EXHIBIT 1

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Robert Michaels, Senior Attorney
Environmental Law and Policy Center
35 East Wacker Drive, Suite 1600
Chicago, IL 60601

Dear Mr. Michaels:

Privileged and Confidential
Attorney Work Product

As requested, we have prepared the following discussion about the impact of applying liquid waste derived from concentrated animal feeding operations (CAFOs) to farm fields in the Maumee River Basin that drains into the Western Lake Erie Basin. We have focused on the application of these waste products to tile-drained fields used for the production of corn and soybeans, as is common in the three state (Indiana, Michigan and Ohio) Maumee River Basin.

As discussed in this letter, we have the following conclusions:

- Fields in the Maumee River Basin are usually drained using subsurface tile drains;
- The soils in the Maumee River Basin are prone to fracturing resulting in the rapid transport of dissolved reactive phosphorus (DRP) to tile drains and drainage ditches;
- Liquid animal manures are widely applied in this watershed;
- When liquid manures are applied to the surface, they pool on the field, then drain through macropores to the subsurface and/or are washed offsite as runoff;
- DRP moves through the subsurface with water and will enter the tile drains or recharge baseflow of the streams;
- Tile drains and baseflow discharge to drainage ditches or streams, transporting the DRP to the Western Lake Erie Basin;
- We have known since 2013, that over 90% of DRP delivered to the Western Basin of Lake Erie came from agricultural practices (including the application of liquid manures); and
- Standard BMPs and the 4Rs (right source, right rate, right time and right place) have not been effective at reducing DRP impact to the Western Lake Erie Basin.

The resumes for the authors are provided in Attachment A. Dr. Julie Weatherington-Rice is a soil scientist with extensive experience in the Western Lake Erie Basin over the last forty years. Dr. Weatherington-Rice has been a pioneer in the science and applications relating to water flow in soils, specifically as it relates to secondary porosity and fracture flow. Dr. Kerry Zwierschke is a Professional Engineer in the state of Ohio with extensive experience in environmental and agricultural engineering. Dr. Zwierschke has over fifteen years of experience with data analysis, engineering, hydrology, hydrogeology and contaminant transport in Ohio.

Water and Contaminant Movement in Soils

Water and contaminants that move with water move downward through the soil profile in two ways. Water and dissolved contaminants move through primary porosity matrix flow and through secondary porosity macropores. Primary porosity is the space between the particles of the soil matrix while secondary porosity (for example fractures) is formed post-deposition. When thinking about primary and secondary porosity, it can be helpful to think about a brick. The particles of a brick can be thought of as grains of soil. If a brick is submerged in water, the inside of the brick only gets wet after an extended period of submersion (primary porosity). If you pile bricks up and pour water over them, water is primarily transported around the bricks through the gaps (secondary porosity). A PowerPoint presentation addressing these pathways *"How water moves from the surface to underlying aquifers"* can be found on the Association of Ohio Pedologists (AOP) web site (Weatherington-Rice, 2022a).

Secondary macropores include physical/chemical-controlled fractures and biologically-controlled biopores that are formed by plant roots and earthworms. Soil scientists have been studying these processes for more than half a century and can determine if secondary porosity will control discharge, allowing for the rapid migration of liquid manures into tile drainage systems (where present) and into the receiving waters. This research has not been restricted to Ohio but has been documented and established worldwide. We have included references from Pennsylvania (Yu et al., 2014), Iowa (Burkart et al., 2004; Helmke et al., 2005) and Canada (Dadfar et al., 2010). As a result of this research, it is possible to predict whether a soil will fracture and, therefore, whether water movement by secondary porosity is a significant pathway for transport of water and contaminants. See Attachment B for additional technical information.

Maumee River Basin Soil Types

The Maumee River Basin is a significant drainage source for the Western Lake Erie Basin and incorporates portions of southeastern Michigan (drained by the St. Joseph River); northeastern Indiana where the Ohio/Indiana St. Marys River and the Michigan/Ohio/Indiana St. Joseph River converge at Fort Wayne to form the Maumee River; and northwestern Ohio. This area is the subject of a United States Geological Survey Water-Resources Investigation Report (Myers and Metzker, 2000). The soils in Ohio, Indiana and Michigan within the watershed are derived from glacial tills (occasionally tile-drained for agriculture), fine-grained stratified sediments (lacustrine deposits, almost always tile drained for agriculture) and coarse-grained stratified sediments (beach ridges and dunes from previous glacial lakes that usually are relatively permeable and do not require tile drainage) (Figures 1 and 2).

The majority of the Maumee River Basin is in Ohio and is incorporated into the Huron-Erie Lake Plains in the *Physiographic Regions of Ohio* map (Figure 3). The *Soils Regions of Ohio* map identifies the area as Region 1-the Lake Plains (Figure 4). The primary soils associations of the agriculturally tile-drained portions found in the region are Hoytville, Nappanee, Paulding and Toledo soils. Because of the nature of the lake-derived glacial deposits and the overlying lacustrine materials, for the most part, these soils are clay loams, silty clays, silty clay loams, loams, and sandy loams. Where beach ridges are present, the Toledo soils can be classified as loamy fine sands or sands. These soil classifications are critical because they can be used to determine if an agricultural field will drain primarily through secondary porosity macropore flow or by primary porosity.

When the soils of Region 1 of the Ohio map are matched against Kim's Textural Triangle (Figure 5), the Hoytville, Nappanee and Paulding soils fall within the area expected to be fractured (unshaded area in Figure 5). Those that are too coarse to be within the fractured zone have 76% or more sand content and, therefore, have such high primary porosity that water and dissolved contaminants drain rapidly through the soil profile in the absence of secondary fractures. Given these soils, water applied to agricultural fields in the Maumee Basin will drain rapidly through the soil profile either by primary porosity (sandy soils in the colored area of Figure 5) or by secondary macropore porosity (soils in the unshaded area of Figure 5).

Tile Drainage in the Maumee River Basin

Historically, the fine-grained lacustrine lowland of the Maumee River Basin was known as the Black Swamp. It was considered unusable before the advent of subsurface agricultural drainage systems. While the larger region settled in the early 1800s, the Black Swamp took longer to settle because extensive drainage systems had to be installed to make the land usable for agriculture. These efforts began about 1850 and continue to this day.

Subsurface drainage (also referred to as tile drainage) is accomplished today by burying perforated plastic pipes in the ground (previously clay or other materials were used). Excess water in the soil profile enters the pipes and is removed from the soil to artificially lower the water table (Ghane, 2018). According to Myers and Metzker (2000), in 1994 approximately 70% of the Maumee River Basin was agricultural. Given the soils in the watershed, in order to be used for agriculture, the water table in these areas must be lowered using subsurface drainage. AgTile-US (Valayamkunnath et al., 2020), provides estimates for land in the USA which uses subsurface tile drainage (Figure 6). Figure 6 shows that the Maumee River Basin has many areas that have subsurface drainage tiles.

Use of Liquid Animal Manure in Agriculture

During the 20th century, dry commercial fertilizer (P_2O_5) was applied at the same time that the seed was planted. The dry fertilizer was placed in a box on the planting bar next to the seed box and the fertilizer was spread into a trench next to the seed trench and then both trenches were closed (using two and four row corn planters). This application was known as banding. These fertilizers were commercially available in the Maumee River Basin. For instance, Federal

Fertilizer built their plant in 1950 in Butler, Indiana in the watershed, six miles from the Ohio State line, (City of Butler Indiana, 2022). Phosphorus applied in this form binds to the soil until plant roots absorb it for plant growth. Therefore, if the soil stays in place, so does the phosphorus (Weatherington-Rice, 2022b).

However, even in the flat Western Lake Erie Basin, soil erosion occurs. With the movement of soil off the farm fields, the dry phosphorus also left the farm fields, contributing to the loading of phosphorus in Lake Erie. By the 1980s, The US Department of Agriculture (USDA) Soil Conservation Service (SCS), later the Natural Resources Conservation Service (NRCS) and the local county soil and water conservation districts encouraged the implementation of no-till and reduced tillage farming practices to reduce soil erosion from farm fields. These efforts were successful and phosphorus levels in Lake Erie reduced as erosion from fields was also reduced.

After 2000, the DRP levels in Lake Erie started to increase. While the phosphorus loading rates associated with erosion diminished (which came from solid P attached to soil particles being washed off the fields into rivers that discharge to Lake Erie), the dissolved reactive phosphorus (DRP) levels began to increase. This situation has continued to affect the water quality of the Western Lake Erie Basin (Weatherington-Rice, 2022b). A primary driver of this rebound is that phosphorus was being applied to agricultural fields in the watershed in different forms. Farmers moved away from using a commercial dry form of phosphorus to using animal-based manure sources of phosphorus and broadcast phosphorus fertilizer. Currently, most phosphorus being applied in the watershed comes from two sources, liquid animal manures (which are mostly water and can be surface applied or injected below the surface of the soil) and commercial fertilizer which is often dry.

As farm fields got larger and farming equipment got larger and was able to plant many more rows of seed, the spacing on the tool bar replaced the fertilizer boxes with more seed boxes. This necessitated a different application method for the phosphorus fertilizer. The current common practice is to broadcast the phosphorus fertilizer over the surface of the fields in the fall after harvest. For efficiency, farmers typically apply enough phosphorus for two to four years of plant growth.

