic liner with leakage detection system should be required, not optional.

4. Soil testing should be required annually instead of once in five years.

5. Thorough mixing should be required before pumpout, and a running average concentration should be used as criteria for planning waste application rates.

6. The Nutrient Management Plan has the following deficiencies or errors:

a. Assumptions of forage production are too high for the area
b. Hay is not harvested from all fields so the nutrients are not removed efficiently
c. Assumptions of rotational grazing are not correct. In fact, grazing practices in the area are not as beneficial as planned, estimates of API are systematically low.
d. STP is rising on most fields increasing the longterm impact on receiving waters. This is not accounted well in the API Planner.
e. A few fields get most of the waste as indicated by historical record.
f. The highly contorted fields added for this permit application are likely to be managed incorrectly as it will be very difficult for a spray rig to follow the buffer boundaries. This effect is further amplified by the steep slopes and erosion that is likely under grazing management, particularly in times of stress, like drought or heavy rain.
g. Increasing STP will reduce the fields’ capacity to take waste.
h. The effects of compaction, due to grazing are not recognized.
i. Karstic geology and gravel bars in the soil have an unrecognized effect on the impact of waste application.

f. Expanding the number of fields is good, but the upland fields are so tortuous that the chance of applying to buffer areas is very high. Some fo these fields have very high slopes and very thin soils that cannot meet the assumptions in the API.
g. the API does not account for erosion of pasture effectively - erosion is very effective in transferring P to receiving waters.

5. Although the rates of waste application are acceptable in the short term, long-term use will cause eutrophication in the receiving waters, specifically the Buffalo River.

References

Sandy Formica. 2002. Land Application of Accumulated Solids from Liquid Waste Systems Demonstration Project. Arkansas Department of Environmental Quality.

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APPENDIX

Supporting tables and Graphs

Table 10–4 Criteria for siting, investigation, and design of liquid manure storage facilities

Risk→ / Vulnerability ↓	**Very high** <1,500 ft from public drinking water supply wells; **OR** <100 ft from any domestic well or Class 1 stream	**High** Does not meet Very High Risk criteria; **AND** Recharge areas for Sole Source aquifers; **OR** 100 to 600 ft from unconfined domestic water supply well (or where degree of aquifer confinement is unknown) or Class 1 stream	**Moderate** Does not meet High Risk criteria; **AND** 600 to 1,000 ft from unconfined domestic well (or where degree of aquifer confinement is unknown) or Class 1 stream; **OR** <600 ft from unconfined nondomestic water supply well (or where degree of aquifer confinement is unknown) or Class 2 stream	**Slight** Does not meet Moderate Risk criteria; **AND** >1,000 ft from unconfined domestic well (or where degree of aquifer confinement is unknown) or Class 1 stream; **AND** >600 ft from unconfined nondomestic water supply well (or where degree of aquifer confinement is unknown) or Class 2 stream
Very high Large voids (e.g., karst, lava tubes, mine shafts); **OR** Highest anticipated ground water elevation within 5 ft of invert; **OR** <600 ft from improperly abandoned well*	**Evaluate other storage alternatives** * (or properly seal well and reevaluate vulnerability)	**Evaluate other storage alternatives** * (or properly seal well and reevaluate vulnerability)		
High Does not meet Very High Vulnerability criteria: **AND** Bedrock (assumed fractured) within 2 ft of invert; **OR** Coarse soils/parent material (Permeability Group I soils as defined in AWMFH, always including GP, GW, SP, SW); **OR** Highest anticipated groundwater elevation is between 5 to 20 ft below invert; **OR** 600 to 1,000 ft from improperly abandoned well*		**Synthetic liner required** * (or properly seal well and reevaluate vulnerability) No additional site characterization required	**Liner required** * (or properly seal well and reevaluate vulnerability) Specific discharge $\leq 1\times10^{-6}$ $cm^3/cm^2/s$ No manure sealing credit Earthen liner design includes sampling and testing of liner material (Classification, Standard Proctor compaction, Permeability)	**Liner required** * (or properly seal well and reevaluate vulnerability). Specific Discharge $\leq 1\times10^{-6}$ $cm^3/cm^2/s$ No manure sealing credit Earthen liner design includes sampling and classification testing of liner material Published permeability data and construction method specifications may be used
Moderate Does not meet High Vulnerability criteria; **AND** Medium soils/parent material (Permeability Group II soils as defined in AWMFH, usually including CL-ML, GM, SM, ML); **OR** Flocculated or blocky clays (typically associated with high Ca); **OR** Complex stratigraphy (discontinuous layering); **OR** Highest anticipated ground water elevation is between 21 to 50 ft below invert; **OR** 600–1,000 ft from improperly abondoned well*	**Evaluate other alternatives or synthetic liner as allowed** Local regulations may apply Consult with area engineer	**Further evaluate need for liner** Specific discharge $\leq 1\times10^{-6}$ $cm^3/m^2/s$ No manure sealing credit Earthen liner/no liner design includes sampling and testing of liner/in-place material (Classification, Standard Proctor compaction/in-place density, Remolded/ Undisturbed sample Permeability)	**Further evaluate need for liner** Specific discharge $\leq 1\times10^{-6}$ $cm^3/cm^2/s$ No manure sealing credit Earthen liner/no liner design includes sampling and testing of liner/in-place material (Classification, Standard Proctor compaction/ in-place density, Remolded/Undisturbed sample Permeability)	**Further evaluate need for liner** Specific discharge $\leq 1\times10^{-6}$ $cm^3/cm^2/s$ No manure sealing credit Earthen liner/no liner design includes sampling and classification testing of liner/ in-place material + in-place density Published permeability data and construction method specifications may be used
Low Does not meet Moderate Vulnerability criteria; **AND** Fine soils/parent material (Permeability Group III and IV soils as defined in AWMFH, usually including GC, SC, MH, CL, CH); **AND** Highest anticipated ground water elevation is >50 ft below invert		**Further evaluate need for liner** Specific discharge $\leq 1\times10^{-6}$ $cm^3/cm^2/s$ No manure sealing credit Earthen liner/no liner design includes sampling and testing of liner/ in-place material (Classification, Standard Proctor compaction/ in-place density, Remolded/ Undisturbed sample Permeability) Scarify and recompact surface to seal cracks and break down soil structure as appropriate	**Liner not required** Specific discharge $\leq 1 \times 10^{-6}$ $cm^3/cm^2/s$ Field classification and published permeability data may be used Construction method specifications may be used Scarify and recompact surface to seal cracks and break down soil structure as appropriate	

