Review of C & H Hog Farm Animal Waste Management Plan

Storage Pond Design

and

Nutrient Management Plan

Final Report

to

Earthjustice

M. D. Smolen, Ph.D.

Lithochimeia, LLC

January 2, 2014

Review of C & H Hog Farm Animal Waste Management Plan

Background

Lithochimeia was retained by Earthjustice for the following scope

> "(to) …"review all documents associated with the permit application as well as pertinent geological, hydrological, and soils information to determine if the best available technology is being employed to manage wastes from the hog facility and the probability of discharge from the site. The review will address the design and proposed management of waste storage ponds on the farm as well as the location and proposed management of waste application areas. Special attention will be paid to the use of the Arkansas P-Index in this NMP, the relationship to EPA CAFO guidance, the design of waste storage and distribution systems, and the implications thereof."

Project Director for this effort is Michael D. Smolen, Ph.D. Dr. Smolen has more than 35 years' experience in water quality and water quality management as affected by agricultural waste management, crop management, and other aspects of watershed management. He has specific expertise in hydrology, water chemistry, animal waste management, and agricultural production systems. In 1994 he received the EPA Regional Administrator's Environmental Excellence Award for Outstanding Service in Implementing the Requirements of the NPDES Region 6 CAFO General Permit. Smolen's C.V. is attached. Material in this report is based on Smolen's site visit to the Big Creek area, public documents relating to the C&H permit application, and material from the professional literature.

Part I of this report addresses the design and operation of the waste storage system at C & H Hog Farm as detailed in the Notice of intent (NOI), the permit approval, and subsequent inspection documents. This report seeks to develop a perspective concerning the adequacy of design procedures used at C & H and protection of Big Creek.

Part II addresses the nutrient management plan presented in the NOI for application of waste water and nutrients to agricultural fields near the C&H facility.

Description of the Waste Treatment System.

The Animal Waste System, as designed by DeHaan, Grabs & Associates, LLC (DHG) for C&H Hog Farm, consists of the following components: (1) concrete tanks under the floor of the farrowing building and the gestation building, (2) Waste Storage Pond #1 (WSP#1), Waste Storage Pond #2 (WSP#2), 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 content of the tanks includes recharge water, added to keep the wastes moveable, and wash water used in sanitizing the animal pens. The tanks have capacity to hold waste and wash water for at least three to five weeks. On a schedule of three to five weeks, the plug is pulled on the tanks allowing the contents to drain by gravity into WSP#1. When WSP#1 fills up, it spills over through a concrete spillway to WSP#2. This arrangement allows much of the solids to settle in WSP#1 (biosolids) and supernatant liquid (liquid manure) to reside in WSP#2.

The difference between Waste Storage Ponds and Animal Waste Lagoons. The waste storage ponds are designed to function strictly as waste storage, i.e. not as animal waste lagoons. An animal waste lagoon would always have water and solids in it, allowing it to function as a treatment system. In an animal waste lagoon, the solids settle to the bottom, where digestion and some denitrification occur,

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gradually reducing the quantity of organics, and the quantity of nitrogen. Typically the solids accumulate as sludge in the lagoon for 20 years or more. The sludge must eventually be removed and disposed as biosolids. These biosolids are high in organic matter and phosphorus. The supernatant liquid of an animal waste lagoon is removed by evaporation and by pumping and land application as needed to maintain the required retain storage volume to prevent discharge.

To operate as a Waste Storage Pond, the ponds must be pumped down to about one foot depth and the contents applied to designated crop fields. As WSP#1 accumulates most of the solids, it must be agitated each time it is pumped down 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 in WSP#1, such that the storage volume will decline, and a large disposal problem will result.

The importance of proper maintenance of waste storage ponds. 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 ofthe 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.

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

The final stage of treatment of manure wastes is the application of the waste or wastewater to the land as fertilizer for 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. However, because the waste system uses water to clean hog barns and flush the waste into an anaerobic storage pond, the waste is highly diluted. Further there may be as much as 60% loss of soluble Nitrogen during storage in the pond and an additional 50% loss due to volatilization of ammonia if applied to the land surface (Chastain, 1999). The result is that 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 about 80 to 90% 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-. 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).

The Nutrient Management Plan (NMP) contained in The C&H NOI estimates the annual fertilizer-P production (expressed as P_2O_5 in wastes as) to be 71,198 lb. If applied evenly to the 630 acres designated in the NOI, the average application rate would be 113lb/ac. Considering that the fertilizer-P recommendation from the UA Soil Testing and Research Lab was zero application for almost every field, there will be excessive application and STP build up. In addition, as discussed in Pat II of this report, 70% of the waste is designated for 30% of the land, so that severe overloading can be expected.

Part I: Review of C&H Permit Application – Waste Storage Pond Design

C & H filed NOI for coverage under the NPDES General Permit ARG590000 on 6/25/2012 and received a letter of approval from ADEQ 8/3/2012. This is the first hog farm covered by the Arkansas General Permit (Permit Number ARG590001). The operation is specified for 2503 swine of over 55 lb (gestation barn) and 4000 swine under 55 lb (farrowing barn). The permanent population of 2503 consists of 2500 breeding sows and 3 boars.

Review of Storage Pond Design

We checked all calculations for waste storage and waste generation by DeHaan, Grabs & Associates, LLC (DHG) and found them to be essentially correct based on permit application details. The calculations are summarized and explained below.

The two hog barns are constructed with slotted floors underlain by concrete lined pits for manure storage. Each pit has a plug that can be pulled to allow manure slurry to drain by gravity into Pond 1. When fully populated, the two barns (gestation and farrowing) will produce about 1020 ft^3/day of waste slurry. The gestation barn pit is designed to be drained every 5 weeks and the farrowing barn every 3 weeks. At this frequency, each pit should be approximately 30% full when the plugs are pulled. Storage volume of pits and waste ponds together are designed to hold 270 days manure, waste water, and rainfall without overtopping. The ADEQ requires 180 days storage. Waste slurry generated in 180 days would be expected to total about 185,000 ft^3 (1.38 million gallons). Storage in Ponds 1 and 2 is calculated without considering leakage or evaporation losses. These calculations are summarized in Table 1 below.

