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SUBJECT: Final Report – Written review of the EPA report and other sources of technical, engineering and scientific information and literature relating to storage basins/lagoon, permeability, assumptions regarding leakage and design.

The EPA report reviewed (Relation Between Nitrate in Water Wells and Potential Sources in the Lower Yakima Valley) on the whole contains minimal actual information with regards to establishing the permeability of the dairy storage basins/lagoons. The report relies upon a single technical paper (Ham, J.M. 2002 Seepage Losses from Animal Waste Lagoons: A Summary of a four-year investigation in Kansas. Trans. ASAE 45:983-992.) as the basis for assigning a range of potential permeability (seepage rate) to the dairy storage basins/lagoons discussed in the report.

It could be argued that using a study of storage basins/lagoons in the state of Kansas that uses only a single dairy among its 20 sample locations as the sole means to establish seepage rates from dairy waste storage ponds in Yakima County, Washington State is poor application of available information. The basic issue at hand though is the methodology used in the EPA report to arrive at a seepage rate through compacted soil liners in Yakima County and consequentially, a seepage volume over time. The study's assumption of a range for seepage is based on assumptions that are supported in generally any technical paper on sealing and/or seepage through compacted soil liners. However, the study fails to recognize that the technical process for constructing a compacted soil liner in Washington State guarantees a soil liner with a ***minimum*** permeability of 1 x 10-7 cm/sec, and the actual seepage rate utilizing the methodology employed in this paper will actually result in a seepage rate that is closer to an order of magnitude less than this.

Possibly the most interesting statement made in the subject EPA report with regards to the issue of seepage/permeability can be found on page 34 and page 51 where the following statement is made: "*EPA is unaware of any state or local requirements that would compel dairies in Yakima County to construct lagoons to any specific level of permeability*." Not to sound condescending, but this statement is utterly ridiculous and ignorant. EPA has an agreement/understanding with the State of Washington that gave/gives regulatory oversight of dairy/livestock nutrient in Washington State to the Department of Ecology (WDOE) --- hence the 1998 Livestock Nutrient Management Act (aka the Dairy Nutrient Management Act) which it is my understanding was essential to EPA agreeing to allow Washington State regulatory oversight of AFO/CAFOs in the state.

The 1998 Washington State Livestock Nutrient Management Act (which subsequently became known as the Dairy Nutrient Management Act - DNMA), requires that all licensed dairy operations in Washington State obtain a conservation district approved and certified nutrient management plan and that all structural and management practices that are prescribed in the plan are implemented. A Dairy Nutrient Management Plan is a tool used by dairy operators to properly collect, store, transfer and utilize the wastewater and manure that is produced on dairy facilities. Each Plan is specific to each individual dairy operation and is written according to United States Department of Agriculture - Natural Resources Conservation Service (USDA-NRCS) standards and specifications contained in the USDA-NRCS Field Office Technical Guide (specifically Section IV on practices

standards) as is required in the DNMA. All structural and management practices that are prescribed in the Plan must also meet or exceed these USDA-NRCS standards and specifications.

As a former professional engineer employed by the South Yakima Conservation District from 2000-2007, I worked under the guidance and understanding that WDOE used as the vehicle to implement the DNMA the standards and specifications set forth in the Field Office Technical Guide (FOTG) of the USDA-NRCS. When it comes to the subject of seepage/permeability through a compacted soil liner for a waste storage pond as it relates to the management of animal waste, USDA-NRCS has developed the Animal Waste Manual Field Handbook. (210–VI–AWMFH, rev. 1, March 2008). The specific portion of this manual that address waste storage ponds is Appendix 10D of the manual. In this manual, USDA-NRCS states:

Defining an acceptable seepage rate is not a simple task. Appendix 10D recommends an allowable seepage quantity that is based on a historically accepted tenet of clay liner design, which is that a coefficient of permeability of 1×10 –7 centimeters per second is reasonable and prudent for clay liners. This value, rightly or wrongly, has a long history of acceptability in design of impoundments of various types, including sanitary landfills. The seepage rate considered acceptable by NRCS is based on this permeability rate, also considering the following:

- When credit for a reduction of seepage from manure sealing is allowed, NRCS guidance considers an acceptable initial permeability value to be 1×10–6 centimeters per second. This higher value used for design assumes that manure sealing will result in a tenth reduction in the initial seepage. Other assumptions are that typical NRCS waste impoundments have a depth of liquid of about 9 feet and typical clay liners are 1 foot thick. The computed seepage rate before manure sealing took effect is then about 9,240 gallons per acre per day, and this rate would reduce to 924 gallons per acre per day when manure sealing reduced the seepage by one tenth. To introduce some conservatism into the design, the NRCS guidance allows a seepage rate of 5,000 gallons per acre per day for initial designs unless State or local regulations are more restrictive, in which case those requirements should be followed.