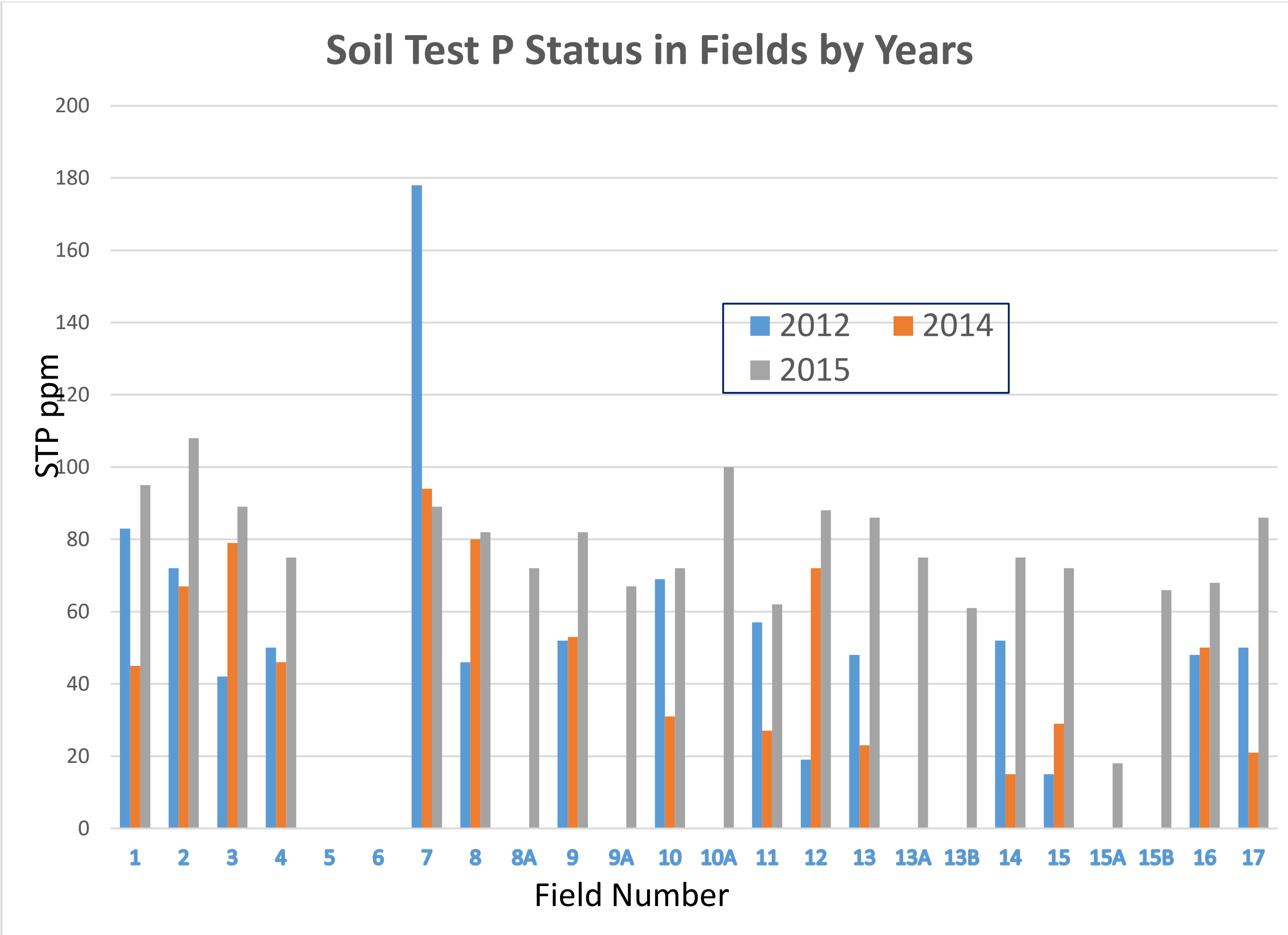
*See local regulations

NRCS Criteria for siting, investigation, and design of liquid manure storage facilities (Table 10-4 of AWMH)

Comparison of state liner design rules for selected states

State	Year	Rule*	Seepage at 6 ft depth
Georgia	2002	391-3-6-21. maximum of 1/8 inch per day (3.67 x 10-6 cm/sec). (or if) located within significant ground water recharge areas must be provided with either a compacted clay or synthetic liner such that the vertical hydraulic conductivity does not exceed 5 x 10-7 cm/sec	3394 gal/ac-day Or 1108 gal/ac-day
Iowa	2006	327 IAC 19-12-5. (a) maximum specific discharge of 1/16 in /day (1.8x10 -6 cm/ sec).	1697 gal/ac/day
Ohio	2010	901:10-2-06. A minimum of three feet of *in situ* soils with a hydraulic conductivity of 1 x 10-7 cm/sec or (b) soil liners designed and constructed using procedures in section 651.1080 of the USDA, Ohio NRCS FOTG CP Standard 521 D. (10) (a) Manure storage ponds or manure treatment lagoons may be constructed within a karst area provided that the facility is designed to prevent seepage of manure to groundwater.	277 gal/ac/day
Missouri	2012	CSR 20-8.300. A. The design permeability of the basin seal shall not exceed 500 gallons per acre per day in areas where potable groundwater might become contaminated or when the wastewater contains industrial contributions of concern. Design seepage rates up to 3,500 gallons per acre per day may be considered in other areas where potable groundwater contamination is not a concern	500 gal/ac/day Or 3,500 gal/ac/day
Iowa	2000	IAC 65.15(11) . The percolation rate shall not exceed 1/16 inch per day at the design depth of the structure.	1,697 gal/ac/day
