TESTIMONY OF SAMUEL V. PANNO (updated October 24, 2012)

I. Introduction

My name is Samuel V. Panno. I am a Senior Geochemist with the Illinois State Geological Survey, Prairie Research Institute, University of Illinois. I have extensive expertise in karst geology, karst hydrology and groundwater chemistry and have published more than 100 peer-reviewed original research papers in those fields.

I am providing testimony as an expert witness on karst regarding proposed changes to regulations (35 Illinois Administrative Code, Parts 501, 502, 504) made by the Illinois Environmental Protection Agency (IEPA) currently under consideration by the Illinois Pollution Control Board.

II. Qualifications

I am an expert in the geology, hydrogeology and groundwater chemistry of karst and other aquifers. My current professional position is Senior Geochemist with the Illinois State Geological Survey, Prairie Research Institute, University of Illinois. I am a Certified Ground Water Professional with The Association of Ground Water Scientists and Engineers, a division of the National Ground Water Association. I have authored and co-authored over 100 peer-reviewed original research articles in a variety of areas of geology, hydrogeology and groundwater chemistry. Some representative publications, most of which I am senior author, include:

Panno, S.V. and Bourcier, W.L., 1990. Glaciation and saline/fresh-water mixing as a possible cause of cave formation in the eastern midcontinent region of the United States: A conceptual model, *Geology*, v. 18, no. 8, p. 769-772.

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Weibel, C.P. and **Panno, S.V.**, 1997. Karst terrains and carbonate bedrock of Illinois. Illinois State Geological Survey, *Illinois Map Series* 8, 1:500,000 Scale.

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Panno, S.V. and D.E. Luman. 2012. Karst map of Monroe County, IL**.** *Illinois State Geological Survey, Illinois County Geologic Map, ICGC Monroe County-SD*, 1:62,500, Report 12 p.

The published research above describes the location and extent of karstified carbonate rock throughout Illinois and its potential for groundwater contamination. Also relevant is my current research using LiDAR imagery, aerial photography and field work to map karst features in Illinois including cover-collapse sinkholes, solution-enlarged crevices visible in road cuts, quarries and outcrops, and associated lineaments. Additional current research includes sampling of groundwater from karst regions of the Midwestern US for bacterial analysis, including karst regions of Wisconsin that are having groundwater quality problems as a direct result of manure application by nearby confined animal feeding operations (CAFOs). I have witnessed, firsthand, the runoff of brown, liquid manure applied to frozen ground in a karst region of Wisconsin. The manure and melt waters raced across fields and residences and entered private wells; in one instance, the manure and melt water flowed, unchanged, from a resident's faucet.

III. Karst Areas of Illinois

Introduction

Carbonate rock comprises approximately 25% of the bedrock surface of Illinois (Weibel and Panno 1997). Carbonate bedrock ranges from Ordovician to Mississippian in age and is located along the margins of the Illinois Basin and along major geologic structures. Sediments overlying carbonate bedrock in Illinois range from zero to more than 100 m of glacial till and loess. Carbonate rock is a major source of groundwater in Illinois and throughout the world with the most productive aquifers having secondary porosity (fractures and bedding plane partings) that permits the transport of water into and through the rock. Porosity is further enhanced by dissolution of carbonate rock and the formation of conduit systems along solution-enlarged fractures and along bedding planes (White 1988). The movement of surface waters (rainwater and snowmelt), through the soil, and into fractures in soluble carbonate bedrock is responsible for the development of karst terrains. Because of the generation of carbon dioxide by root respiration and microbial activities in soils overlying carbonate rock, infiltrating water becomes acidic prior to entering fractures, joints and bedding planes in carbonate rock. Small amounts of calcite and/or dolomite (the dominant minerals of carbonate rock) dissolve releasing calcium, magnesium and bicarbonate ions until the water approaches saturation with calcite and/or dolomite (White 1988). Slow dissolution over thousands to hundreds of thousands of years gradually enlarges joints, fractures, and pathways along bedding planes through which groundwater moves. Some solution-enlarged pathways become large conduits or caverns through which groundwater flows to points of discharge (e.g., springs).