Table 1 summary of waste and wastewater generation

From NOI NMP	ft^3	gallons	Annual total (gallons)
180 day waste	97,979	732,934	
180 day spillage & wash water	19,596	146,588	
total waste 180 days	117,575	879,522	1,759,044
Recharge in 180 days	65,880	492,817	
Total waste & recharge 180 days	183,455	1,372,339	2,744,678
WSP1 rainfall	19,119	143,020	
WSP2 rainfall	32,324	241,800	
Total Storage-waste and rain (not including design storm)	234,898	1,757,159	3,514,318

The waste ponds are designed to operate in series, i.e. all wastewater enters Pond 1 until it is full. Pond 1 is designed with a spillway into Pond 2 and, therefore, acts as a settling basin, accumulating more solids than Pond 2. Water in Pond 2 should be clearer than Pond 1. There is no reinforced spillway outlet

from Pond 2. If the embankment of Pond 2 were overtopped due to unusual weather or poor management, there would be erosion of the embankment with possible catastrophic failure. The waste storage ponds are built on the side of a hill with 10% slope, making stability of the embankment structure critical. The ADEQ requires capacity to contain a 25-yr 24-hr storm with 1 ft freeboard in each pond. The 25-yr 24-hr storm is approximately 7 inches depth. The freeboard is necessary as multiple storms a little smaller than the design storm could occur before the pond can be pumped down.

Pond 1 overflows into Pond 2 at 9.1 ft (depth to spillway), with 1.6 ft remaining to the top of embankment. As-built plans show actual capacity to spillway is about 90,000 ft^3, or 90 days of storage.

Pond 2 is designed for a maximum depth of 11.7 ft with 1 ft freeboard. As-built plans show maximum operating depth 10.8 ft or capacity of about 225,000 ft^3. Total capacity for the two-pond system as built is about 315,000 ft^3, or 2.36 million gallons, a little less than designed, but considerably more than required by Arkansas rules.

Opinion: Waste Storage Pond Sizing

Our estimate of waste produced is consistent with that of the permit design engineers, DeHaan, Grabs, & Associates. Neglecting rainfall, leakage, and evaporation, Pond 1 would take about 15 weeks to fill at the waste generation rate projected. Again neglecting rainfall, leakage and evaporation, we would expect to fill Pond 1 and reach a depth of about 6 ft in Pond 2 in 180 days. Our analysis confirms the following points:

- The waste holding ponds are sized appropriately for at least 180 days of storage and a 25-yr 24-hr design storm. Discharge is permitted if a storm exceeds the design storm, but no emergency spillway is provided in case such discharge should occur.
- Waste storage volumes are calculated correctly, based on reasonable waste generation spillage, and pit recharge rates. No recycling of water from the waste storage ponds is shown.
- Rainfall and evaporation estimates match the requirements for Newton County, AR

Review of SPAW Model Analysis

As required in the AR rules, the designers have analyzed the likelihood of this waste system overtopping using the SPAW model. Their analysis uses 47 years of rainfall data from a nearby weather station. The data used are appropriate for this analysis. It is unlikely the result would be different if 100 years of historic data had been available.

SPAW analysis by DHG suggests the two-pond system will not overflow if the wastes are pumped out every six months. Their simulation shows annual maximum pond depth to range from 7.0 to 10.8 ft in Pond 2, with average maximum depth 8.99 ft. The maximum allowable depth in Pond 2 is 11.7 ft (Sheet 15 of DGH Plan sheets). Pages 8 – 25 of Certification and QA-QC Section show the SPAW printout. Area of the pond(s) used in the SPAW analysis is shown as 0.70 acres., but the "As-Built" drawings show the top area of Pond 2 as 0.76 acres and Pond 1 is about 0.5 acres for a total of about 1.2 acres. In addition there is also some contributing area from berms surrounding the two ponds that must be considered. Therefore, there should be something more like 1.5 acres considered for rainfall input to the system, or twice the area shown as model input. This is important because all model calculations of water balance are computed in volumes (acre-ft) that are sensitive to the area factor.

Maximum volume used in SPAW is shown as 5.66 acre-ft (af), which isr approximately the volume of Pond 2 (about 5.32 af depending on the actual depths considered for full and empty). Total volume of both ponds should be about 7.40 af.

At the end of the SPAW printout, total values for sections of the water balance are presented on an average monthly basis. The total of all precipitation inputs is shown as 1.33 af. If this is adjusted for area (0.7 acres), the precipitation amount would be about 22.8 inches, or about ½ the average annual precipitation for the area (43.7 inches at Marshall, AR). The model also considers water input from Bank Runoff, Seepage from Banks, and the waste input from the barns and the water losses from evaporation, seepage through the liner, and pump down every 6 months. The modeler may have adjusted some of these inputs and outputs to reflect the system accurately, but it is difficult to determine this from the information presented.

The SPAW printout shows good water balance (this is an important check the model: on average water inflow must equal water outflow). According to the model, average annual input (precipitation plus wastewater) is about 10.45 a-f. Of this, 73% is pumped out and applied to fields, 11.7% evaporates, and 14.6% leaks.

Opinion: SPAW Modeling

I would recommend that the complete details of the SPAW simulation be requested to check the validity of the modeler's conclusion that the embankment will not be overtopped. The SPAW simulation is particularly important for two reasons; (1) it is used to determine if the waste storage ponds can overflow, and (2) the design assumes there will NEVER be an overflow event. If overflow occurrs, catastrophic failure of the embankment is likely, because the design does not include a stabilized emergency spillway

Review of Pond Liner Design

The waste storage ponds were designed based on the United States Department of Agriculture Natural Resource Conservation Service (NRCS) Field Office Technical Guide (FOTG) and Chapter 10 of the Agricultural Waste Management Field Handbook (AWMFH) (USDA-NRCS, 2009). These NRCS publications offer design and testing procedures approved in most states, including Arkansas) and commonly used in the agricultural industry. However, the NRCS FOTG and AWMFH defer to the states for specific requirements for seepage and/or liner design.

