PREFILED TESTIMONY OF DONALD A. KEEFER TO THE ILLINOIS POLLUTION CONTROL BOARD PUBLIC HEARING IN ELIZABETH, ILLINOIS, NOVEMBER 14, 2012 REGARDING PROPOSED AMMENDENTS TO CAFO RULES

INTRODUCTION

My name is Donald A. Keefer. I am a Senior Hydrogeologist and the Head of the Hydrogeology and Geophysics Section at the Illinois State Geological Survey (ISGS). The ISGS is a division within the Prairie Research Institute at the University of Illinois on the Urbana-Champaign campus. I also am a Licensed Professional Geologist with the State of Illinois.

I have a Bachelor of Science in Geology from the University of Illinois, and a Master of Science degree in Agronomy (with a focus on soil water quality) from the University of Illinois. I have worked at the ISGS for 27 years, where I have been involved with research related to understanding the movement of water and agricultural chemicals through soil and geologic deposits, and the characterization and mapping of aquifers to aid in management and protection of groundwater resources.

During my tenure at the Survey, I have lead or co-lead research on the movement of water and chemicals in tile drained and undrained agricultural soils, the occurrence of agricultural chemicals in shallow groundwater and the application of geologic characterizations and maps for siting and screening locations for various land uses. I have authored and co-authored original research reports, proceedings and articles in a variety of areas including hydrogeology, groundwater quality, and geologic modeling and mapping. I also have given many presentations on these same topics. I have also provided testimony at an IPCB hearing related to the LMFA rulemaking effort, where I testified regarding the vulnerability of aquifers to contamination from potential sources of contamination such as CAFOs and related activities.

I am providing testimony on the importance of macropores on the transport of water and constituents through soil, and the nature of soil water and shallow groundwater flow in an agricultural field with subsurface tile drains. I also will address a few concerns I have regarding language in some of the proposed changes.

COMMENTS ON MACROPORES AND THEIR IMPACT ON WATER AND CONSTITUENT MOVEMENT

When geologic materials are deposited and then exposed at land surface, they undergo weathering due to the combined interactions of climate, water, animals, microbes, plants, landscape position and the constituent minerals in the geologic deposits. Over enough time, this weathering of the geologic deposits forms soil. Differences in these weathering factors help determine the nature and thickness of the soil over time. Soil is a mixture of mineral particles and organic matter. These components are combined together into a porous mixture in which plants can grow and through which water can infiltrate and flow. As soil develops, the mineral and organic particles often coalesce into aggregates. The size, shape and distinctness of aggregates are what comprise the soil structure. The amount and interconnection of pore spaces, within and between aggregates, influences how much water can infiltrate and be held in the soil and how quickly it can flow. The pore spaces in a soil can be classified into 2 categories: micropores and macropores. As the names indicate, micropores are small and macropores are large. The USDA has assigned the size of 0.08mm as the threshold between these categories. With this approach, micropores are smaller than 0.08mm while macropores are 0.08mm or greater.

Micropores in a soil are typically the spaces between the mineral and organic particles. These pores can be much smaller than 0.08mm, and water flow through micropores will generally follow a tortuous path. Accordingly, water flow and constituent transport through micropores will be relatively slow and will have ample opportunity to interact with the mineral and organic particles and any soil microbes that are in these spaces. Macropores in a soil are formed by a range of processes and have different shapes, sizes and lengths. Earthworms and plant roots create large, typically cylindrical macropores. These can be important for some water and constituent movement. The most common type of macropore includes the fractures or openings between individual soil aggregates. These inter-aggregate pores are typically planar and, together, form a vast network of macropores that extend from land surface to the maximum depth of weathering. If the underlying geologic deposits are jointed or fractured, the soil aggregate macropores can eventually connect with this larger joint network, increasing the reach of the macropore network. One very important characteristic of macropores is that they are relatively straight and not very tortuous, particularly relative to flow paths through soil micropores. The large size and lack of tortuosity mean that water flow and constituent transport through macropores can be very rapid.

I have conducted research using fluorescent dyes that showed rapid movement from land surface to depths of 4 to 5 feet within minutes and with less than 1" of irrigation. The staining from the dye showed that most of the transport was through the inter-aggregate macropores. This type of transport is widely recognized in the scientific literature. In Illinois soils, soil macropores are ubiquitous to depths of over 5 feet. Corn root macropores have been observed as deep as 15 feet from land surface. Research at the ISGS and by others has shown that these chemicals can be detected in shallow sand and gravel aquifers that are buried by between 20-50 feet of fine-grained clayey deposits. This suggests macropores are common below soils in many Illinois clayey glacial tills to depths of 20-50 feet. Again, it is likely that inter-aggregate macropores and connected joint networks are the most likely fraction of macropores responsible for water and constituent transport through fine-grained soils and geologic deposits in Illinois.