The term "karst" is defined by Ford and Williams (1989) as "…terrain with distinctive hydrology and landforms arising from a combination of high rock solubility and well developed secondary porosity." Quinlan et al. (1991) define a karst aquifer, in terms of hydraulics, as "…an aquifer in which flow of water is or can be appreciable through one or more of the following: joints, faults, bedding planes, and cavities – any or all of which have been enlarged by dissolution of bedrock." Soluble bedrock in Illinois includes limestone and dolomite. Quinlan et al. (1991) further state that "as a generalization, if carbonate rocks such as limestone, marble, or dolomite are present,…assume that the water moving through these rocks is in a karst aquifer – until or unless convincingly proved otherwise. This statement is correct probably 95% of the time. Assume also an Orwellian nature to the definition of a karst aquifer: All carbonate terranes are karstic and underlain by one or more karst aquifers, but some are more karstic than others." Of those areas within Illinois that are underlain by carbonate rock, about 35% of that area or 9% of the state (Figure 1) are close enough to the surface to show exposures and be part of the freshwater aquifers currently being used by residents and municipalities. These areas are included in five regions that contain karst features at and near the surface (Weibel and Panno 1997; Panno and Weibel 1997; Panno and Weibel 2010). Berg (2001), in discussing sensitivity of groundwater to contamination, stated that "Karst areas are the most sensitive of any geologic setting because contaminants can be transported very rapidly." Features that are typical of karst terrain include closed depression (sinkholes), caves, large springs, fluted rock outcrops (including cutters and grikes along road cuts and in quarries) (Ford and Williams 1989), blind valleys, swallow holes (White 1988), lineaments (Lattman and Parizek 1964) and recently discovered crop lines (http://www.isgs.illinois.edu/sf-archive/crop-lines.shtml). However, the apparent absence of karst features on the ground surface (e.g., sinkholes) does in no way preclude the presence of an underlying karst aquifer. This is because sinkholes are part of a continuum that extends from large-scale sinkhole drains down to nano-scale macropores (C. Alexander, University of Minnesota, personal communications, 2009).