The NOI shows soil profiles from 3 borings, and indicates that soils from the 7 ft to 11 ft zone in two of three borings were selected for use in constructing a compacted clay liner. The AWMFH indicates the soils should be tested for permeability, particle size, and the Plasticity Index (PI). Test results for PI are presented in the NOI, and results from one sample tested for permeability is presented in the QA-QC Certification document. PI for the selected soils range from 41 to 55 and soil classification is indicated as group III or IV. No particle size test is shown. The permeability was shown to be 5×10^{-7} cm/sec. The AWMFH indicates that soils with PI greater than 30 typically exhibit suitably low permeability for use in a pond liner if there is suitable compaction and management to prevent desiccation. The handbook notes that soils with high PI typically have a tendency to crack when dried, resulting in leakage. The AWMFH recommends:

"High plasticity soils like those in group IV should be protected from desiccation in the interim period between construction and filling the pond. Ponds with intermittent storage should also consider protection for high PI liners in their design." NRCS AWMFH, Chapter 10

The "protection" recommended includes addition of dispersant chemicals, use of a geomembrane, or synthetic liner, or covering the clay with a less plastic soil. The permeability is documented as 5×10^{-7} cm/sec from testing one sample as shown in the QA-QC Certification document. The liner and the

embankment forming the ponds were constructed in 6-inch lifts, and each lift was tested for compaction as required.

Pond Liner Design. Animal waste lagoons and storage ponds are typically designed on one of two approaches (or a combination approach). In some states, liner characteristics, permeability and thickness are designated, and in other states a specific leakage rate is designated. The principle concern is the seepage rate (gallons/acre/day) or the specific seepage rate (gallons/day), but this is very difficult to measure with accuracy unless the leakage is extremely high. Liner characteristics, on the other hand, can be specified with some precision, and leakage can be predicted accurately if the design is followed. Leakage or seepage is related to liner permeability and depth as described by Darcy's Law.

- Darcy's Law: $Q = k \times i \times A$
    - Q= total seepage (gallons/day)
    - k = coefficient of permeability
    - i = hydraulic gradient (ft/ft)
    - A = cross sectional area perpendicular to flow (ft^2)
- Specific Discharge = $\frac{Q}{A} = \frac{k(H+d)}{d}$
    - Specific discharge = total seepage (gallons/day/acre)
    - k = coefficient of permeability
    - H = maximum depth of water above the liner
    - d = thickness of the clay liner

The parameters used in estimating pond leakage are often reported in different units. Seepage or leakage is often reported in gallons/acre/day, while coefficient of permeability (k) is often reported in metric units, cm/second. Liner thickness (d) and water depth (H), are typically reported in ft.

Comparison of leakage and permeability with other design standards. The standard used by DHG for design of the waste storage pond clay liners at C&H was a seepage rate of 5,000 gal/acre/day, based on recommendation in the NRCS FOTG and AWMFH. As indicated earlier, these NRCS documents do not actually set standards but defer to state requirements. The NRCS AWMFH recommends, "In the absence of a more restrictive State regulation, assume an acceptable specific discharge of 5,000 gallons per acre per day."

NRCS recommendations allow up to one order of magnitude reduction in permeability due to clogging of liner material by solids from the manure. Credit for manure sealing is not recommended by NRCS in the most vulnerable situations, such as areas with karst geology or high seasonal water tables (see Appendix.)

Comparison with 10-state standard

The 10-State Standard differs considerably from the design recommended by NRCS. The most significant difference is that the Pond considered in the 10-State Standard is only 6 ft deep as quoted below, whereas animal waste lagoons or storage ponds are often much deeper. The extra depth increases pressure on the liner resulting in increased leakage. The Pond 2 at C&H may be as much as 13 ft deep. The 10-state Standard says

> "To achieve an adequate seal in systems using soil, bentonite, or other seal materials, the hydraulic conductivity (k) in centimeters per second specified for the seal shall not exceed the value derived from the following expression where L equals the thickness of the seal in centimeters.

$$k = 2.6 \times 10^{-9}L$$

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The "k" obtained by the above expression corresponds to a percolation rate of pond water of less than 500 gallons per day per acre [4.7 m^3/(ha·d)] at a water depth of 6 feet (1.8 m) and a liner thickness of 1 foot (0.3 m), using the Darcy's law equation."

In the current storage pond design, k = 1.19 x 10^{-7}cm/sec, which is lower than measured for the *in situ* clay (k$_s$ = 5 x 10^{-7}cm/sec) that was used in the construction of the waste storage ponds.

Table 2 compares the allowed seepage rates allowed by various states for animal waste systems, adjusted to a standard depth of 6ft and assumed liner thickness of 1 ½ ft. Table 1 also includes the recommendations of NRCS and the 10-State Standards.

Table 2 Comparison of state liner design rules for selected states

State	Year	Rule*	Equivalent 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^{-6} cm/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	462 gal/ac/day

State	Year	Rule*	Equivalent seepage at 6 ft depth
		waste retention structure bottom	
		Minimum thickness of one and one half (1.5) feet. For Maximum hydrostatic head of 10.5 feet	
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 1×10^{-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	no discharge
		HIGH RISK AREA – HIGH VULNERABILITY. – synthetic liner required (or seal and reevaluate vulnerability)	no discharge
		HIGH RISK AREA – MODERATE VULNERABILITY – specific discharge 1×10^{-6} cm/sec (no manure sealing credit)	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 = 2.6×10^{-9} L the "k" obtained by the above expression corresponds to a percolation rate	500 gal/ac/day
* Extracted from Table 10-4 AWMFH (page 10-26) Criteria for siting, investigation, and design of liquid manure storage facilities, based on Risk and Vulnerability (See Appendix). **Recommended Standards for Wastewater Facilities. 2004 Edition. Health Research Inc.			

Opinion: Credit for Manure Sealing when estimating leakage

The AR rules are not clear on what standard should apply, but all recommendations and the rules of other states agree that a tight seal should be required, particularly for areas with (1) karst geology and (2) exceptional resource waters, like the Buffalo River. There is considerable controversy over whether or not credit should be applied for manure sealing. If conditions are right, and there is no preferential flow due to weak spots or cracks in the clay liner, organic matter from the manure is expected to infiltrate the clay and clog pores, reducing permeability. According to this theory, a seal is created that would reduce the conductivity (permeability) of the liner by as much as an order of magnitude (in other words if the seal initially allowed 5,000 gal/day to leak, manure sealing would reduce this to 500 gal/day). If, however, there are weak spots or leaks in the clay, these areas will not clog, and may develop into serious leaks due to preferential flow.