Starting in the 1970s, traditional, low concentration animal husbandry (resulting mostly in solid manure) began to be replaced with CAFOs and smaller concentrated animal husbandry systems that use less land and use liquid manure handling systems. This trend became more pronounced in the 1990s. To accommodate these larger facilities, SCS/NRCS and OSU Cooperative Extension encouraged the building of liquid waste handling systems. Often, cost-share funds were offered as incentives.

Why did the use of liquid animal manure as fertilizer increase? Initially, farmers switched because they had to pay for the commercial fertilizer and they could get the liquid manure for free, even often applied for free, because it was a waste product. As CAFOs increased in size and number, producers were often left with more liquid animal manure than they had farm fields for application, so the liquid manure was transported to other farm fields in the vicinity for use as fertilizer (Weatherington-Rice, 2022b). Under the current brokerage system, farmers pay a minimal charge for liquid manure used to fertilize the fields. Figure 7 shows the increase of animal units in the watershed after 2000. Ohio EPA estimates that there is 80% more liquid animal manure being generated in the watershed than there was in 2000. Only large facilities are regulated and more large facilities are waiting to be permitted.

The other factor is that with changes in farming equipment, application methods changed. Liquid manure has a high water content because of the equipment used to apply it to farm fields. If it were drier (a thicker slurry), the manure solids would clog the spray nozzles (used to surface apply the liquid manure) and the injectors (used to inject the liquid manure into the soil below the surface). Simply thickening the manure (which would reduce the mobility of the solids and associated nutrients through the subsurface) would require a new type of machinery to be built, manufactured and purchased.

It is important to note that CAFOs and animal facilities that generate liquid manure are not distributed evenly throughout the Maumee River Basin. The Environmental Working Group (EWG) compiled data for the watershed draining into the Western Basin of Lake Erie (EWG, 2022) showing that many animal feeding operations are not permitted (purple) and also that they are concentrated in different areas of the watershed (Figure 8). Figure 8 should be compared to Figure 9 that shows where the crop farms are located (Myers and Metzker, 2000). Given that liquid manure must be transported from each animal feeding operation and applied to fields, fields in close proximity to an animal feeding operation are the most economically viable for disposal of this wastewater.

Behavior of Liquid Waste Applied to Tiled Fields

When water is applied to cropland, it can take several routes (Figure 10). Some can be absorbed by the growing plants in the field and be transpired back into the atmosphere. Some can directly evaporate back to the atmosphere. Some can run off the field to the closest body of water as surface runoff. Some can be move through the soil profile and enter agricultural field tiles and discharge as tile drainage. Some can seep down to become baseflow for surface water or it can continue to move downward and recharge the regional groundwater flow. The relative amounts of water following each route depends on the time of year, soil type, and other environmental conditions. When water moves through the soil profile it can move through primary porosity or secondary porosity. In the Maumee River Basin, much of the time (with the exception of late winter and early spring when the soil is frozen or waterlogged), water will primarily move through the soil profile through the fractures/macropores (secondary porosity).[1]

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[1] There is an uncommon exception to the pathways illustrated in Figure 10, depending on the prevalence and condition of biopores. In soils that are in long term no-till, that have not suffered any compaction from farming equipment and where each biopore and fracture are inhabited by living and healthy earthworms, the earthworms will block up the biopores and fractures to avoid being dosed with liquid manure. They will maintain the blockage until the liquid manure has migrated into the soil matrix and/or been washed off the site via surface flow. If the soil is compacted, little to no migration into the soil is physically possible unless macropores are available to transport the liquid and the liquid manure will remain pooled on the surface until it is either evaporated or is washed off the field with the next rain event. In September 2021, Frank Gibbs gave a zoom presentation updating the most recent findings about the success of healthy earthworms in biopores blocking rapid water movement through secondary porosity to tile drainage and underlying baseflow. The presentation was given at the OARDC Northwest Agricultural Research Station near Hoytville, Ohio. The presentation was part of the Association of Ohio

Liquid animal wastes are more than 90% water and they behave the same as water when applied to farm fields. Therefore, in tile drained fields, some liquid manure will be absorbed by growing plants, some will evaporate, some will be washed off as surface runoff and enter surface water, some will drain through the soil profile until it enters tile drainage and is discharged to surface water, some will seep down and become baseflow to surface water bodies and some will recharge the regional groundwater. Therefore, the application of liquid manure to agricultural fields in the Maumee River Basin results in transport of DRP (and other constituents, including nitrogen and bacteria) in the liquid manure to the rivers and into Lake Erie through surface runoff, migration to tile drainage, and/or transport in baseflow.

Frank Gibbs, reported in the August 20, 2006 article in the State Line Observer, made an eloquent plea for reducing the amount of water in the liquid manure (Attachment C). He explained his research that encountered liquid manures moving through the soil to the tiles in a matter of minutes, even when the conditions were ideal for application of liquid manure. Gibbs pointed out that even when the farmer did everything right, the liquid manure still moved rapidly into the tile.

Much of the initial Gibbs and Shipitalo research was done in northwest Ohio, because Gibbs was stationed in Findlay. The Ohio Fracture Flow Working Group has held field days all over Ohio that used Gibbs' tile smoker. These field days also used a technique developed by Ralph Haefner and the United States Geological Survey Water Section in Ohio to dye fractures with an environmentally safe dye. No matter the tillage practices and the soils, fractures and biopores transferred smoke indicating the presence of macropores. Photographs from a demonstration in Wooster, Ohio (outside the Maumee River Basin) are included in Attachment D. During this demonstration, a field tile was located that drained both a corn field and a hay field. The corn field had been reworked as much as possible-moldboard plowed, disked, raked, planted and cultivated several times for weed control prior to planting with corn. The expectation was that this amount of disruption would have eliminated transport via secondary porosity (macropores). Nonetheless, smoke traveled through the tile, into the corn field and was visible at the surface. Similar demonstrations have been done throughout Ohio, and all demonstrate the prevalence of macropores and, therefore, the transport of water and associated contaminants via secondary porosity.

The phosphorus in liquid animal wastes exists primarily as DRP. Phosphorus, in this form binds poorly to the soil, instead, it moves through the soil with water. Trying to get DRP to bind to compacted soil clods is like trying to get water to soak into a brick. It's possible to put a brick in a pail of water and wet the outside of the brick, but the brick would have to soak in that bucket for a very long time before much water would soak into the interior of the brick. Before the DRP can be sorbed to the soil, the water and the DRP applied to the field, is transported through the soil profile through secondary porosity (Weatherington-Rice, 2022b).

Pedologists (soil scientists) Fall Field Days continuing education program. The zoom presentation was captured on video, has been edited, and will soon be available on the Association of Ohio Pedologists web page, https://www.ohiopedologist.org/education.

Liquid manure (and the DRP and dissolved nitrogen) moves through the soil to the underlying tile drainage systems (where present), which degrades water quality and impairs the receiving bodies of water-streams, rivers and lakes. These relationships were studied at length by the Ohio Lake Erie Phosphorus Task Forces I and II and were documented in their final reports (April 2010 Final Report and the November 2013 Task Force II Final Report). This Task Force determined that 90% of the DRP delivered to the Lake Erie Western Basin came from agricultural practices, much of which came from the field application of liquid animal manures. These liquid manures rapidly move offsite and into the receiving waters of the tributaries to Western Lake Erie. Julie Weatherington-Rice served as the Ohio Academy of Science Fracture Flow Working Group representative on both Task Forces.

Effect of Best Management Practices (BMPs) on DRP Loss through Tiles

There are many factors that contribute to the movement of DRP into the Western Lake Erie Basin. Some are beyond our control and beyond the scope of a TMDL. For example, changes in rainfall patterns relating to climate change, and increase in the pH of precipitation. It is, therefore, imperative that we address practices within the Maumee River Basin that are within our control to reduce DRP transport to surface water. Addressing agricultural pollution is difficult due to the diffuse nature of this pollution. However, there are steps that can be taken to reduce the transport of DRP to the Western Lake Erie Basin from agricultural land uses. As with most environmental problems, there are options for addressing DRP transport from agricultural land. Current options include treating subsurface drainage and runoff to remove DRP; changing application methods to reduce the transport of DRP to surface water; and changing the way in which pollution sources (including manure from CAFOs) are handled prior to application.

Management of nutrient loading from farm fields has traditionally been achieved using the 4Rs (applying fertilizer from the right source, at the right rate, at the right time and in the right place) and using BMPs. Traditional BMPs, associated with reducing phosphorus loading to rivers, streams and lakes, target soil erosion. Before the advent of no-till cropping and the use of liquid animal manures for fertilizers, the spring application of granular fertilizers was common. The majority of phosphorus loss from fields was, therefore, a result of erosion of the soil and concomitant transport of sorbed phosphorus to surface water bodies. BMPs that address soil erosion (including no-till, low till, grassed waterways, cover crops and buffer strips) address phosphorus loading by reducing the transport of phosphorus sorbed to soil particles (Winsor, 2023). However, these BMPs do not significantly reduce the transport of DRP from liquid animal manure to surface water via subsurface drainage.

Liquid animal manure can be spread on the surface of fields or injected into the soil. When surface applied, the DRP in liquid manure can be washed from the fields if rainfall occurs shortly after application. When liquid manure is surface applied or injected, some portion of it can be transported through the subsurface (through macropores) to drain tiles and transported to surface water; or it can migrate through the subsurface to the groundwater where it can be discharged as baseflow to the surface water. When liquid manure is injected into the soil (below the surface), it was thought to minimize movement to the tiles. However, as Gibbs discussed (Attachment D), even with good conditions and correct equipment, the water and transported contaminants appears rapidly in the tile drains. One effect of this is that DRP and other contaminants are rapidly transported to surface water and subsequently to the Western Lake Erie Basin. The other impact, is that the liquid manure that is applied to fields to provide nutrients for plants, is removed too rapidly for crops to take up the nutrients.