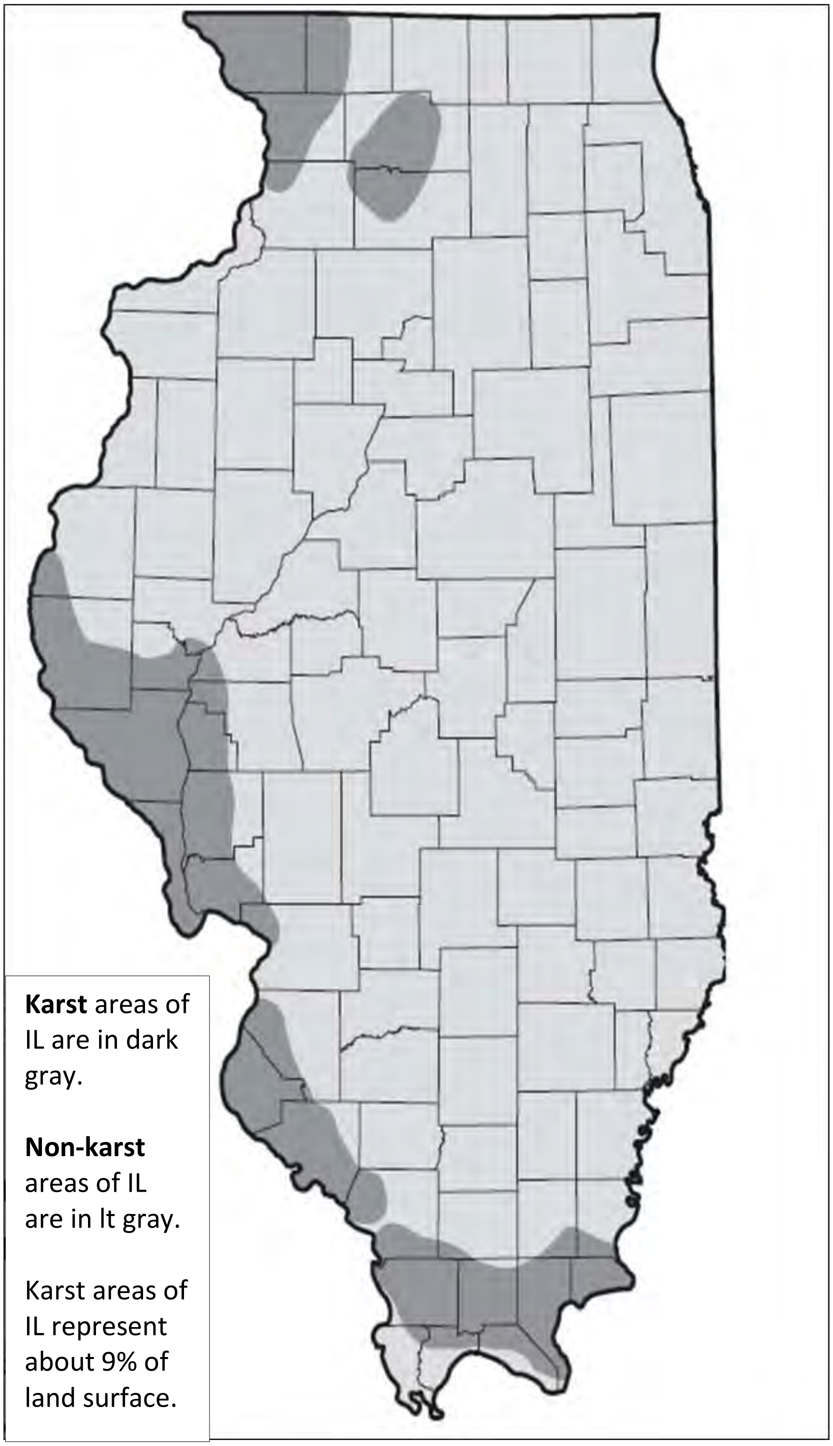

Figure 1. Map of the karst areas of Illinois. Specifically, the map only shows those areas underlain by karstified carbonate rock and overlain by less than 50 feet of unconsolidated materials are represented in dark gray. From Weibel and Panno (1997).

Recent work by Lindsey et al. (2010) has shown that sinkhole density is an important parameter from an aquifer vulnerability assessment point of view. Lindsey et al. (2010) develop three categories for sinkhole density using karst areas from four states in the eastern United States, which include the following: low (less that 1 sinkhole/100 km^2); medium (1-25 sinkholes/100 km^2); and high (greater than 25 sinkholes/100 km^2). Linsey et al. (2010) also determined that nitrate concentrations, indicative of anthropogenic (typically agricultural lands) contamination, were significantly greater in high and medium sinkhole density areas than low sinkhole density areas. The relatively large pathways present in fissured or karstified carbonate rock allow rapid movement of water into and through the rock bodies. These rock bodies often constitute locally important aquifers in Illinois: however, when near land surface, fissured and karst aquifers are highly susceptible to surface-derived contamination. Recharge to the karst aquifers often is rapid, can be analogous to water movement to and through agricultural drainage tiles (Schilling and Helmers 2008), and carries with it materials (often macroscopic) from the land surface that can include human and animal wastes, agricultural chemicals, urban runoff, and other waste products associated with the human culture of a region. In contrast, recharge to non-karst aquifers typically undergoes a slow migration through fine, granular materials (e.g., thick, clay-rich glacial diamicton) that generally provide sufficient time and an environment for chemical, biological, and physical degradation and retardation of pollutants. Unfortunately, residents who draw groundwater from karst aquifers for domestic use often risk ingesting surface-borne contaminants.

It is my professional opinion that changes proposed in Section 502.620 h, j are not sufficiently protective of groundwater and nearby surface water quality. According to the proposed changes, less than one foot to two feet of soil cover over a karst aquifer would be acceptable for land applied liquid manure. In a karst terrain, two feet of unconsolidated sediment provides little protection for the underlying karst aquifer from surface-borne contaminants like nitrate and enteric bacteria. Macropores (fractures in soils) can extend for six or more feet into the soil and provide a fast-track for recharge water that can bypass any beneficial effects of the soil zone. Fifty feet of unconsolidated material overlying a karst aquifer is the thickness necessary for protection (Dr. Calvin Alexander, University of Minnesota, personal communications, 2012).