In general, macropores can be considered as ubiquitous in soils with the primary inter-aggregate networks related to the depth of the soil weathering profile. In much of the Midwestern US, this is often in the 5-6' depth range. Macropores due to plant roots, and joints or fractures in geologic deposits are also common, though at much lower densities, and extend to much greater depths.

WATER AND CONSTITUENT MOVEMENT IN TILE-DRAINED AGRICULTURAL SOILS

Subsurface drainage tiles are used to lower the water table in a relatively short time, and are used in agricultural fields where water tables are often shallow. In agricultural fields, tile drains are typically installed at a depth of approximately 3 ft and are used to ensure that crop roots have sufficient oxygen to maintain crop health during wet periods.

Water flow through tile drained soils can be complicated. Most of the water in a saturated soil will be found in the micropores. These can comprise 30% of the volume of the soil. When drainage tiles are present, most of the water flow during a rainfall event can occur in the macropores. These may only comprise 1-2% of the volume of the soil, but they can dominate the water and constituent movement in tile-drained soils. The resulting water flow in a tile drained soil during a rain event can be dominated by flow of infiltrating water through macropores. When the rain slows or stops, flow through macropores will be supplied by water from micropores.

In one study on the U of I South Farms, herbicides were detected in tile effluent and shallow groundwater immediately after a post-application rain. These results pointed clearly to the importance of preferential transport due to macropores. In my research and in the research of many others, herbicides, nutrients, bacteria, hormones, and antibiotics applied to the land surface through normal agricultural methods, are commonly detected in tile effluent with signatures attributed to rapid transport through macropores. In a 1996 study, we showed that a tracer applied parallel to a subsurface drainage tile, at an offset of 15 meters from the tile, was detected in tile effluent after less than 1” of rainfall. Other observations from that study demonstrated how tile effluent during and immediately following high-intensity rainfall events was dominated by rainwater, relative to later times when the effluent was composed primarily of water that had been in soil micropores prior to the rainfall.

SUMMARY

Regarding macropores, if a definition is deemed necessary, the USDA provides a useful definition. Pores less than 0.08mm are considered micropores and those greater or equal to 0.08mm are considered macropores.

Macropores are ubiquitous in soils and can provide a means for preferential transport of a portion of any land-applied chemical. If the concentration and half-life are sufficient and the electrical charge of the chemicals is neutral or negative, there is real potential that some of these chemicals can be transported rapidly to significant depth. If the water table is within 5’ of land surface, these chemicals can be transported to the water table and then laterally, through macropores at the upper portion of the saturated zone. With regards to livestock waste applied to fields without tile drains, it appears that the constituents with the largest risk for transport to aquifers within 50 ft of land surface are likely to be nitrate, pathogens, hormones and antibiotics. In areas where there are no aquifers within 50 ft of land surface and where there are no private large-diameter water supply wells within 800 ft, it appears unlikely that macropores will facilitate any significant contamination to surface water or groundwater supply well from properly-managed livestock waste application.

Regarding subsurface drainage tiles, it needs to be recognized that land applied chemicals are often found in tile effluent, and can be rapidly discharged to surface water through tile drainage systems. The age and liquid content of the applied manure may influence the likelihood of transport of significant concentrations of pollutants to drainage tiles. There does not appear to be any way to ensure discharge of pollutants at acceptable levels without monitoring. Significant concern needs to be given to the risk of pathogen, hormone or antibiotic transport to surface waters through subsurface drainage tiles due to land application of livestock waste.

COMMENTS WITH LANGUAGE IN PROPOSED RULE CHANGES

Section 501.254. Definition of Groundwater. I would propose the following:
Underground water which occurs within the saturated zone ~~and~~ of geologic materials where the fluid pressure in the pore spaces is equal or greater than atmospheric pressure~~.~~, as demonstrated by the water level in a shallow well.