Liquid animal manures (applied to farm fields) have been transported through subsurface drainage and into receiving streams, resulting in fish kills. Hoorman and Shipitalo (2006) investigated 98 incidents in Ohio between the years of 2000 and 2003 where animal wastes contaminated subsurface drainage effluent across Ohio. As can be seen in Figure 11 many of the contaminated sites were found in northwest Ohio, either in the Maumee River Basin or in nearby river basins.

According to Hoorman and Shipitalo (2006), "*Regardless of whether mismanagement occurred, preferential flow of the liquid wastes to subsurface drains via soil macropores was a major contributing factor to off-site movement of contaminants associated with liquid waste applications.*" These authors discuss that tillage has been proposed as a method to disrupt macropores and minimize the transport of liquid wastes to drainage systems. The authors examined 14 incidents where tilling was noted as occurring prior to offsite movement of contaminants from liquid animal manure. The authors concluded that, "*Tillage will probably reduce movement of liquid wastes to subsurface drains, but it is not likely to eliminate it in all situations...Similarly, avoiding application in a relatively narrow zone above the sub-drains will probably not be entirely effective as recent studies have suggested that solutes and particulate matter can move laterally up to several yards (meters) in the near surface soil horizons before moving downwards in preferential flow paths in tilled soils.*"

It has been suggested that controlling flow from tile drains can mitigate the impact of DRP on receiving waters by maintaining the DRP in the tile lines. Flow from tile drains can be controlled by plugging the tiles or by engineered structures that control the depth of water in the tile. In order to use this methodology, every drain tile outlet must be plugged or equipped with a flow control structure. Given the number of tile drains in a typical field in northwest Ohio, this would be very expensive. Even if the tiles are plugged, or the depth of water is controlled, in order to plant tile drained fields, the water table must be lowered to allow equipment to operate in the fields. This results in tile drainage being discharged in the spring months. It is important to note that even if the water in the subsurface of a tile drained field cannot discharge through the drain tile, the water (and the associated DRP) can move down through the subsurface. This water (and DRP) will then become part of the the underlying groundwater that discharges as baseflow to the streams and rivers in the watershed. Simple tile plugs have been used for decades but Frank Gibbs warns against them stating that they blow out with a good rain, allowing the recently applied liquid manures to be rapidly discharged from the mains draining to open ditches. Hoorman and Shipitalo (2006) state that "*Drain line stops should only be used as an emergency measure and in instances where the systems have been modified for their use.*"

The TMDL discounts DRP loss through subsurface drainage because "*current nutrient management standards*" and state law and regulations include "*requirements aimed to reduce the risk of these discharge events.*" We have reviewed the regulations the TMDL is referring to, Ohio Administrative Code 901:10-2-14(C) and (E), as well as the appendices and tables (including Appendices A, B, C and E). These rules are complex and, therefore, challenging to apply in reality.

Appendix B assumes that the drier the soil is, the more liquid the matrix will absorb and the higher the loading rate can be. This ignores the presence of macropores and the fact that the drier the soil, the more dominant the macropore flow will be. This table sets up the perfect storm to short circuit the liquid manure into the tiles. Additionally, applying liquid manure when soils are wet (at or near field capacity), increases the chance of liquid manure running off the fields as surface runoff.

The rules otherwise focus on surface BMPs taking care of the movement of the liquid manure off the fields and directly into surface water. The rules encourage the use of tile plugs if tile discharges are observed, but as noted earlier, plugs can fail and blow out. Between the higher loading rates for drier soils, the reliance on surface BMPs and counting on tile plugs as a back-up, these rules have set up conditions for failure. This set of rules will not significantly reduce DRP going to the lake from liquid manure.

It may also be possible to employ treatment systems, including wetlands to mitigate the impact on receiving waters. However, significant areas of land and/or technology implementation will be needed to create treatment systems for both baseflow and tile drainage in this watershed to remove DRP from surface water before it enters the rivers and Lake Erie. It is known that wetlands can provide a sink for phosphorus in the vegetation, but vegetation is only a temporary sink for phosphorus, as the vegetation decomposes in the fall and winter, much of the phosphorus is released back into the water and soil. Therefore, if wetlands are to be used as a phosphorus sink, it will be necessary to remove vegetation from the wetlands on a regular (annual) basis.

Other BMPs relating to subsurface drainage have been investigated and are still being developed. USDA-ARS has been developing underground P-removal structures (filters) that trap phosphorus in the matrix and reduce the transport of DRP to surface water bodies. These filters could be installed at drain tile outlets but would be expensive and the filter medium would need to be replaced when phosphorus binding locations are exhausted (Winsor, 2023). Dr. Zwierschke has been involved the design of a constructed wetland that collects tile drainage and surface runoff from a farm field in northwest Ohio. The wetland effluent is treated in a filter to remove DRP prior to discharge to surface water. It is, however, not practical to build wetlands (and a P-filter) to treat drainage effluent and surface runoff from every field in the Maumee River Basin.

Ghane (2018) summarizes the pros and cons of subsurface drainage in Table 1 (reproduced below). There clearly are benefits to the farmer and without drainage much of the Maumee River Basin would still be the Black Swamp. However, when addressing the issues of nutrient transport, it is clear that tile drainage increases the transport of DRP, nitrates and other water contaminants. When these systems are coupled with liquid manure application, the discharge to Lake Erie is increased.

Table 1. Pros and Cons of Subsurface Drainage in Humid Regions.

Pros	Cons
Increases crop yield	Excess phosphorus transport
Less variability in yearly crop yield	Excess nitrate transport
Increases soil aeration	Less groundwater recharge
Improves soil structure	Accelerates loss of soil organic matter
Decreases surface runoff	
Provides timely field operations and trafficability	

Two-stage ditches were considered as a solution around the turn of the 21st century but they have not proved to be as successful as hoped. Two-stage ditches are designed to replicate natural stream processes by incorporating extended side benches. Two-stage ditches have been used to reduce sediment discharge (and consequently, can reduce phosphorus associated with erosion). There have been mixed results using two-stage ditches to reduce DRP from surface water in ditches and might be part of the solution if used in conjunction with other BMPs (Kindervater, 2017).

The previously discussed BMPs and measures to reduce DRP in surface water, require implementation over the entire watershed, in every farm field. However, changing the way manure is handled at the source (CAFOs and animal operations) requires changes at a finite number of facilities (at the source). For a small family farm, liquid manures can be treated in a septic tank and leach field. Manure from a few beef cattle, chickens, ducks and/or goats can be managed as a dry manure, composted and applied to the farm fields and/or the family garden depending on the nutritional needs of the soil and projected crop(s). Nutrient soil testing is recommended for application rates. However, treatment of wastes from larger facilities (including CAFOs), remains a major concern.

A possibility for CAFOs are large-scale composting facilities that stabilize the phosphorus into a more stable form. The City of Columbus composts biosolids resulting from wastewater treatment at a site south of Columbus. The product (Com-Til) is used as an organic fertilizer and soil conditioner and is sold to wholesalers in Central Ohio. In addition, Dr. Fred Michel presented results of an ongoing study at OARDC (Ohio Agricultural Research and Development Center) relating to the composting of manure from horses, cows, hogs and poultry. The composted manure can be transported further (due to the weight differential) and, due to the form of the phosphorus in the composted manure, is less prone to leach DRP that can be washed from the fields by surface runoff or be transported through the soil to subsurface drains and to surface water.

Another current fertilizer application method is broadcasting dry fertilizer after the growing season. In some cases, the application is incorporated with tillage which both disturbs the crop residue and breaks the surface of the soil allowing for erosion from the fields with each rainfall event and snowmelt event after application. In these situations, not only the soil but the fertilizer can be washed away. If the broadcast fertilizer is not incorporated, then it is exposed to fall rain events and snow melts. Once the fertilizer is mixed with water, it dissolves and becomes part of the DRP load that is contributed to the watershed. Shipitalo et al. (2013) noted that research has concluded that the weather and timing of rainfall relative to tillage and nutrient application are the dominant factors contributing to nutrient loss from fields when using broadcast fertilizer. In 2018, Korucu et al. concluded that broadcasting fertilizer in the fall when a cover crop is actively growing, improves soil structure and reduces sediment and nutrient losses in surface runoff due to rainfall shortly after fertilizer application.

In the Maumee River Basin TMDL process, Ohio EPA acknowledges the significant reduction that will be required from non-point sources, including nutrient management (identified in their slides as including commercial and manure) (Figure 12). It is the opinion of the authors that the reduction sought by Ohio EPA in the TMDL process will not be met unless the amount of DRP entering surface waters in the Maumee River Basin from fertilizer/liquid manure application to farm fields is quantified and technology is applied to reduce loading from this source. This reduction in loading can be achieved by treating manure (for example in packaged wastewater treatment systems or composting) rather than applying liquid manure to farm fields. Winsor (2023), quoted Chad Penn (USDA-ARS), "*Since municipal wastewater treatment P sources have been mostly addressed, agricultural sources in the Maumee River have become the main concern.*"

A review of a recent *Western Lake Erie harmful algal bloom season projection* (NOAA and NCWQR, August 3, 2022) shows that the projected total annual harmful algal bloom (HAB) severity in 2022 is expected to approximate HAB severity in 2021. The cumulative total bioavilable phosphorus (TBP) loads for the Maumee River at Waterville in 2022, Ohio are projected to be almost as high as 2021 (Attachment E). As learned by the Ohio Lake Erie Phosphorus Task Force, approximately 90% of the phosphorus measured at Waterville comes from agricultural sources. Therefore, since the DRP loading for 2022 is expected to be almost as high as 2021 and considerably higher than 2020, it appears that manure management programs in the watershed will be required to measurably reduce the impact of phosphorus in the watershed.