Karst in Illinois

Cover-collapse sinkholes have long been the indicator of choice of regulators for karst terrain and underlying karst aquifers. While it is true that sinkholes are *commonly* present and are indicators of karst terrain, sinkholes are not *always* present or obvious in areas underlain by extremely sensitive karst aquifers. Further, not all sinkholes are static entities; that is, sinkholes can be filled in by human activities such as plowing (e.g., Panno and Luman 2012). Unfortunately, the pathway to the bedrock aquifer can still be present, but not obvious. Therefore, if one characterizes a terrain solely on the presence-absence of sinkholes, they risk misidentifying an area such as one with thin soils overlying a karst aquifer. Further, sinkholes are not the only vector for infiltration into a karst aquifer. Macropores (e.g., desiccation cracks, worm holes, root channels) within the unconsolidated sediment extend several meters into the soil zone and can allow contaminated surface water to quickly bypass the soil zone and rapidly enter the underlying aquifer with little or no change. It is possible to see the depth that surface-borne contamination has reached using profiles of geochemical data (e.g., nitrate and chloride) from municipal and private well samples (e.g., Hackley et al. 2007; Panno et al. 1996; Panno et al. in review) and comparing their concentrations to background values determined for Illinois by Panno et al. (2006).

Karstified carbonate rock in Illinois contains a secondary porosity and permeability thanks to abundant fractures in soluble rock and the formation of solution-enlarged crevices. Many assume that if there are no sinkholes in an area, the area is by definition, not karst. This assumption is incorrect because depending on the thickness of the soil zone, sinkholes may be noticeable or be obscured by land use (esp. row-crop agriculture). Further, in areas with very thin soils (less than 25 feet) or thick clay-rich soils, sinkholes may not be obvious or present; however, the underlying carbonate bedrock can be (and usually is) replete with solution-enlarged crevices that constitute a karst aquifer. Surface-borne contaminants can enter the aquifer via macropores in the soil, via streams that flow from areas with thick, clay-rich sediments and no sinkholes to areas with numerous sinkholes and losing streams, or from excavations. Consequently, any portion of Illinois underlain by carbonate rock and with less than 50 feet of overburden may qualify as karst terrain. An example of the problems associated with less than 50 feet of unconsolidated material overlying karstified bedrock is the development of sinkholes in a school yard resulting from pumping of a nearby well in Dongola, IL (Panno et al. 1994).

Because many of the residents in rural areas have private wells within the karst aquifers, and because municipalities adjacent to rural areas have wells within karst aquifers, effluent of any kind discharged onto the surface could enter wells that tap into the creviced network and groundwater flow rates within karst aquifers are often at miles per hour.

IV. RECOMMENDATIONS

I strongly recommend that Very Large to Large CAFOs should not be permitted in karst areas of the state as defined by carbonate bedrock where the thickness of unconsolidated materials is less than 50 feet, particularly in those areas lacking in clay-rich glacial till (i.e., Driftless Areas of Illinois). Karst areas should be identified from a combination of previous publications (e.g., Weibel and Panno 1997), and regional and site-specific investigations involving field work using appropriate techniques for karst studies (e.g., trenching and dye tracing) as outlined by Quinlan et al. in Environmental Protection Agency (1989).

A major problem with the proposed changes to 35 Illinois Administrative Code, Parts 501, 502, 504 is the use of “sinkholes” as *the* indicator of karst. Karst should be defined as any area with carbonate bedrock showing fractures, joints, partings and/or dissolution features (e.g., solution-enlarged crevices) capable of transmitting water. It is important to understand that sinkholes are only one of many indicators of karst terrain and underlying karst aquifers. Quinlan et al. (1991) stated that “some people confuse a sinkhole with the karst itself. This is like confusing Cyrano de Bergerac’s nose with the man himself. All will agree that there was a lot more to Cyrano than just his nose. So also, there is far more to a karst than just a sinkhole or cave.” Further, sinkholes (especially cover-collapse sinkholes that are common in Illinois) are not permanent features, but can be filled in as the result of human activities (e.g., plowing of fields) particularly where soils are thin (less than 25 feet). Regardless of sinkhole expression, the pathways to bedrock are still present and the sinkholes can and typically will reappear. Other indicators of karst terrain include creviced exposures (natural outcrops, road cuts, and quarries), caves, trellised stream patterns, lineaments and recently discovered crop lines (http://www.isgs.illinois.edu/sf-archive/crop-lines.shtml). Consequently, incipient sinkholes and macropore pathways to the underlying karst aquifer are present in the karst areas of Illinois and can remain undetected. Unconsolidated materials of less than 25 feet provide insufficient protection to groundwater from land application of liquid manure produced at these facilities. Optimally, areas potentially suitable for siting of large and very large CAFOs should be identified based on the absence of all indicators of karst terrain and a minimum of 50 feet of unconsolidated materials overlying karst bedrock.