Opinion: Design and protection of high plasticity (PI) clay liner.

The liner design was based on a single sample of *in situ* clay that was used as a liner. With only one sample, there is no way to determine how consistent this clay is, and whether or not the conductivity measured is representative of the entire stock pile. The inspection report from July 23, 2013 indicates that "gravel to cobble-sized coarse content" was observed in the clay liner (073447-INSP.pdf). This

suggests the final clay liner could be quite different from the sample tested, which was supposed to be "fat clay." The presence of coarse particles can reduce the permeability of the liner. Cracks and rocks are visible in the photograph by ADEQ, Tony Morris 7/23/13, shown in Figure 1.

The storage ponds at C&H are designed to be pumped down very close to the bottom periodically (at least once every 6 months). Consequently much of the clay liner will be exposed for long periods. This will lead to cracks developing in the liner, reducing the effectiveness of the seal. [Note cracking has already been observed during a site inspection on July 23, 2013 (see item 3 in letter from Jason Bolenbaugh, ADEQ, to Jason Henson in reference 073447-INSP.pdf).] The NRCS recommends protecting the clay liner from cracking by applying a layer of lower PI material over the clay, not allowing the liner to dry out, or using a more specialized system with dispersants or bentonite added. If the ponds are pumped dry and cracking occurs at the bottom, consequences could be very serious.

Figure 1 Liner cracks (from inspection report visit by ADEQ, Tony Morris 7/23/13)

Discussion of leakage rate and liner design

The overall area of the two ponds is about 1.1 acre when full and 0.48 acre when pumped down to a 1 ft depth. Consequently the leakage of pond 1 will vary from 125 gal/day when empty to 1,335 gal/day when full, and Pond 2 will vary from 243 gal/day to 3,850 gal/day when full. In a normal 6-month cycle, Pond 1 will be full by the end of the first 90 days and remain full until the ponds are pumped. Pond 2 will remain empty until Pond 1 overflows and will reach about 6 ft depth by the end of the 6 month period, giving an average of about 1500 gal/day over the 6 month period.

It is convenient to think of seepage or leakage from a pond in terms of the change in depth at the surface of the pond. So if the pond has an area of 1 acre, and seepage is 1 inch, the volume of seepage is 26,154 gallons, or 1/12 of 1 acre-foot. Since permeability is normally reported in cm/sec, any leakage rate reported in English units must be adjusted for the number of seconds in a day (86,400) and the number of cm in an inch (2.54).

A leakage rate of 1/8 inch per day corresponds to about 45.6 inches per year. This leakage is into the soil surrounding the pond and the soil and geologic layers beneath the pond. Porosity of these soil materials typically ranges from around 0.3 to 0.45 (the water can only go into the pore space), so the distance traveled in a year for leakage of 45 inches is likely to be 100 to 150 inches. This means it will take time

before any leakage can be detected, but if a limestone formation, solution channel, or gravel deposit is encountered by the leakage plume, there could be short circuiting to ground water, to a spring, or to Big Creek.

Opinion: Waste Storage Pond Design

The waste storage ponds were designed using the currently accepted standards for animal waste storage ponds in an area with few ecological or groundwater concerns. However, the location selected for this hog farm has both ecological and ground water concerns. Otherwise, my concerns for the design presented arise from the fact that only one sample of clay was tested for permeability,I am not sure the SPAW modeling is correct, and there was neither testing of the final liner permeability nor installation of monitoring wells.. My special concerns for this application are that

1. The ponds were constructed on a hillside with 10% slope,
2. There is no emergency spillway, so if the embankment is overtopped there is likely to be serious erosion and potential loss of the entire contents of the pond.
3. Leakage of the liner is likely due to cracking unless measures are taken to protect the clay.
4. The pond liner does not provide enough protection for a karst area or for an area where gravel deposits and short circuit routes to the creek are common

Big Creek is the main tributary of the Buffalo River and deserves extra protection, which is not provided by this design.

Part II: Review of C&H Permit Application - Nutrient Management Plan

Part I of this report reviewed the design of the Waste management System with specific attention to storage ponds as presented in the C&H NOI for coverage under the NPDES General Permit ARG590000 submitted on 6/25/2012 and approved on 8/3/2012. As indicated previously, this is the first hog farm covered by the Arkansas General Permit (Permit Number ARG590001). The operation is specified for 2503 swine of over 55 lb (gestation barn) and 4000 swine under 55 lb (farrowing barn). The permanent population of 2503 consists of 2500 breeding sows and 3 boars.

Part II addresses the design of the nutrient management plan presented in the NOI for application of waste water and nutrients to agricultural fields near the C&H facility.

Review of Waste Management System Design

We checked the DeHaan, Grabs & Associates, LLC (DHG) calculations for Nitrogen and Phosphorus generation in manure and found them to be essentially correct based on ASABE Standard D384.2. Their estimate of 92,811 lb of N per year and 71,196 lb/yr P_2O_5 (31,091 lb as P) will be used in the subsequent discussion. Note, if manure with this this amount of P_2O_5, were applied uniformly across 630 acres,, the average application rate would be 113 lb/ac. Considering that the UA recommendation was zero P_2O_5 for almost every field in the plan, this would be very much in excess.

The volume of waste water presented by DHG is 117,575 ft^3 plus 65,880 ft^3 of recharge water, and about 52,000 ft^3 of rainwater for 180 days gives 235,375 ft^3/yr or about 3.52 million gallons/yr. The total volume presented in the Nutrient Management Planner is 2.761 million gallons. Depending on operation of the two waste storage ponds, as much as 80% of the phosphorus will be retained in WSP#1 due to settling (80% efficiency, or about 48,414 lb as P_2O_5. The remainder would be in WSP#2, or 12,104 lb will be in WSP#2. Note there can be no volatilization losses of P. If the volume of WSP#1 is 1.66 million gallons and WSP#2 is 1.85 million gallons, this gives a concentration of 29 lb/1000 gallons in WSP#1 and 6.5 lb/1000 gallons in WSP#2. The value for WSP#2 differs substantially from that used in the Nutrient Management Planner.