- ***If State or local regulations prohibit designs from taking credit for future reductions in seepage from manure sealing, then NRCS recommends the initial design for the site be based on a seepage rate of 1,000 gallons per acre per day, the approximate seepage predicted for a site with 9 feet of head, a 1-foot-thick clay liner and a coefficient of permeability in the liner of 1×10–7 centimeters per second.*** (emphasis added) Applying an additional safety factor to this value is not recommended because it conservatively ignores the potential benefits of manure sealing. One problem with basing designs on a unit seepage value is that the approach considers only unit area seepage. The same criterion applies for small and large facilities. More involved three-dimensional type analyses would be required to evaluate the potential impact of seepage on ground water regimes on a whole-site basis. In addition to unit seepage, studies for large storage facilities should consider regional ground water flow, depth to the aquifer likely to be affected, and other factors.

The procedures in appendix 10D to the AWMFH provide a rational approach to selecting an optimal combination of liner thickness and permeability to achieve a relatively economical, but effective, liner design. It recognizes that manipulating the permeability of the soil liner is usually the most cost-effective approach to reduce seepage quantity. While clay liners obviously allow some seepage, the limited seepage from a properly designed site should have minimal impact on ground water quality. Numerous studies, such as those done by Kansas State University (2000), have shown that waste storage ponds located in low permeability soils of sufficient thickness have a limited impact on the quality of ground water. (the KSU reference is -- *Animal waste lagoon water quality study. Ham, J.M., L.N. Redd, and C.W. Rice. Manhattan, KS.*)

The seepage rate that the Ham study of 2002 referenced in the subject EPA document concludes: "Seepage rates from 20 lagoons averaged 1.1 mm/d and ranged from 0.2 to 2.4 mm/d. Fifteen of the 20 lagoons had seepage rates between 0.5 and 1.5 mm/d. The variation among locations was small despite large differences in soil types and depths to groundwater. ***On average, the Ks of lagoon liners was 1.8 x 10–7 cm/s***." (emphasis added)

It must be noted that this seepage rate is ***greater*** (i.e. higher seepage rate) than the 1.0 x 10-7 cm/s that is required by legislation in the State of Washington as agreed to in the DNMA using USDA-NRCS waste storage pond design criteria for a compacted soil liner to have ***minimum*** seepage rate of 1.0 x10-7 cm/sec.

Washington State USDA-NRCS ***does not allow*** as part of the design of a compacted soil liner, credit for the reduction of permeability by one order of magnitude that is recognized to occur from the clogging of soil pores biologically in a waste storage pond (both by the Ham paper cited in the EPA study, and in numerous other technical papers on the subject). I strongly suggest that the Washington Dairy Products Commission and/or Washington Dairy Federation send a written request to Mr. Larry Johnson, State Conservation Engineer, Washington State NRCS requesting that he verify/clarify this position (not allowing credit for biological sealing when designing a compacted soil liner for an animal waste storage pond in Washington State). I do not think that Mr. Johnson can/will respond to a legal request in this matter as it would most likely be responded to with a denial initially claiming federal sovereign immunity.

Because of this position to not allow credit for biological sealing to be factored into the design of a compacted soil liner for animal waste storage ponds in Washington State, all animal waste storage ponds in Washington State designed and installed under the Dairy/Animal Nutrient Waste Management Act were/are required to be installed with an established minimum soil permeability rate of 1x10-7 cm/sec, not the 1x10-6 cm/sec that is presumed by the study, that becomes 1x10-7 cm/sec when taking credit for biological sealing of soil pores.