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Thank you for the opportunity to provide testimony regarding proposed changes to Title 35 Illinois Administrative Code, Parts 501, 502, 504.

Respectfully submitted,

Samuel V. Panno, M.S., CGWP
Illinois State Geological Survey
Prairie Research Institute
University of Illinois

TESTIMONY OF SAMUEL V. PANNO

I. Introduction

My name is Samuel V. Panno. I am a Senior Geochemist with the Illinois State Geological Survey, Prairie Research Institute, University of Illinois. I have extensive expertise in karst geology, karst hydrology and groundwater chemistry and have published more than 100 peer-reviewed original research papers in those fields.

I am testifying today on behalf of the Illinois State Geological Survey, which is part of the Prairie Research Institute at the University of Illinois in Champaign-Urbana, regarding proposed changes to regulations (proposed amendments to 35 Illinois Administrative Code, Parts 501, 502, 504) made by the Illinois Environmental Protection Agency (IEPA) currently under consideration by the Illinois Pollution Control Board.

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I am an expert in the geology, hydrogeology and groundwater chemistry of karst aquifers. My current professional position is Senior Geochemist with the Illinois State Geological Survey, Prairie Research Institute, University of Illinois. I am a Certified Ground Water Professional with The Association of Ground Water Scientists and Engineers, a division of the National Water Well Association. I have authored and co-authored over 100 peer-reviewed original research articles in a variety of areas of geology, hydrogeology and groundwater chemistry. Some representative publications include:

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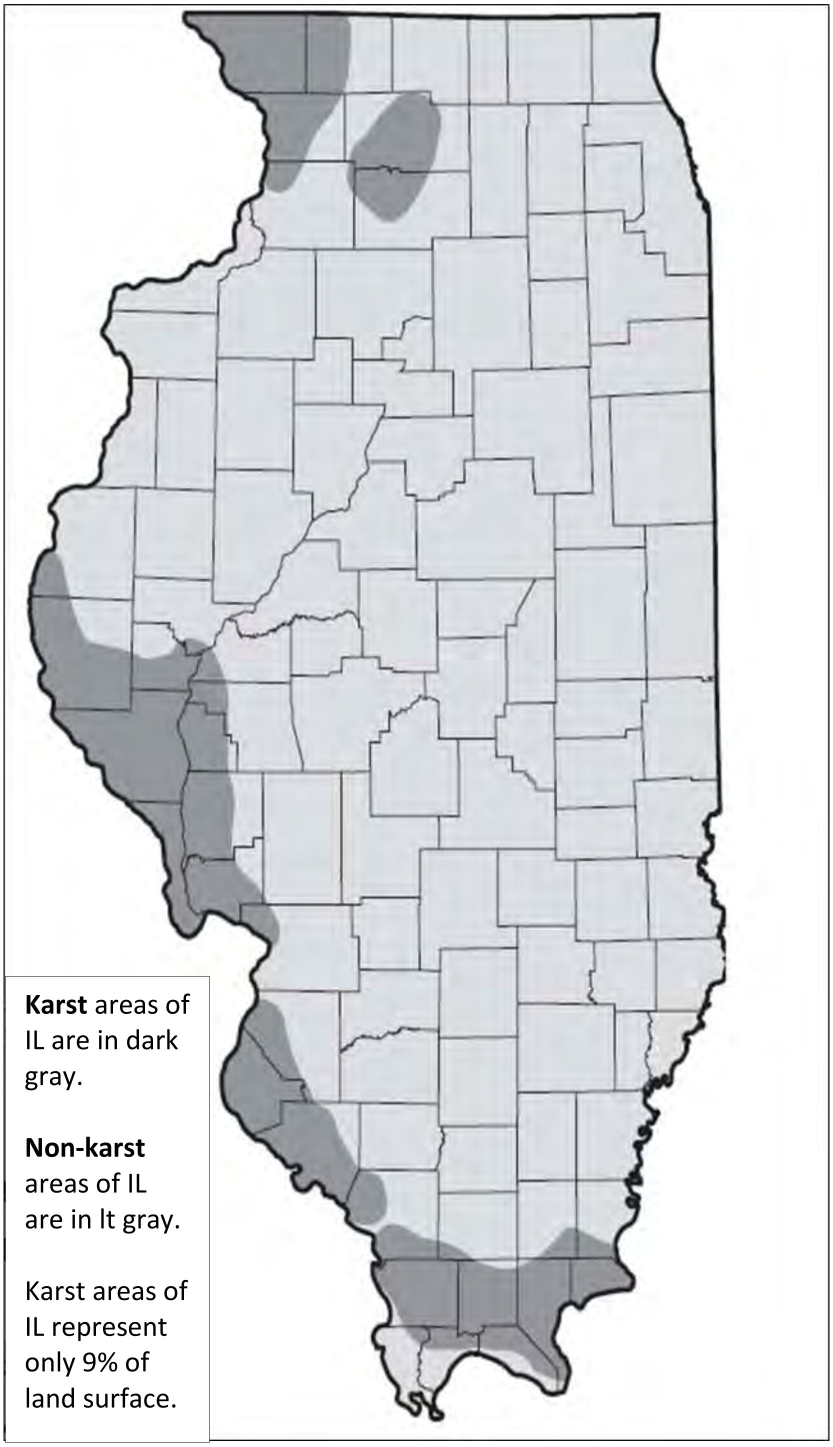
The late Dr. J. Quinlan, a foremost expert in karst hydrogeology, stated that if the bedrock of an area is composed of carbonate rock, the area should be considered karst and underlain by a karst aquifer unless proven otherwise (Malcolm Field, U.S. Environmental Protection Agency, personal communications, 2010). The term "karst" is defined by Ford and Williams (1989) as "…terrain with distinctive hydrology and landforms arising from a combination of high rock solubility and well developed secondary porosity." Of those areas within Illinois that are underlain by carbonate rock, 35% of that area (9% of the state) is included in five regions that contain karst features at and near the surface (Weibel and Panno 1997; Panno and Weibel 1997; Panno and Weibel 2010). Berg (2001), in discussing sensitivity of groundwater to contamination, stated that "Karst areas are the most sensitive of any geologic setting because contaminants can be transported very rapidly." Features that are typical of karst terrain include closed depression (sinkholes), caves, large springs, fluted rock outcrops (including cutters and grikes along road cuts and in quarries) (Ford and Williams 1989), blind valleys, swallow holes (White 1988), lineaments (Lattman and Parizek 1964) and crop lines ((http://www.isgs.illinois.edu/sf-archive/crop-lines.shtml). However, the apparent absence of karst features on the ground surface (e.g., sinkholes) does in no way preclude the presence of an underlying karst aquifer. This is because sinkholes are end-members of a continuum that extends from large-scale sinkhole drains down to nano-scale macropores (C. Alexander, University of Minnesota, personal communications, 2009).

Figure 1. Karst areas of Illinois. Specifically, those areas underlain by karst aquifers and with unconsolidated materials less than 50 feet thick. From Weibel and Panno (1997).



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It is clear to me that changes proposed in Section 502.620 h, j are not sufficiently protective of groundwater and nearby surface water quality. According to the proposed changes, less than one foot to two feet of soil cover over a karst aquifer would be acceptable for land applied liquid manure. In a karst terrain, two feet of unconsolidated sediment provides little protection for the underlying karst aquifer. Macropores (fractures in soils) can extend for six or more feet into the soil and provide a fast-track for recharge water that can bypass any beneficial effects of the soil zone. Fifty feet of unconsolidated material overlying a karst aquifer is the thickness necessary for protection (Dr. Calvin Alexander, University of Minnesota, personal communications, 2012).