It is not clear where DHG obtained the values for Water Extractable P (WEP), which they used in the Nutrient Management Planner. The Arkansas PI is very sensitive to this value. Kleinman et al (2005) in a survey of WEP in Livestock Manures found Hog slurry to have WEP values ranging from 20% to 90% of the total P. This would have a very large impact on the subsequent field-specific assessment of N and P transport, which is a term of the permit as discussed below.

General Comments on the Nutrient Management Plan (NMP)

The NPDES permit specifies *terms* and other *requirements that* are enforceable elements of the Plan. The terms of the permit can only be adjusted with approval of the Director, and such approval may require public notice. Other requirements are elements that may be adjusted by the operator, but must be presented in the NMP and reported annually. The permit used by the CAFO follows the "narrative approach" specified in 3.2.5.2 of the permit. The narrative approach makes the methodologies for determining the application rates the principle terms of the permit, rather than specific rates and timing designations. However, Section 3.2.5 states that the NMP (whether linear or narrative)

> "…must include the fields available for land application; field-specific rates of application **properly developed**, as specified in Parts 3.2.5.1 through 3.2.5.2 of this section, **to ensure appropriate agricultural utilization of the nutrients in the manure**, litter, or process

wastewater; and **any timing limitations** identified in the nutrient management plan concerning land application on the fields available for land application." (Emphasis added.)

Specifically required (3.2.5.2.a and b) are:

- Maximum amount of N and P in lb/acre from all sources for each field and the factors necessary to determine that rate, and
- The field-specific assessment of potential for N and P to be transported from each field
- Timing limitations for application

The factors that are terms of the permit include:

- The realistic yield goal for each crop in each field (including pasture or forage)
- The N and P recommendations from UA for each field
- The methodology to account for: N and P soil test, credits for N in the soil, source and form of the of manure, N and P in the manure (considering volatilization, mineralization, and plant availability), and timing of manure applications

And based on these factors, the following projections are required for each field, although these are NOT TERMS OF THE PERMIT (3.2.5.2.c)"

- Amount of manure or waste water to be applied
- Credits for N that will be plant available, considering multi-year applications
- Form and method of application

Evaluation of the Terms of the Permit.

The NMP consists of a series of spread sheets called, the Arkansas Nutrient Management Planner (version 3/3/2010). This spread sheet is designed for developing a plan and allows the designer to test alternative scenarios to balance the available liquids and nutrients from storage ponds against field-specific crop needs. The spread sheet calculates the surplus or deficit for each nutrient, based on yield goal, crop requirements, fertilizer amount and source, and residual sources, but it must be provided by the planner. This spread sheet has been used many times and works well if the inputs are correct. The spread sheet also calculates the Arkansas Phosphorus risk Index (API) based on additional input specified by UA).

Embedded in the spread sheet are the following assumptions, which are not explained in the NMP:

- Waste will be spread on 17 fields (although Field #5 has been withdrawn, removing 23.75 acres accessible to the travelling gun sprinkler from the plan)
- All wastes will be applied to the land from March to June (no other time periods are considered even though it might be necessary or preferred by the operator to apply waste at another time). [Note there is no consideration of limitations related to timing of manure application.]
- Fields 1-4 and 10-17 will receive their wastes from WSP#1 by vac tanker, although no equipment is specified as available.
- Waste from WSP#1 is assumed to be biosolids, although no equipment or procedure for mixing or agitation is presented. If this pond is not well mixed by agitation before pumping, the solids will accumulate in the pond. [Note the original inspection letter from July 23, 2013, indicated there is no equipment on site for agitation. (See August 9, 2013 Letter from Tony Morris to Jason Henson 9-ARG500001_Isnpltr_20130723_JB-Initial Draft)

- Fields 5-9 will receive wastes from WSP#2 from a big gun irrigation sprinkler, although the amount of waste specified cannot be met from WSP#2 alone, and very different considerations are necessary if WSP#1 is used.
- Wastes will be applied on a Nitrogen basis on all fields, with unrealistically high yield goals and no accounting for other sources such as soil N (Fields 5-9 will receive 489 lb/ac Nitrogen, 376 lb/ac P2O5, and 379 lb/ac K_2O, extremely high rates of application considering the soil test reports.)
- Residual N and soil test P, and UA recommendations are ignored.
- The field designated for emergency pumping is Field #7, which has the highest STP, is located in the flood plain, and is designated for application through the travelling gun sprinkler.

Maximum amount of N and P in lb/acre from all sources. Field specific assessments are presented in the NMP as spread sheets using the Arkansas Nutrient Management Planner with 2009 PI. The planner incorporates all the factors designated in 3.2.5.2 a-c, but management depends on the knowledge, training, and intent of the person using the planner. In this case, many of the entries are wrong, and many of the computations have been ignored, resulting in a management plan that cannot be followed in any environmentally sensitive way.

The NMP presents soil test information for each field. It does not provide 24-inch samples as specified in the permit (Section B.3.c (1)). In addition, the 6-inch soil test values presented are not used in the NMP. The NMP presents a very simple 5-year crop rotation plan and yield goal for each crop, i.e. no rotation and all yield goals are the same, 6.5 tons/acre regardless of whether the forage will be grazed or harvested for hay.

Opinion: Maximum Amount of N and P for each field.

This *term of the permit* is presented as an unrealistically high value for each field because the planner employed very high yield goals and incorrect assumptions concerning the amount of waste as discussed below. It is possible that these incorrect volumetric assumptions were used intentionally to make sure that all the designated fields will be permitted for land application in the future without substantial modifying the terms of the permit. Designating an extremely high value for maximum application rate would assure that the maximum value will not be exceeded and there would be no need to open the permit to public review. This would, however, violate the spirit of the permit and not protect the water resource.

A realistic yield goal is a required factor in the permit.

It is important because harvesting hay is the only means of removing significant amounts of N and P from these fields. The NMP assumes a yield goal of 6.5 tons/acre and 24.7 lb of P removed for each ton of hay (56.6 lb as P_2O_5) on a dry matter basis. If this yield is not obtained, and/or the hay is not removed from the field, the P will remain in the field and contribute to future fertility. Grazing removes very little P, as virtually all P is deposited back on the field. Only the P that is harvested as beef is actually removed.