Summary and Conclusions

Ohio EPA's slides (Figure 12) demonstrate that a significant reduction of DRP is going to be required as part of the TMDL process and that a large reduction in phosphorus loading will be required from improving agricultural source management including manure application in the Maumee River Basin. Liquid animal manures applied to the surface of a field, pool on the field, then drain through macropores to the subsurface or are washed offsite in the next storm. DRP moves with water. Liquid animal manures injected into the soil are short circuited into the macropores due to fracturing, moving quickly to the tile drains and baseflow of the streams. Fields that are first plowed to break up the macropore connections are subject to erosion and the DRP deposited on the soil is carried away with the rainfall when erosion occurs. The soils in the Maumee River Basin are prone to fracturing resulting in rapid transport of the DRP to tile drains and drainage ditches. Once DRP enters the tile drains or baseflow for the streams and ditches, the DRP is discharged into the rivers and into Lake Erie. In 2013, it was determined that 90% of DRP delivered to the Western Basin of Lake Erie came from agricultural practices, including field application of liquid manures. The 4Rs of nutrient stewardship and current BMPs (which primarily target the transport of phosphorus associated with erosion) do not significantly reduce the transport of DRP from liquid animal manure to surface water via subsurface drainage. BMPs that are currently being investigated, including p-filters, require the installation of equipment at the outlet of drain tiles across the watershed. It is, therefore, be necessary to look at managing animal manure differently at the source (CAFOs) or reducing the volume of liquid manure that is applied to farm fields to accomplish significant DRP reductions from drainage effluent in the Maumee River Basin.

The soils and agricultural practices that result in rapid DRP transport from farm fields to the Western Lake Erie Basin in the Maumee River Basin have similarities across the area. This means that neighboring watersheds (including the Sandusky River in Ohio and the southern portion of the watershed of the Raisin River in Michigan) are likely subject to similar processes.

As with most environmental concerns, there are no easy and cheap answers. If CAFOs continue to operate in the Western Lake Erie basin, manure management must be addressed (costing the industry money). If liquid manure is to be applied to farm fields, measuring and mitigating DRP movement to surface water must be addressed (costing farmers money). Not doing either of these things will negatively impact Lake Erie and harmful algal blooms will continue to be a problem in the Western Lake Erie Basin.

Respectfully submitted,
BENNETT & WILLIAMS ENVIRONMENTAL CONSULTANTS, INC.

Julie Weatherington-Rice, PhD

Julie Weatherington-Rice, PhD, CPG, CPSS
Senior Scientist

KHughesZwierschke

Kerry Hughes Zwierschke, P.E., PhD.
Principal Engineer

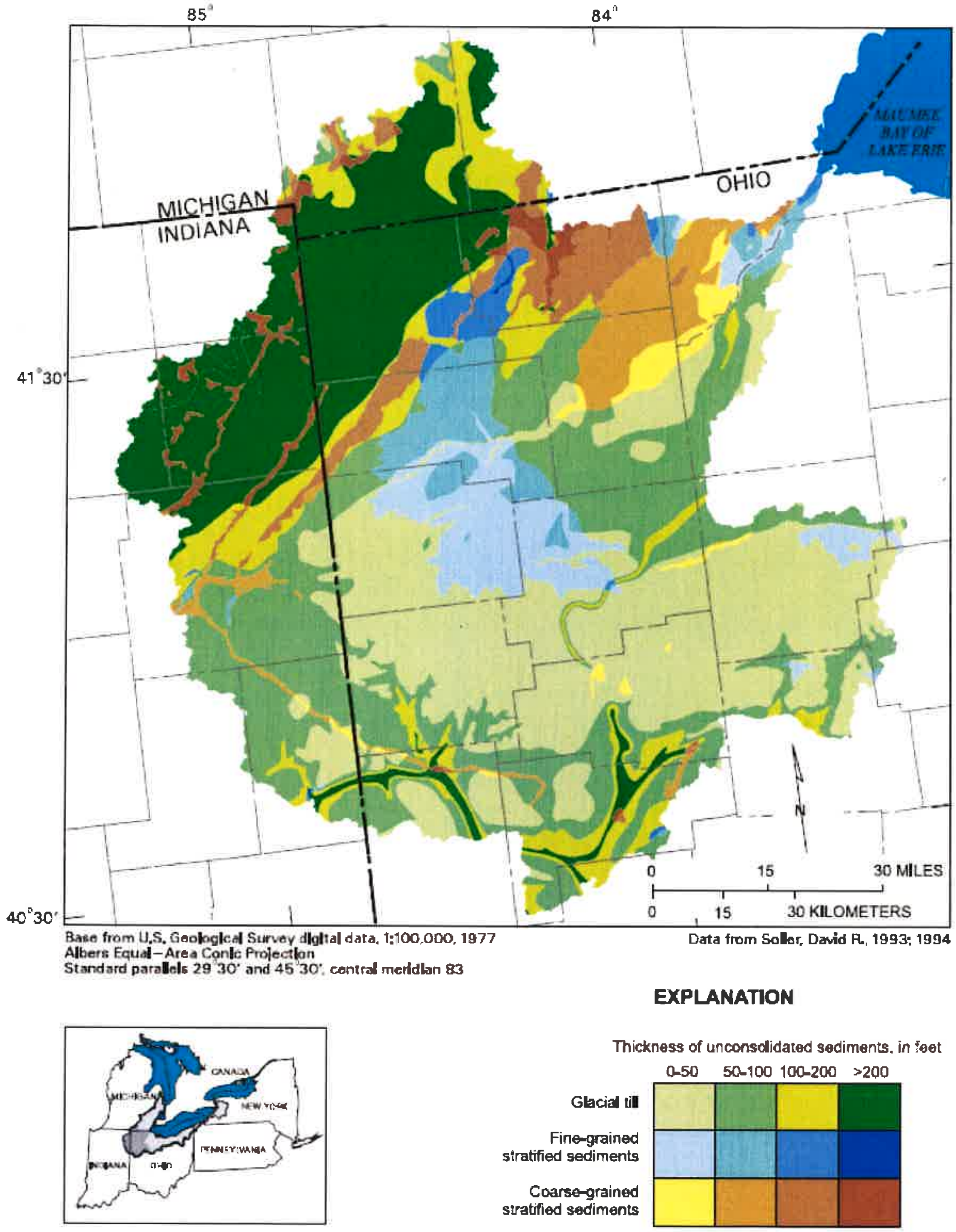

Figure 2. Distribution and thickness of unconsolidated sediments in the Maumee River Basin.

Figure 1. Distribution and thickness of unconsolidated sediments in the Maumee River Basin (from Myers and Metzker, 2000).