Karst in Illinois

Cover-collapse sinkholes have long been the indicator of choice of regulators for karst terrain and underlying karst aquifers. While it is true that sinkholes are present and are indicators of karst terrain, sinkholes are not always present or obvious in areas underlain by extremely sensitive karst aquifers. Further, not all karst areas of Illinois have obvious sinkholes and not all sinkholes are static entities; that is, sinkholes can be filled in by human activities (e.g., plowing). Unfortunately, the pathway to the bedrock aquifer can still be present, but not obvious. Therefore, if one characterizes a terrain solely on the presence-absence of sinkholes, they risk misidentifying an area such as one with thin soils overlying a karst aquifer. Further, sinkholes are not the only vector for infiltration into a karst aquifer. Macropores (e.g., desiccation cracks, worm holes, root channels) within the unconsolidated sediment extend several meters into the soil zone and can allow contaminated surface water to quickly bypass the soil zone and rapidly enter the underlying aquifer with little or no change.

Karstified carbonate rock in Illinois contains a secondary porosity and permeability thanks to abundant fractures in soluble rock and the formation of solution-enlarged crevices. Many assume that if there are no sinkholes in an area, the area is by definition, not karst. This assumption is incorrect because depending on the thickness of the soil zone, sinkholes may be noticeable or be obscured by land use (esp. row-crop agriculture). Further, in areas with very thin soils (less than 25 feet) or thick clay-rich soils, sinkholes may not be obvious or present; however, the underlying carbonate bedrock can be (and usually is) replete with solution-enlarged crevices that constitute a karst aquifer. Surface-borne contaminants can enter the aquifer via macropores in the soil, via streams that flow from areas with thick, clay-rich sediments and no sinkholes to areas with numerous sinkholes and losing streams, or from excavations. Consequently, any portion of Illinois underlain by carbonate rock and with less than 50 feet of overburden may qualify as karst terrain.

Because many of the residents in rural areas have private wells within the karst aquifers, and because municipalities adjacent to rural areas have wells within karst aquifers, effluent of any kind discharged onto the surface could enter wells that tap into the creviced network and groundwater flow rates within karst aquifers are often at miles per hour.

IV. RECOMMENDATIONS

I strongly recommend that Very Large to Large CAFOs should not be permitted for construction in karst areas of the state as defined by Weibel and Panno (1997) or the U.S. Geological Survey (http://water.usgs.gov/ogw/karst/), or over carbonate bedrock where the thickness of unconsolidated materials is less than 50 feet (as defined in Illinois by the Illinois State Geological Survey Drift Thickness Map (http://www.isgs.illinois.edu/maps-data-pub/statewide.shtml), particularly in those areas lacking in clay-rich glacial till (i.e., Driftless Areas).

It is important to understand that sinkholes are only one of many indicators of karst terrain and underlying karst aquifers. In addition, sinkholes (especially cover-collapse sinkholes that are common in Illinois) are not permanent features, but can be filled in as the result of human activities (e.g., plowing of fields) particularly where soils are thin (less than 25 feet). Regardless of sinkhole expression, the pathways to bedrock are still present and the sinkholes can and typically reappear. Other indicators of karst terrain include creviced exposures (natural outcrops, road cuts, and quarries), caves, trellised stream patterns, lineaments and crop lines (http://www.isgs.illinois.edu/sf-archive/crop-lines.shtml). Consequently, incipient sinkholes and macropore pathways to the underlying karst aquifer are present in the karst areas of Illinois and can remain undetected. Unconsolidated materials of less than 25 feet provide insufficient protection to groundwater from land application of liquid manure produced at these facilities. Optimally, all indicators of karst terrain and 50 feet of cover by unconsolidated materials overlying creviced bedrock should be used to define karst areas susceptible to groundwater contamination from these facilities.

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Thank you for the opportunity to provide testimony regarding proposed changes to Title 35 Illinois Administrative Code, Parts 501, 502, 504.

Respectfully submitted,

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