Opinion: Realistic Yield Goal

The yield goal, 6.5 tons/acre is not realistic. Although such high rates are possible for improved Bermudagrass varieties with carefully managed fertilizer and water, a realistic goal for the area would be more like 3.5 to 4 tons per acre. Most UA fact sheets on hay production and grazing in the Newton County assume 3 to 4 tons/acre yield.

The N-application rates recommended in the soil test reports is 170 lb/ac , applied in three separate applications depending on the duration of grazing. Specifically recommended was application of 60 lb/ac in the spring, an additional 60 lb/ac applied later for continued grazing, and an additional 50 lb.ac if grazing continues into the fall. Therefore the maximum recommendation for grazing would be 170 lb/ac, N split across three grazing periods. This is considerably less than the 489 lb/ac specified in this plan. . As specified, the STP and API will accumulate to ecologically dangerous levels in only a few years.

The county average for this system of production is a little over 2 tons/acres (USDA-NASS Arkansas Crop Production Report, August 2010). Oklahoma recommends a yield goal of 3 to 4 tons/acre for common Bermudagrass (OSU Fact Sheet PSS-2263, Fertilizing Bermudagrass Hay and Pasture), and UA Cooperative Extension Service, Self-Study Guide 7: Hay Production, Table 1 indicates a realistic goal for common Bermudagrass to be 2-5 tons per acres.

Limitations on timing of waste application

All entries to the planning software indicates application of wastes during the period March to June, however, the plan implies there will be two pump outs each year. The storage is unlikely to last more than about 250 to 270 days without danger. Frozen ground is likely, and periods of heavy chronic rainfall are likely. It is important that the ponds are pumped down before the winter period to assure adequate storage to avoid the need for emergency pumping.

Opinion: Limitations on timing

The planners have not presented any limits to timing of manure application as required. Clear limitations to the timing of waste application are an extremely important element of the NMP. If wastes are applied to saturated soils or frozen soils, the probability of water quality degradation is extremely high.

Assumptions Concerning Nutrient Losses.

The NOI estimates production of 92,611 lb/yr of N and 71,196 lb/yr of P_2O_5. By assuming unreasonable losses of P_2O_5 (80%) through an unspecified mechanism, the amount of P_2O_5 available to apply to fields is reduced to 14,213 lb. They also assume 80% loss of N (60% storage and 50% application). This is not an unreasonable estimate as actual losses depend on the storage, handling, and application system.

Opinion: Phosphorus Losses in Storage.

The assumptions concerning Phosphorus losses in the storage ponds are much too high and can only be explained if there will be improper use of the storage pond, i.e. no removal of biosolids during waste application.

Phosphorus, unlike N does not volatilize, and the P must be accounted for. Therefore all the P present in the system should be available for application to fields in one form or another. A reasonable assumption is that 15% of the P may be tied up in a form unavailable to plants. Considering that waste will be applied year after year to some fields, even 15% may be a high estimate of loss. If significant losses of P are noted in waste analyses submitted to the laboratory, it would indicate that solids are not being removed efficiently from the waste storage ponds. This should be considered a term of the permit, as operation as a "storage pond" is specified, not as a lagoon. Reasonable N and P concentrations and assumptions are available in Chastain et al (1999).

Volumetric Assumptions in the Waste Allocation Tables.

The plan allocates 21.4 million gallons of waste annually to nearby fields for hay or rotational grazing, even though the total waste available in both storage ponds is only about 3.5 million gallons over the course of the year. The NMP spread sheet shows even less waste water (2.7 million gallons). Thus the plan leaves a deficit of 13.804 million gallons for WSP #2 and a deficit of 3.58 million gallons for WSP #1. In other words, there is not enough water in WSP#2 to follow the planned applications to fields 6, 7, 8, and 9. As WSP#1 has a higher concentration of N and P than WSP#2, it cannot be used without recalculating the application rates.

The spread sheet also shows that 70% of the waste will be applied to 30% of the area (fields #5, #6, #7, #8, and #9) where it can be applied by the traveling gun. This may be the plan, as it would be the most economical means of waste disposal – involving no tank trucks or other expensive hauling equipment

Opinion: Application Volumes and Sources of Wastes

The volumes and sources identified in the NMP are incorrect and cannot be used to guide the application of waste to the available fields. Not only is there a 15 million gallon deficit in this plan, the source of waste (WSP#1 or WSP#2 are not designated If the waste allocation tables had been set and up used correctly, the total waste to be allocated to fields should have totaled about 3.5 million gallons (full year waste generation) instead of 21.4 million gallons, and the planner should have revised the spread sheet for a second round of calculations to estimate a reasonable allocation to fields. This was not done, leaving the application rates at an unrealistically high level, more than 6 times too high.

Opinion: Waste utilization vs. Waste Disposal

The NMP is supposed to specify waste application rates that will *utilize the nutrients to achieve realistic production goals*. This is also the requirement of the Clean Water Act Agricultural Stormwater Exemption, which requires that manure and process waste water be applied to utilize nutrients at "agronomic rates." The application rates in this plan are completely out of balance for the crops selected and should be considered *waste disposal* not agronomic utilization. The plan as presented is designed for waste disposal rather than agronomic waste utilization because the application rates exceed crop nutrient requirements. Rates of both N and P application exceed the recommended rates for agronomic utilization. A rapid increase in Soil Test P and long-term water quality impacts are to be expected.

Inappropriate assumptions employed in the planning spread sheets should make this *term of the* permit unacceptable. The waste volumetric errors, field application rates, and the errors in estimates of Phosphorus losses make this plan unusable and inappropriate for environmental protection.

Buildup of Soil Test P.

Fields nearest the C&H facility (fields 1-10) had the highest soil test P of any of the fields in the plan. Field #7, located directly downhill from the production facility and designated for waste application by a traveling gun, had Soil Test P (STP) of 356 lb/ac, well in excess of any P requirement for a crop. As these areas are used for waste application, they will continue to build up STP because the hay crop is limited by Nitrogen and available moisture, consequently most of the N will be removed, but the crop will leave behind a lot of P, which it cannot consume every year that waste is applied. Much of the P left behind becomes part of the mineral soil, not readily available to plants or to runoff and not detected in the normal soil test analysis. However, as much as 20% of the excess P will be added to the STP in later seasons increasing the runoff concentration of P.