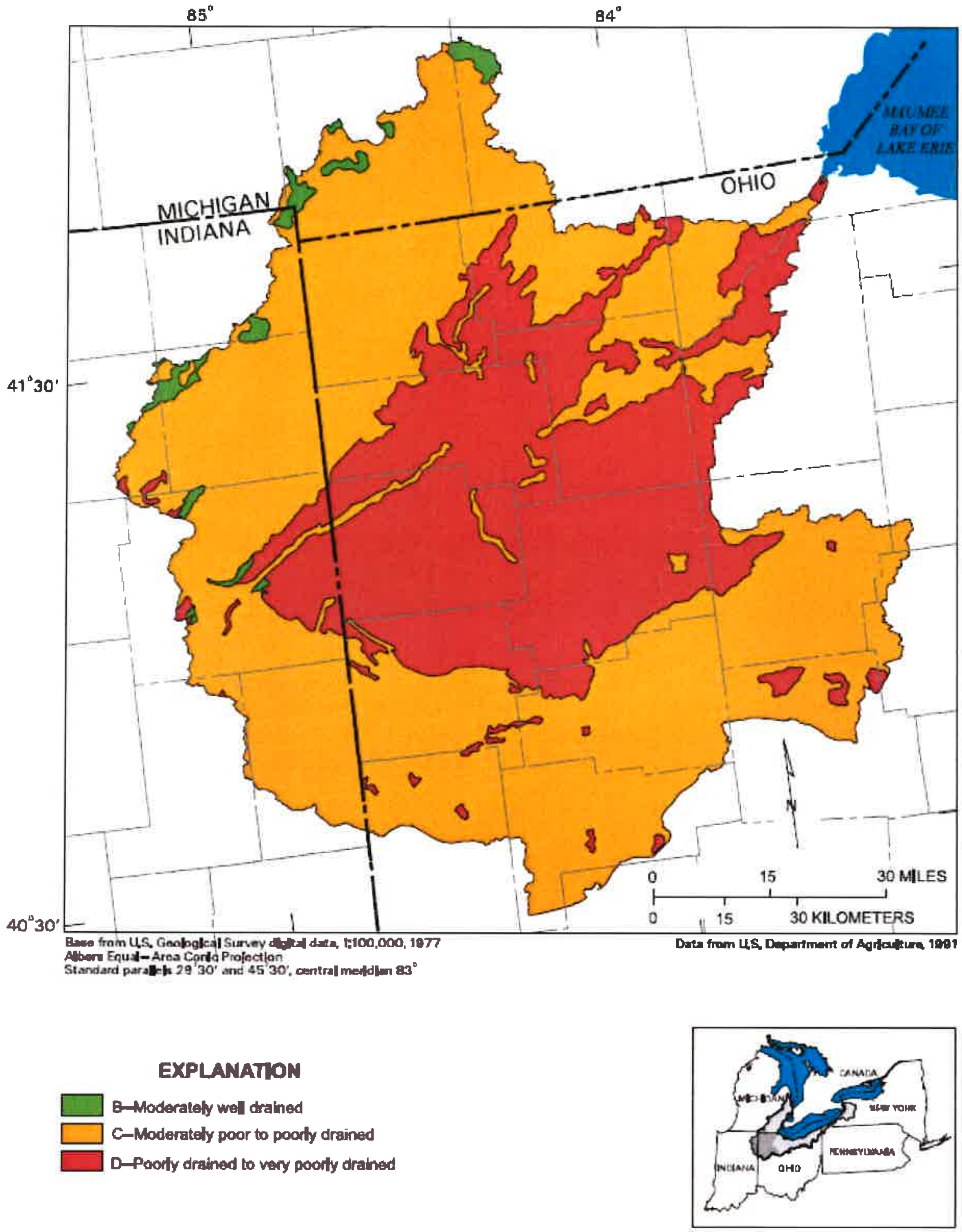

Figure 3. Soil hydrologic groups in the Maumee River Basin.

Figure 2. Soil groups in the Maumee River Basin (from Myers and Metzker, 2000).

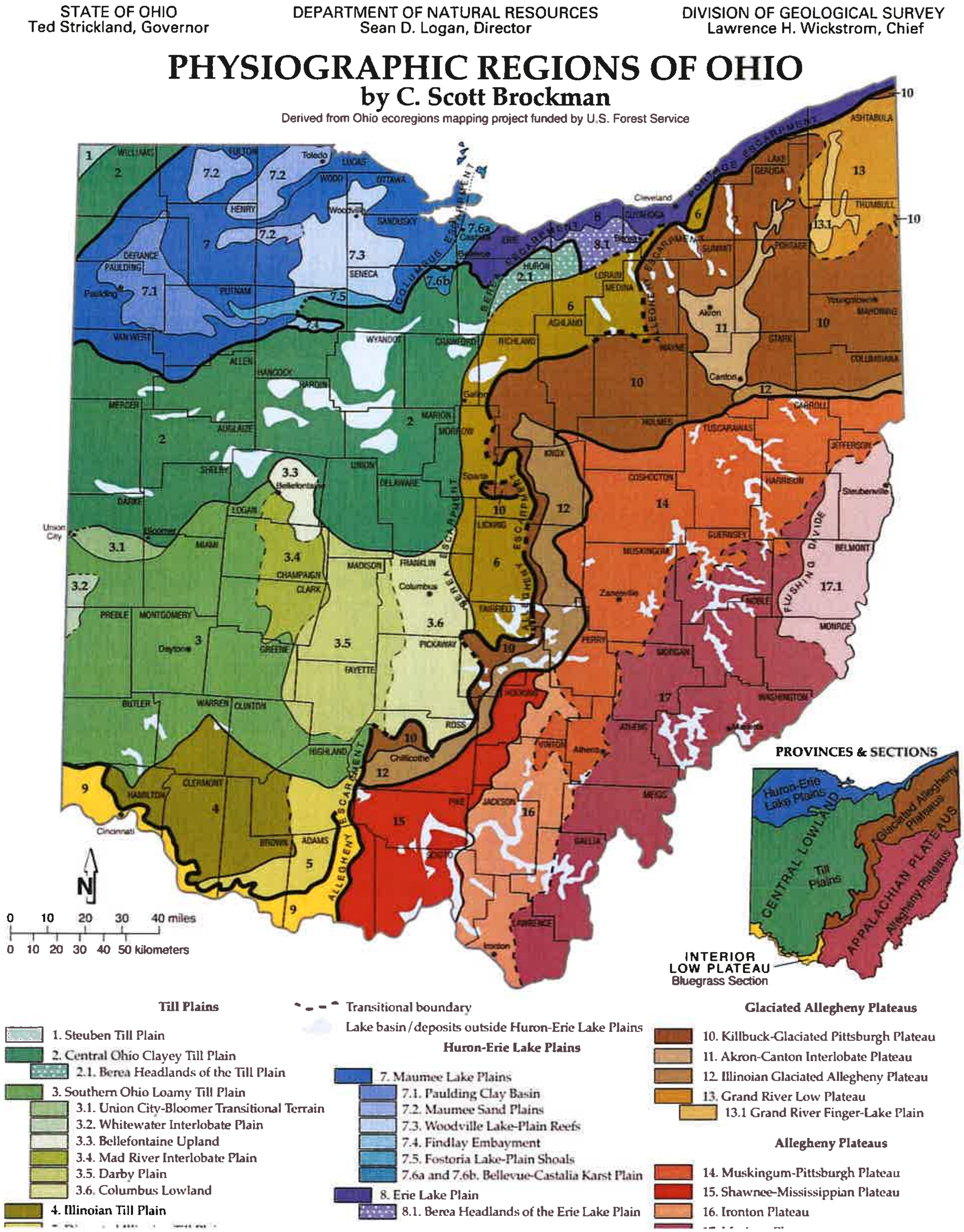

Figure 3: Physiographic regions of Ohio (Brockman, 2016).

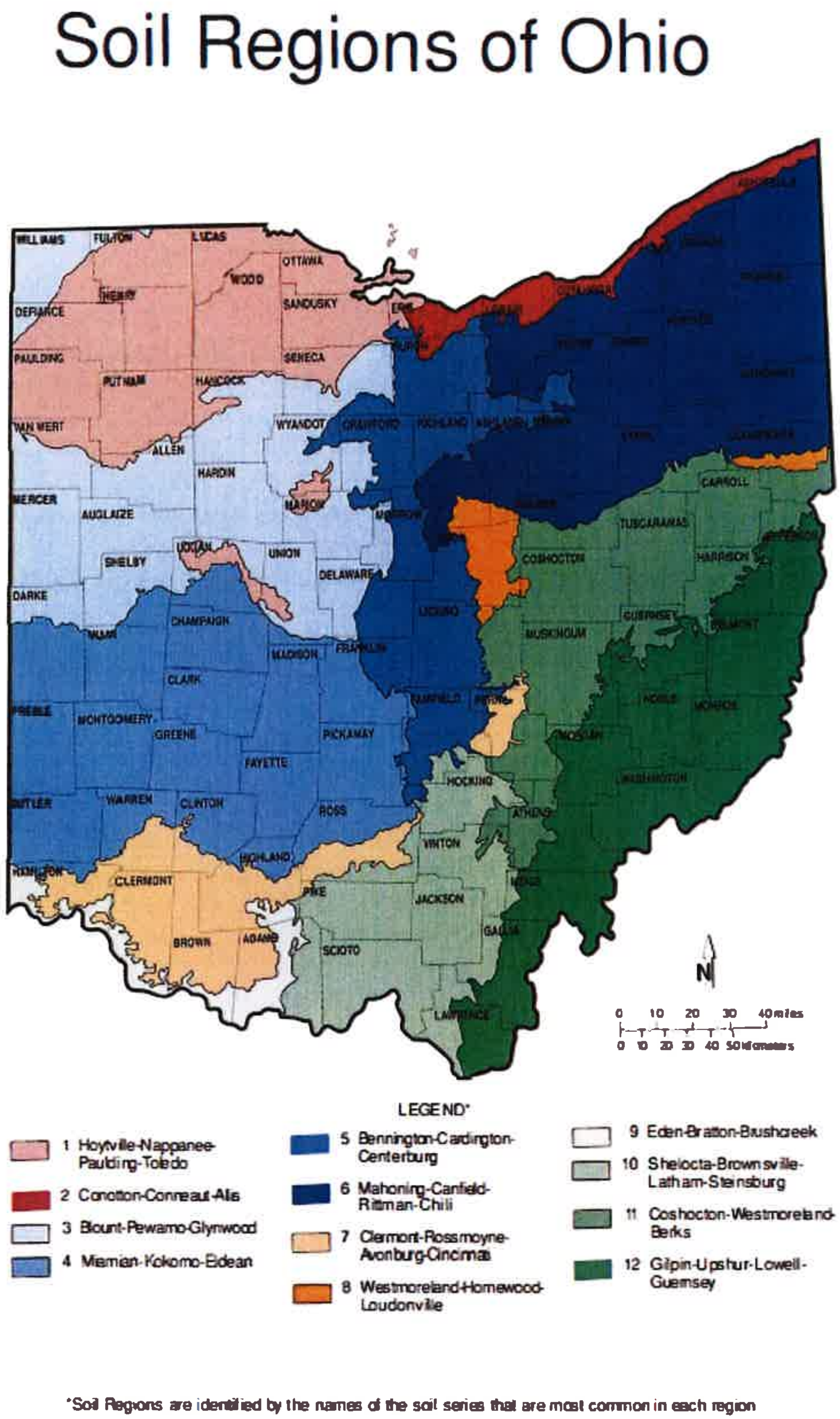

Figure 4: Soil regions of Ohio (Ohio Department of Agriculture, 2018).