The saturated hydraulic conductivity of the soil (or modified soil) liner in Washington State is established prior to installation of the liner. This is generally done by using soil compacted using the ASTM "Modified Proctor" test, (ASTM D1557) and establishing the saturated hydraulic conductivity of the soil (at maximum density) under a falling head condition (ASTM D5084). Once a soil (or possibly soil modified with bentonite) that has been compacted to a known maximum density established by ASTM D1557 is tested and has a permeability determined that is not greater than 1.0 x 10-7 cm/sec (as established by ASTM D5085), the soil is installed per NRCS-USDA prescribed standards and specifications and then field tested to be sure that it has obtained at least the prescribed/tested density. This establishes that the compacted soil liner will have a minimum permeability of 1.0 x 10-7 cm/sec (generally less since the 1.0 x 10-7 cm/sec is the minimum to meet the standard). Therefore, upon the introduction of animal solids to waste storage pond in Washington State under the Dairy Nutrient Management Act, according to published articles (including the Ham report cited in the EPA study) a compacted soil liner meeting Washington State guidelines would have an effective minimum permeability rate of 1x10-8 cm/sec after taking credit for biological sealing, and not the 1x10-7 cm/sec that EPA uses to arrive at their seepage volume conclusions. Using their own line of reasoning, because Washington State doesn't allow for this reduction credit when designing a compacted soil liner, the seepage rate/volume that the subject EPA study should be using should be reduced by at least one order of magnitude. Therefore, when credit for a reduction of seepage from manure sealing is taken (as the Ham document and numerous other technical papers listed later in this report validate as being realistic) the computed seepage rate in Washington state for an engineered compacted soil liner before manure sealing took effect is then about 924 gallons per acre per day (the AWMFH Appendix 10D computed rate). *When the credit for biological sealing that is documented in virtually any technical report on the subject is now applied, this seepage rate being reduced by this factor of 10, now becomes 92.4 ga/ac/day since the minimum k is theoretically 1x10-8 cm/sec.*

Technical papers which document the conclusion that biological sealing and its being responsible for decreasing soil permeability by ***at least*** one order of magnitude (a factor or 10):

"Research has shown that these seals are credited with reducing the flux from holding ponds by one or more orders of magnitude due the very low hydraulic conductivity of the sealing layer" J.S. Tyner & J. Lee, 2004 -- *Influence of Seal and Liner Hydraulic Properties on the Seepage Rate from Animal Waste Holding Ponds and Lagoons,* Transactions of ASAE 47(5): 1739-1745

"Infiltrating manure creates a physical and/or biological seal atop the natural liner" A.C. Chang , W.R. Olmstead, J.B. Johansos, & G. Yamashita, 1974 – *Sealing Mechanism of Wastewater Ponds*, Journal Water Pollution Control Federation 46(7): 1715-1721

"Unlined earthen impoundments for liquid manure have gained acceptance in recent years as treatment lagoons and storage facilities. Expensive impermeable liners are often not needed because of the self-sealing nature of liquid manure in soils" W.R.DeTar, 1979 – *Infiltration of Liquid Manure into Soil*, Transactions of ASAE 22(3): 521-528

"…. a 200-fold reduction in infiltration rate occurs after flooding the bottom of a pond with liquid manure. This phenomenon is caused primarily by the clogging of the soil pores by suspended particles and by the high viscosity of the liquid." S. Davis & H. Weisheit, 1973 – *Dairy Waste Ponds Effectively Self-sealing*, Transactions of ASAE 19(1): 69-71

"Following the introduction of wastewater into a lagoon, the hydraulic conductivity of the earth linig will most likely be reduced by at least an order of magnitude due to physical, chemical, and biological processes, commonly termed seal formation." S. Baram, S. Arnon, Z. Ronen, D. Kurtzman, & O. Dahan, 2012 *Infiltration Mechanism Controls Nitrification and Denitrification Processes Under Dairy Waste Lagoon*, Journal of Environmental Quality 41: 1623-1632

"Laboratory scale experiments on dairy waste infiltration into clay, loam, and sand sediments have shown that all sediment types have similar infiltration fluxes (4.6 to 6.9 x 10-7 cm/s) within 10 days of manure application" J.L.B Culley & P.A. Phillips, 1982. *Sealing of Soils by Liquid Cattle Manure*, Canadian Agricultural Engineering 24(2):87-89