Mass balance analysis shows that P will continue to build up in the soil if the waste from C&H is applied on the basis of its N content (as done in this NMP). This plan assumes N application at rate of 489 lb/ac. As a result, the P_2O_5 application rate will be 379 lb/ac. By assumptions in this NMP, the P-removal rate by crops is 57 lb/ac. This leaves behind 322 lb/ac every year. This would increase STP as much as 30 to 60 lb/ac every year. As most of the waste will be applied to the nearby fields, these fields will be extremely high in STP within only a few years. The problem is particularly troubling in fields 6, 7, 8, and 9, which are designated to receive most of the waste through a traveling gun. As STP builds up, these fields will remain a source of pollution for many years.

Opinion: Buildup of P in the Soil.

Management of hay land and grazing land as specified in this Plan is sure to build up STP very rapidly as virtually all the P applied is not needed by the crop. Research has shown that STP increases about 20 lb/ac (6-inch basis) for every 100 lb of excess P applied. If this plan is followed, the excess P is at least 100 lb/ac, with much more than that specified for fields 6 through 10. Note that all these fields have more "above adequate" STP and Field #7, which already has STP over 300 lb/ac. "Above Adequate," is generally regarded as "Very High." Research by Pote et al., (1995), Sharpley (1995), and others have shown clearly that phosphorus leaching into runoff increases with increasing STP in all soils.

Note the Plan uses a 4-inch soil depth rather than a 6-inch depth in its calculations of the Arkansas Phosphorus Index (as discussed below). This reduces the estimate of plant available nutrients by one-third, because the lab reports concentration of P in a sample of soil 6 inches deep. [A 6-inch depth across one acre weighs about 2 million lb., so if the parts per million value reported is multiplied by 2, it gives STP in pounds per acre. This is a good assumption because in fields that have received waste for several years, the concentration is fairly uniform through the full six inch-depth.] Using a 4-inch depth has a small effect on the API, but a very large effect on mass balance calculations estimating build-up of STP.

Field-Specific Assessment of Potential for N and P to Be Transported from each Field

The potential for nitrogen and phosphorus transport from each field is a term of the permit. It is estimated here by using the Arkansas Phosphorus Index (API) and the spread sheet used by the NOI planner (the Arkansas Nutrient Management Planner with 2009 PI). The incorrect assumption noted above is built into the planner spread sheet. The procedure used to calculate the API is described in detail in the Appendix.

As discussed above, the spread sheet locks in the assumption of 4-inch depth, even though the UA Soil Test reports are based on a 6-inch sampling depth. [Note the Nutrient Utilization Plan 3.(c) 1 specifies 20 soil cores to be sampled to a depth of 24 inches, with the top 6 inch portions combined and analyzed for P, Cu, and Zn.] Using the assumption that the core sample is only 4 inches deep, a STP of 83 ppm would be considered 110 lb/ac instead of 166 lb/. Although 47 states use a P-index approach for assessment of potential to transport P, they are all different, and comparisons have shown that although they consider most of the same factors, they generally arrive at different conclusions concerning risk of pollution.

To reproduce the API values, including those that were either left blank or unreadable in the NOI, we inserted the actual values from the NOI into the Arkansas Nutrient Management Planner spread sheet (see Attachment: C&H ARNMP as in NOI.pdf). The resulting Planner spread sheet gave a value of "High" for 8 of the 17 fields in the first year of application. One field, Field #7 had an index value of 150, or "Very High." This value is so high that application of P as either manure or fertilizer should be discontinued! Further, when the spread sheet is run with these values, it puts out the following

message, " WARNING! An application rate is planned that exceeds crop N needs. The application rate should be reduced."

Opinion: Errors in Planning Wastewater Disposal and Lack of Application Timing Plan

This NMP is almost useless as a guide to management of the wastewater and therefore should not be acceptable as term of the permit. DHG assumes that although P will build up in the areas soils, it is not a concern due to the moderate risk., ignoring the fact that P will build up in some soils. Eventually most of the moderate APIs will advance to High and Very High (See attached Planner Spread Sheet).

The current plan, assumes the NMP will be followed, but as shown, it cannot be followed because the amount of wastewater available is not correct. Will the manager have the right type equipment to agitate WSP#1 before pumping? Will WSP#1 be used to apply waste to Fields 6, 7, 8, or 9, and if so what are the limits? And what is the actual timing planned for application to fields? If the timing is not correct, considerably more nutrient will be lost to runoff and ground water.

It is very important to agitate WSP#1 whenever it is pumped out, otherwise it will build up solids and create a disposal problem that has been well documented by a study by the ADEQ Environmental Preservation Division under a 319 grant (Sandy Formica, 2002). This ADEQ study showed that many Licensed Animal Waste Management Systems (LAWMS) had waste storage ponds that were not operated properly and consequently had N and P concentrations much higher than expected and frequent odor and disposal problems as a result. The NMP at C&H also has no clear operating instructions.

The environmental problems associated with this management plan are numerous. The fields that are designated to receive most of the wastes are flood plain fields. Because of their location they are frequently flooded; they typically have buiried gravel bars that provide an efficient pathway from the field to the creek. A few of these fields even have high erosion rates that will increase the loss of soil and nutrients even more than that reflected in the API.

Opinion: Miscalculation and Misuse of the Risk Index

Even using the values presented in this NMP, with huge volumetric errors and overestimated storage losses of P, more than half the fields are identified as having too much risk to be used without limiting P or applying BMPs. One field, Field #7, which is also designated as the field to use for emergency pumping, has so much STP (237 lb/ac based on 4-inch sample or 356 based on 6-inch), that no further P should be applied. Also, this field is in the flood plain of Big Creek, and may unavailable in such an emergency.