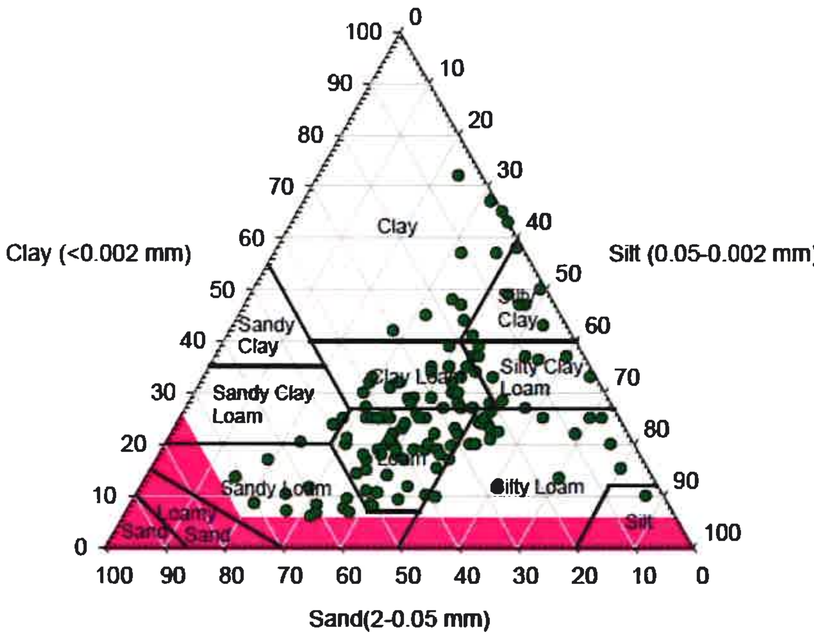

Figure 4.8. Fracture-prone zones for Ohio soil textural data combining mud-pie tests data with field data (173 total points) with the boundary between fracture-prone and non fracture-prone areas modified as postulated by previous researchers (Tomes et al., 2000; Connell, 1984). The unshaded regions show the fracture-prone regions.

Figure 5: Soil textures in Ohio expected to have water and water-soluble contaminants migrating from the surface to tile drainage, baseflow and groundwater by secondary porosity macropore fracture flow (Kim, 2007).

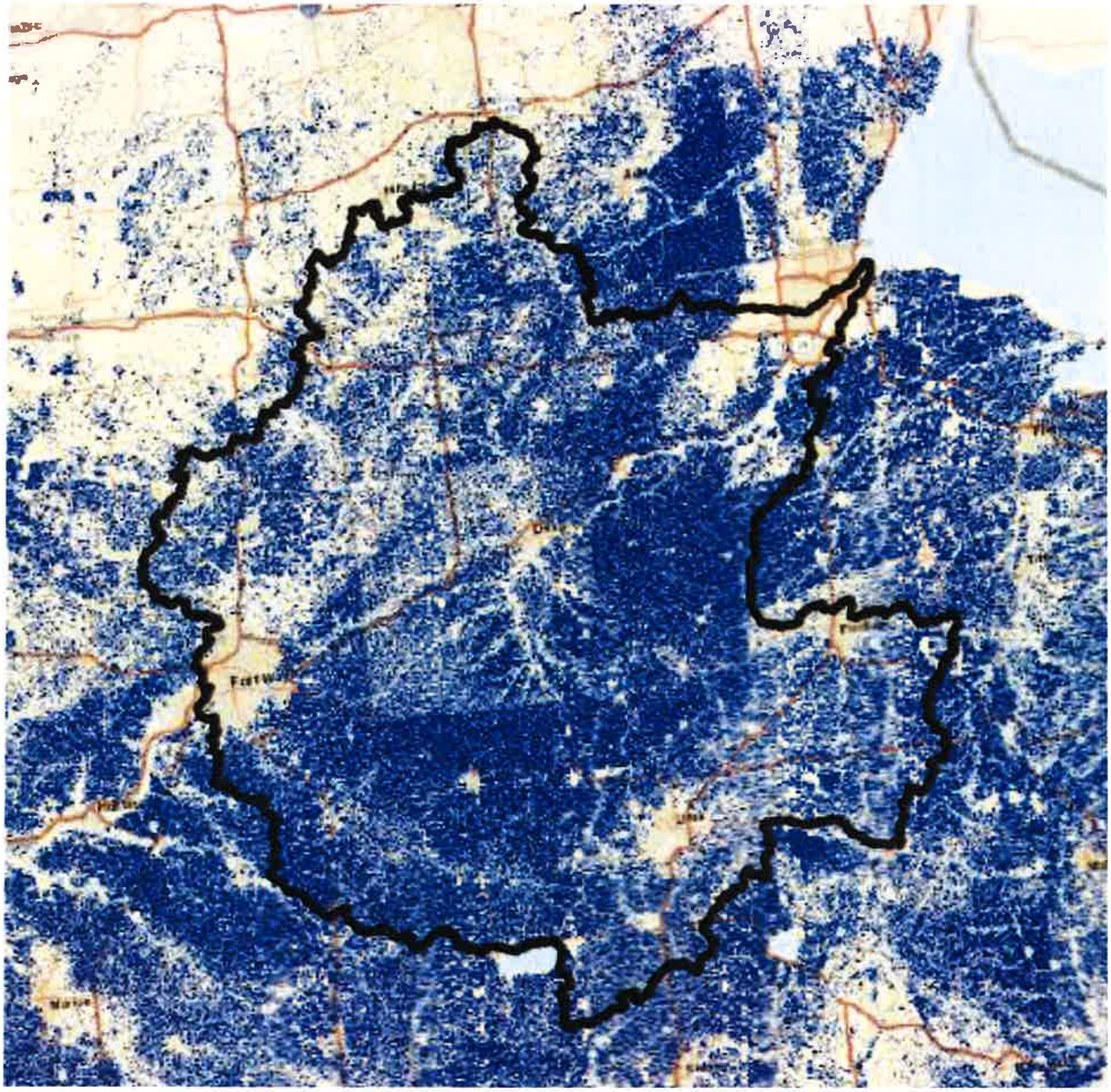

Figure 6. AgTile-US results showing tile drained cropland in blue.

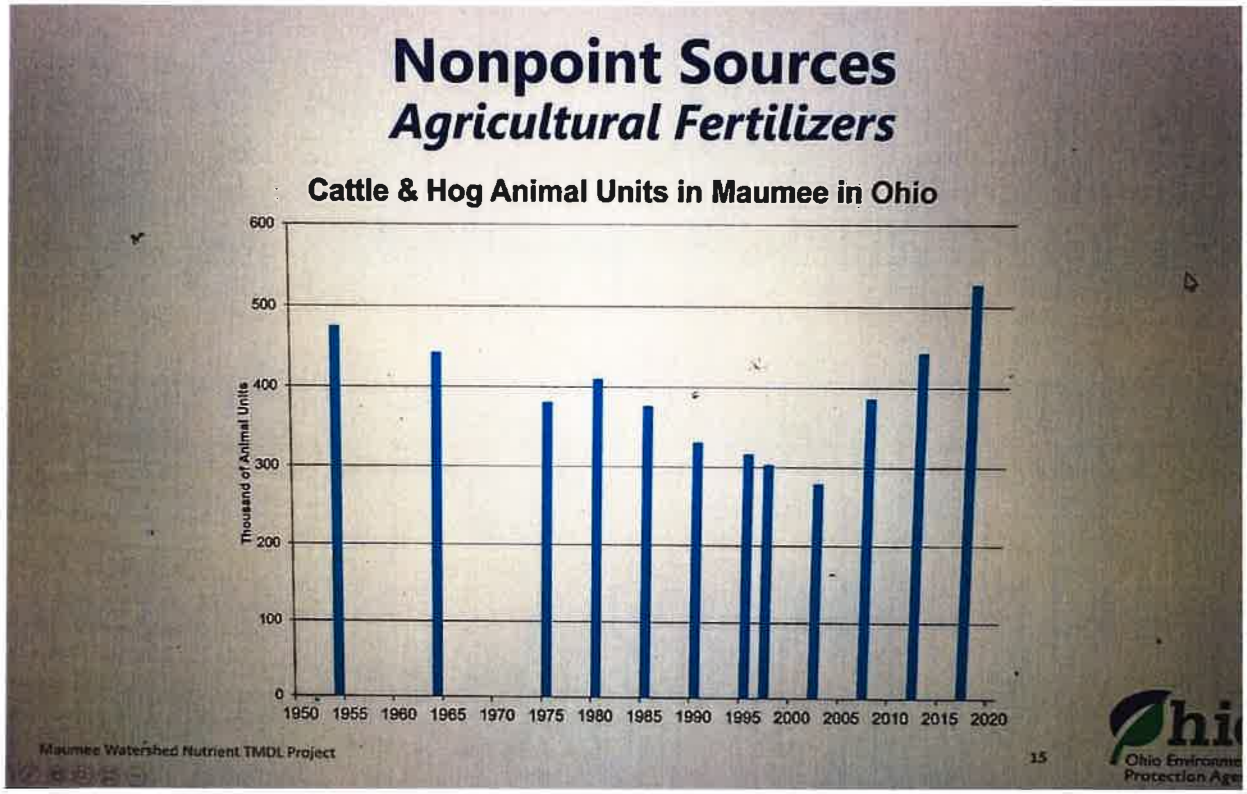

Figure 7: Increases in cattle and hog feeding units in the Maumee River Basin since 2000 (Ohio EPA, 2022).