Nebraska	2000	130-8-007. materials and construction methods so that percolation does not exceed 0.13 inches per day (3.82 x 10-6cm/sec).	3,530 gal/ac/day
Oklahoma		35:17-4-11. Hydraulic conductivities of no greater than I x 10-7 cm/sec. …(B) At least four (4) representative undisturbed core samples, one from each corner of the waste retention structure bottom Minimum thickness of one and one half (1.5) feet. For Maximum hydrostatic head of 10.5 feet	462 gal/ac/day
North Carolina	2006	15A NCAC 02T .1005 . (IF) less than four feet above bedrock shall have a liner with a hydraulic conductivity no greater than 1 x 10^{-7} centimeters per second.	462 gal/ac/day
NRCS FOTG PART 651 Chapter 10* (Table 10-4)	2010	**VERY HIGH RISK - VERY HIGH VULNERABILITY (KARST) –** evaluate other alternatives **HIGH RISK AREA – HIGH VULNERABILITY.** – synthetic liner required (or seal and reevaluate vulnerability) **HIGH RISK AREA – MODERATE VULNERABILITY** – specific discharge 1 x 10-6 cm/sec (no manure sealing credit)	no discharge no discharge 6500 gal/ac/day with no credit for manure sealing
10 State Standard**	2005	seal shall not exceed the value derived from the following expression where L equals the thickness of the seal in centimeters. k = 2.6 x 10-9L the "k" obtained by the above expression corresponds to a percolation rate	500 gal/ac/day

* Extracted from Table 10-4 (page 10-26) Criteria for siting, investigation, and design of liquid manure storage facilities, based on Risk and Vulnerability.
**Recommended Standards for Wastewater Facilities. 2004 Edition. Health Research Inc.



Soil Test P Status in Fields by Years
STP ppm
200
180
160
140
120
100
80
60
40
20
0
2012
2014
2015
1
2
3
4
5
6
7
8
8A
9
9A
10
10A
11
12
13
13A
13B
14
15
15A
15B
16
17
Field Number