The API is a good tool for promoting good management of animal waste application fields as it gives incentive for controlling erosion and installing BMPs, but it provides a means for producers to continue applying manure and wastewater to fields that have way too much P already. Another concern is that the API considers only transport through surface runoff. It gives no weight to subsurface transport of P through buried gravel deposits that are frequently found in Ozark flood plains (Fox et al., 2012) or solution channels in the karst limestone of the area. Further there is no consideration of the ammonia released to the atmosphere when wastes are applied by a traveling gun.

Opinion: Is there Enough Land Available for this Operation?

As discussed above, it is not possible to determine the actual potential to dispose of the wastes from C&H on the designated fields using the current NMP. Even if the waste pond capacities and waste distribution amounts are brought back to alignment, most of the fields receiving waste will be out of

balance for nutrients. Although it may be possible to develop a plan to reduce API with significant restrictions on application rates, designation of additional buffer areas, and installation of other BMPs, the C&H operation would be a continuing problem because the API does not address all the concerns of the Big Creek flood plain fields. Finally, using the API to justify over-application of manure to fields already high in P trades short-term expedience for long term problems. It is well-known that the STP takes decades to decline after all sources of fertilizer have been withdrawn. Consequently we can expect the high STP that will develop in the C&H application fields to contribute excessive P to runoff for many years to come.

The concern for excess nutrients would be particularly severe if the WSP#1 solids were applied to any of the high STP soils such as those in Fields 5, 6, or 7. The contents of WSP#1 are too rich for use on fields that already have a Medium to High API. Clearly there is not enough water in WSP#2 to support the use of a traveling gun on fields 6, and 7, so use of WSP#1 is likely to be employed. Finally use of the traveling gun applicator is likely to cause obnoxious odor problems.

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APPENDIX

Calculation of the Arkansas Phosphorus Index

The API consists of three parts: a Source Potential, a Transport Potential, and a BMP Multiplier. The Source Potential for various types of wastes is based on results of rainfall simulator experiments measuring concentration of P in runoff from simulated rainfall on 1 m^2 plots. The Source Potential in the API is calculated as follows:

> Source Potential = 0.0018 STP + 0.029 WEP + .00145(TP-WEP)
>
> Where STP is Soil Test P and
>
> TP is total P in the waste

By looking at the coefficients in this equation, you can see the largest factor is WEP, with a coefficient of 0.029. WEP is typically a very small fraction of the total P in the waste. The impact of the fraction of Total Phosphorus that is not water extractable (TP-WEP) has a coefficient of 0.00145, and the STP has a coefficient of 0.0018, indicating smaller impact. This has the effect of reducing the effect of very much the elevated STP commonly found in waste application areas.

The Transport Potential is based on professional judgment of the relative impact of factors like high or low Erosion Rate, Runoff Volume, and frequency of flooding using the following equation:

Transport Potential = Soil Erosion + Runoff Class + Flooding Frequency + Application Method + Application Timing

Where:

> Soil Erosion varies from 0 to 1
>
> Runoff Class varies from 0 to 1.5
>
> Flood Frequency varies from 0 to 2
>
> Application Method is 0.1 for incorporated, 0.2 for surface applied, and 0.5 for frozen ground
>
> Application timing is 0.1 for July to October, 0.25 for March to June, and 0.6 for Nov to Feb

The Transport Potential for a relatively flat field in the flood plain of Big Creek would be
Transport Factor = 0.2 + 0.2 + .5 + .2 + 0.2 + .25 = 1.55

The BMP Multiplier, too, is a set of factors based on the effectiveness of BMPs. For example, if the producer has a riparian forest buffer between the field and the creek, the BMP Multiplier would be 0.8 (20% effective). If the Forest Buffer is fenced, the Multiplier is 0.75 (25% effective). If there is a field border practice installed between the field and the fenced riparian buffer, the BMP Multiplier would be 75% x 90% = 67.5%.

The actual assessment of N and P transport is the numeric vale of the API, where

> API = Source Potential * Transport Potential * BMP Multiplier

The API is a good tool for promoting good management of animal waste application fields as it gives incentive for controlling erosion and installing BMPs, but it provides a means for producers to continue waste applying manure and wastewater to fields that have way too much P already. Another concern is that the API considers only transport through surface runoff. It gives no weight to subsurface transport of P through buried gravel deposits that are frequently found in Ozark flood plains or solution channels in the karst limestone of the area. Further there is no consideration of the ammonia released to the atmosphere when wastes are applied by a traveling gun.

Risk→ / Vulnerability↓

Risk categories (columns):

- **Very high** — Does not meet <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

Vulnerability categories (rows):

- **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*
- **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*
- **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 abandoned well*
- **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.

Vulnerability ↓ / Risk →	Very high	High	Moderate	Slight
Very high	Evaluate other storage alternatives	Synthetic liner required * (or property seal well and reevaluate vulnerability) No additional site characterization required	Liner required * (or property seal well and reevaluate vulnerability) Specific discharge $\leq 1 \times 10^{-6}$ cm³/cm²/s No manure sealing credit Earthen liner design includes sampling and testing of liner material (Classification, Standard Proctor compaction, Permeability)	Liner required * (or property seal well and reevaluate vulnerability), Specific Discharge $\leq 1 \times 10^{-6}$ cm²/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
High	* (or property seal well and reevaluate vulnerability)	Further evaluate need for liner Specific discharge $\leq 1 \times 10^{-6}$ cm³/m²/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 $\leq 1 \times 10^{-6}$ cm²/cm²/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 $\leq 1 \times 10^{-6}$ cm²/cm²/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
Moderate	Evaluate other alternatives or synthetic liner as allowed	Further evaluate need for liner Specific discharge $\leq 1 \times 10^{-6}$ cm³/cm²/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)	Liner not required Specific discharge $\leq 1 \times 10^{-6}$ cm³/cm²/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	—
Low	Evaluate other alternatives * (or property seal well and reevaluate vulnerability) Local regulations may apply Consult with area engineer	Further evaluate need for liner Specific discharge $\leq 1 \times 10^{-6}$ cm³/cm²/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, Undisturbed sample Permeability) Scarify and recompact surface to seal cracks and break down soil structure as appropriate	Liner not required Specific discharge $\leq 1 \times 10^{-6}$ cm³/cm²/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	—

Evaluate other storage alternatives * (or property seal well and reevaluate vulnerability)

*See local regulations