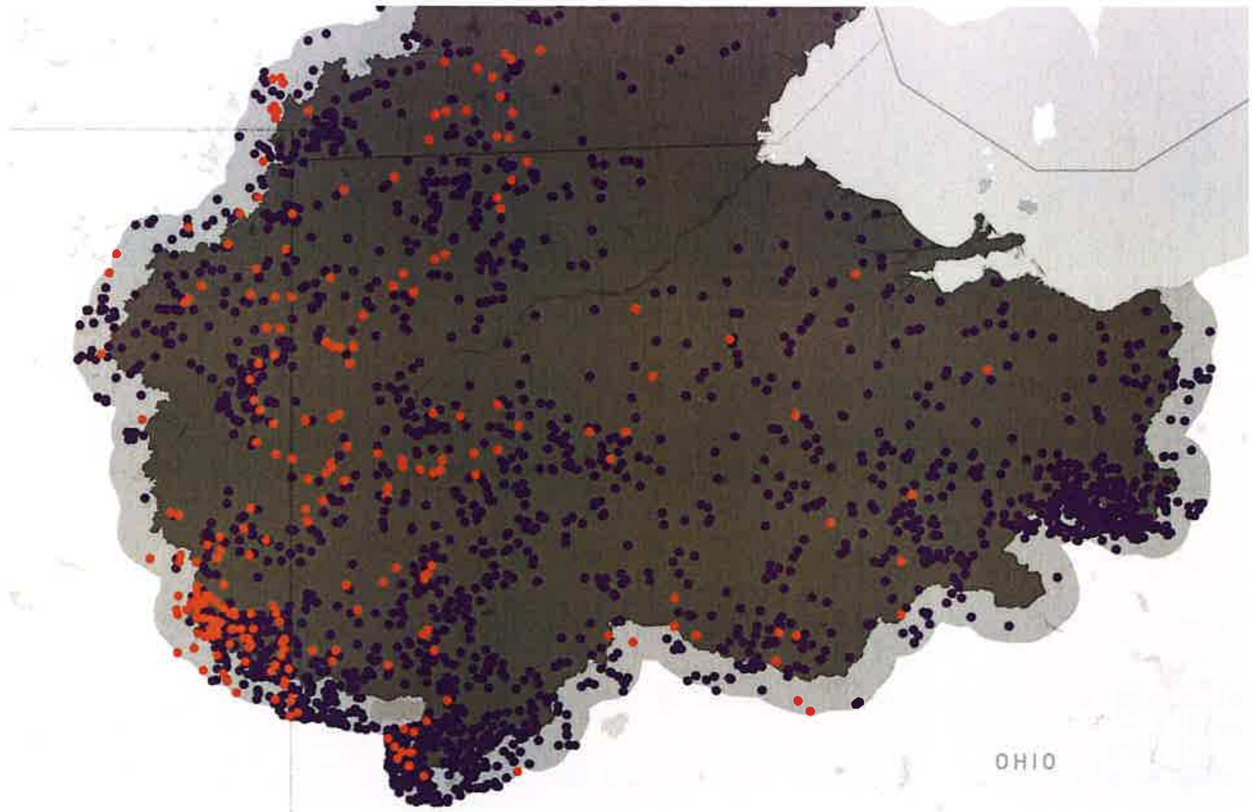

Figure 8. Locations of animal feeding operations in the western Lake Erie basin (EWG, 2022). Orange are permitted operations and purple are unpermitted.

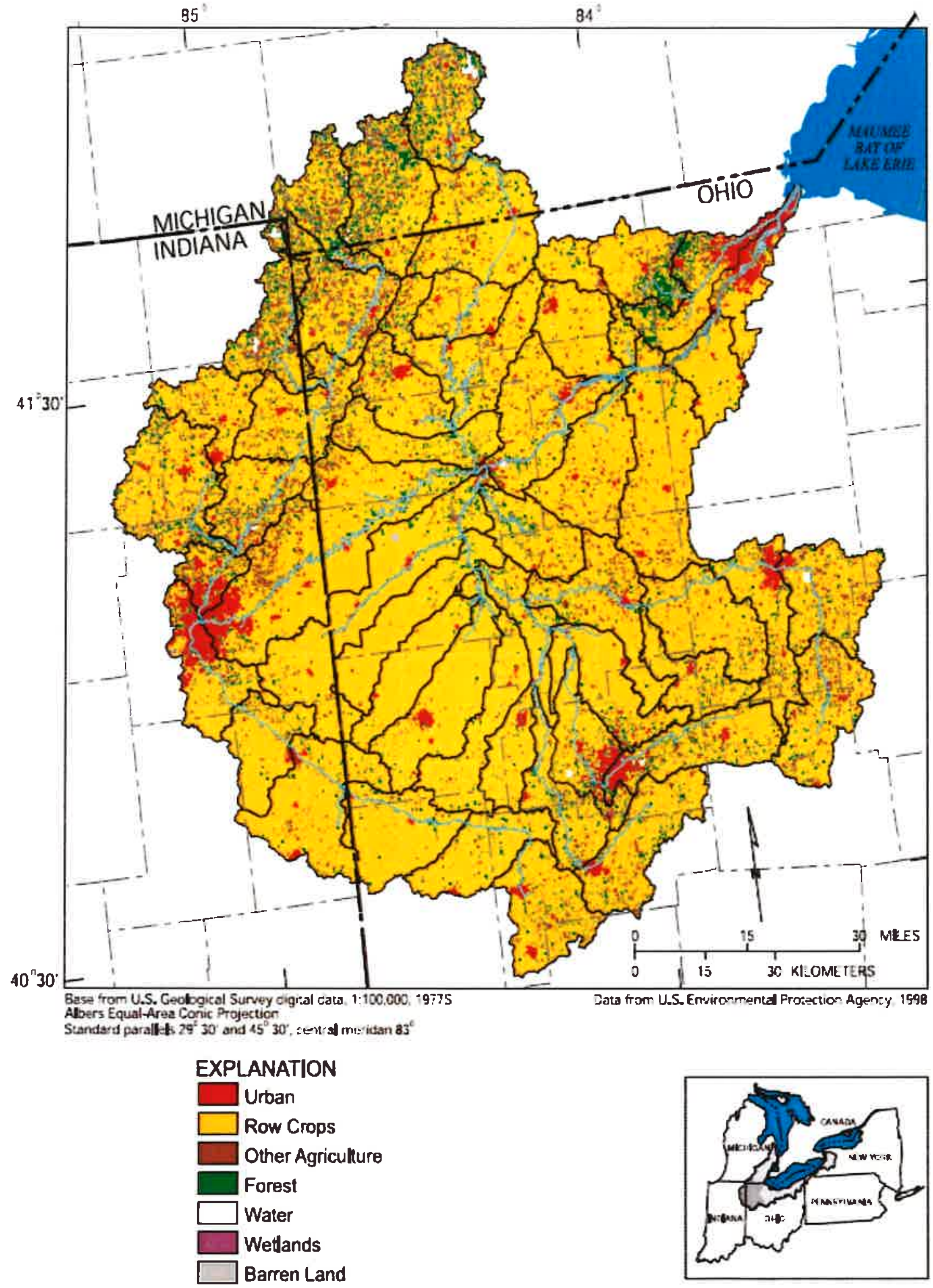

Figure 4. Land use in the Maumee River Basin, 1994.

Figure 9. Land use in the Maumee River Basin (from Myers and Metzker, 2000).

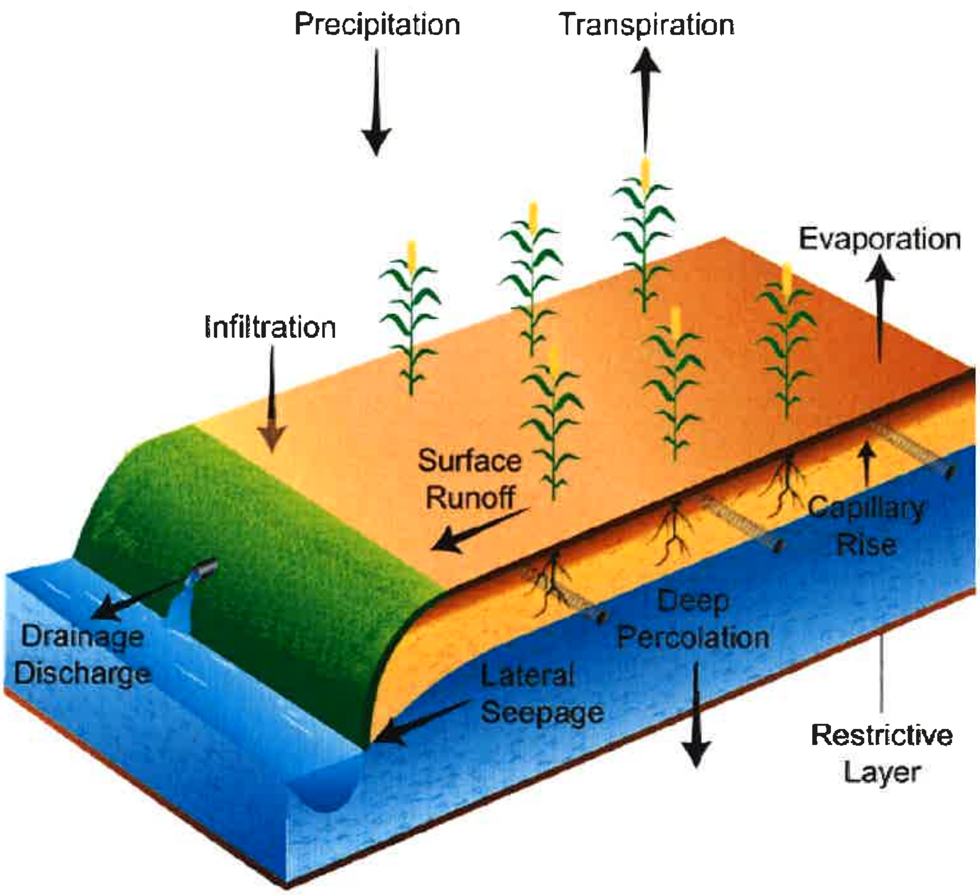

Figure 4. The water cycle on a field with subsurface (tile) drainage. Not to scale.