502.106(b)(1). This section notes that the Agency cannot require NPDES permits for certain CAFOs unless they meet specific conditions. Subsection 1 includes pollutants being discharged into waters through man-made ditches, flushing systems or other similar man-made devices. I would encourage consideration for inclusion of subsurface drainage tiles in this section. There are many published studies of drainage tile discharge with high concentrations of pollutants from livestock waste application. Given all the variables associated with implementation of a successful livestock management plan, it seems that monitoring would be needed to ensure a given waste application was not resulting in contamination of surface waters.

502.615 (a)(6). Nutrient Transport Potential…Tile Inlet Locations. Tile drainage research has shown that land-applied chemicals can be rapidly transported to subsurface drainage tiles, through macropore flow, not through tile inlets. I would encourage that subsurface tile drains be considered as potential routes for contamination of surface waters.

502.620. Protocols to Land Apply Livestock Wastes. Subsection (k). This suggests that livestock wastes must be applied at no greater than 50% of the agronomic nitrogen rate for land where the minimum depth to seasonal high water table is less than or equal to 2' from land surface. The rules do not specify how this would be determined. The USDA Soil Surveys are a reliable predictor of soil characteristics, including the seasonal high water table depth. The most recent USDA NRCS Soil Survey could be used to determine the seasonal high water table depth. This information could be ignored, if the field was found to be underlain by a systematic drainage tile network.

502.630(a)(1)(A) Winter Application Prohibition. The rule currently states that surface application of livestock waste on frozen, ice covered, or snow covered ground is prohibited, unles..(A) No practical alternative measures are available to handle the livestock within storage facilities or to dispose the livestock waste at other sites… I am concerned that this approach may be insufficient to protect surface water quality. Liquid components of the waste cannot infiltrate the soil until the soil is thawed and drained. During warm spells, the soil will thaw from the top down. The livestock waste will be frozen to the surficial ice or snow and will be included in runoff at any melting event.

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Mehnert, E. W.S. Dey, H.H. Hwang, D.A. Keefer, T.R. Holm, T.M. Johnson, W.C. Beaumont, M.C.F. Wander, R.A. Sanford, J.M. McDonald, S. Shiffer, 2005. Mass Balance of Nitrogen and Phosphorous in an Agricultural Watershed: The Shallow Groundwater Component. Illinois State Geological Survey Open-File Series Report 2005-3, 123p.

Links to articles of relevance to the proposed rules.
USDA publication on soil quality indicators, with the classification of micropore/macropores.
http://soils.usda.gov/sqi/assessment/files/soil_structure_sq_physical_indicator_sheet.pdf

Peer reviewed article discussing experiences from Iowa and recommendations for policy changes to alleviate the nutrient management problems associated with CAFOs.
http://www.jswconline.org/content/55/2/205.short

Peer reviewed article summarizing a review of literature on the movement and persistence of fecal bacteria in agricultural soils and subsurface drainage. Abstract suggests field studies observed, "significant transport of bacteria to tile drains under common manure management practices. " Also, results, "suggest that the transport of bacteria through undisturbed soils is primarily controlled by macropore flow phenomena."
http://lshs.tamu.edu/docs/lshs/end-notes/movement%20and%20persistence%20of%20fecal%20bacte-1148364108/movement%20and%20persistence%20of%20fecal%20bacteria%20in%20agricultural%20soils%20and%20subsurface%20drainage%20water.pdf

Peer reviewed article looking at leaching of estrogenic hormones to drainage tile from application of hog manure. From the abstract "Transport of estrogens from the soil to the aquatic environment was governed by pronounced macropore flow and consequent rapid movement of the estrogens to the tile drains. These findings suggest that the application of manure to structured soils poses a potential contamination risk to the aquatic environment with estrogen, particularly when manure is applied to areas where the majority of streamwater derives from drainage water."
http://pubs.acs.org/doi/abs/10.1021/es0627747

Peer reviewed article showing increased risks of nitrate leaching in Iowa tile drained soils under livestock waste application.
http://www.sciencedirect.com/science/article/pii/S0167880905000927

Peer reviewed article showing potential for increased pollution risk with certain applications of liquid swine manure.
https://www.soils.org/publications/jeq/abstracts/36/2/580

Respectfully submitted,

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CERTIFICATE OF SERVICE

I, Donald A. Keefer, herby certify that I have filed the attached **NOTICE OF FILING** and **PRE-FILED TESTIMONY OF MYSELF** upon the attached service list by depositing said documents in the United States Mail, postage prepaid, in Champaign, Illinois on October 24, 2012.

Respectfully submitted,

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