Figure 10. Impact of subsurface drainage on water movement (from Ghane, 2018).

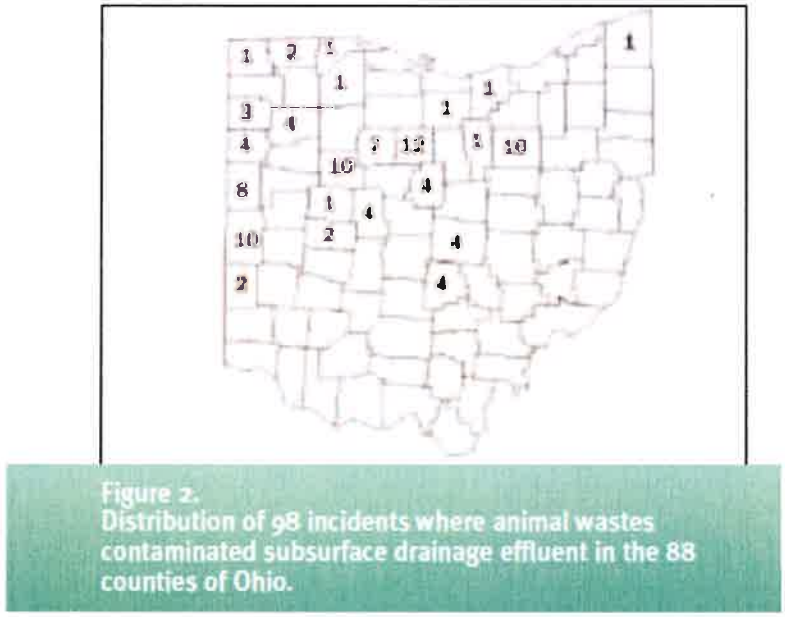

Figure 11. Locations of incidents where animal wastes contaminated subsurface drainage effluent in Ohio (from Hoorman and Shipitalo, 2006).

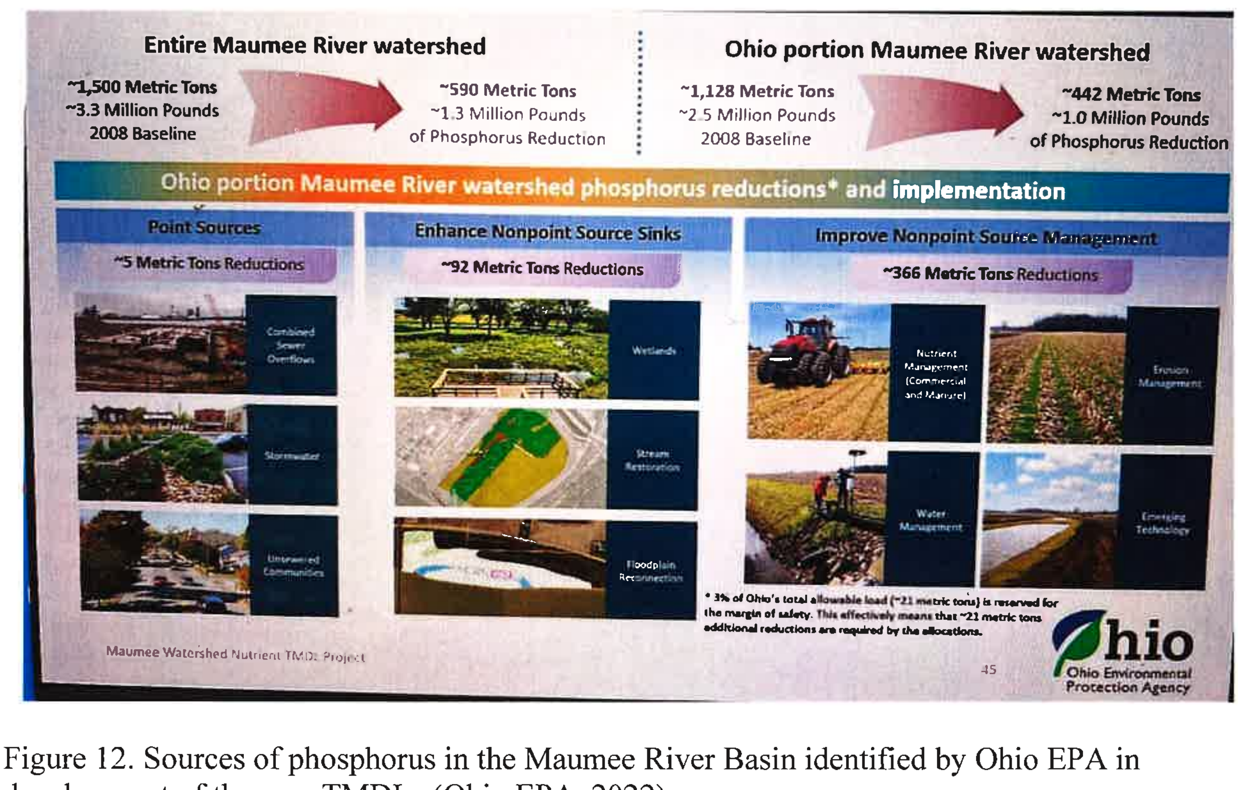

Figure 12. Sources of phosphorus in the Maumee River Basin identified by Ohio EPA in development of the new TMDLs (Ohio EPA, 2022).

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Attachment A
Resumes

JULIE P. WEATHERINGTON-RICE

Bennett & Williams

EDUCATION

BS EARTH SCIENCES EDUCATION - The Ohio State University, 1974
MS GEOLOGY & MINERALOGY - The Ohio State University, 1978
Ph.D. Soil Science and Geographic Information Systems - School of Natural Resources - The Ohio State University, March 2004.
ADJUNCT ASSISTANT PROFESSOR – Food, Agricultural, and Biological Engineering, The Ohio State University, appointed June, 2004.
ADJUNCT ASSISTANT PROFESSOR – Science Department, Pontifical College Josephinum, appointed Summer, 2008

Dissertation topic:

Fracture occurrence and ground water pollution potential in Ohio's glacial and lacustrine deposits: A soils, geologic, and educational perspective.

Completed (Published) Related Papers:

Christy, A.D., and J. Weatherington-Rice. 2000. Field workshop on subsurface fractures in glacial till and their environmental implications: An educational experience for professionals and decision-makers. *Ohio Journal of Science* 100(3/4):94-99.

Malone, R.W., S. Logsdon, M. J. Shipitalo, J. Weatherington-Rice, L. Ahuja, L. Ma. 2003. Tillage effect on macroporosity and herbicide transport in percolate. *Geoderma* 116:191*215.

Malone, R. W., J. Weatherington-Rice, M. Shipitalo, N. Fausey, L. Ma, L. Ahuja, R. D. Wauchope, Q. Ma. 2004. Herbicide leaching as affected by macropore flow and within-storm rainfall intensity variation: a RZWQM simulation. *Pesticide Management Science* 60:277-285 .

Weatherington-Rice, J., A.D. Christy, and J. L. Forsyth. 2000. Ohio's Fractured Environment. *Ohio Journal of Science* 100(3/4):36-38.

Dissertation Papers published in the April 2006 Special Issue of The Ohio Journal of Science:

Weatherington-Rice J, Angle MP, Christy AD, and Aller L. 2006. DRASTIC Hydrogeologic Settings Modified for Fractured Till: Part I. Theory. *Ohio J Sci* 106(2):45-50.

Weatherington-Rice J, Angle MP, Christy AD, Gerhing R, and Aller L. 2006. DRASTIC Hydrogeologic Settings Modified for Fractured Till: Part II. Field observations. *Ohio J Sci* 106(2):51-63.

Weatherington-Rice J, Bigham J. 2006. Buried Pre-Illinoian-Aged lacustrine deposits with "green rust" colors in Clermont County, Ohio. *Ohio J Sci* 106(2):35-44.

Weatherington-Rice J, Hall G. 2006. Fracture and gully formations in glacial fill: Field observations at the WillowCreek Landfill, Portage County, Ohio and at historic earthen dam failure sites in the US. *Ohio J Sci* 106(2):27-34.

Other Related Papers published in the April 2006 Special Issue of The Ohio Journal of Science:

Weatherington-Rice, J., Hottman, A., Murphy, E. M., Christy, A.D., and M Angle. 2006. Fractured tills, Ohio's ground water resources, and public policy considerations addressed by DRASTIC maps. *Ohio J Sci* 106(2)64-73.

Weatherington-Rice, J., Christy, A. D., and M. P. Angle. 2006. Further explorations into Ohio's fractured environment: Introduction to *The Ohio Journal of Science's* second special issue on fractures in Ohio's glacial tills. *Ohio J Sci* 106(2):4-8.

Other Related Papers in Draft and Press (October, 2010)

Kim, E. K., Kang, Y. W., Christy, A. D., and J. Weatherington-Rice, in press, Laboratory Method for Predicting Boundary Conditions of Soil Textures that Support Fracture Development, *Transactions of the American Society Agricultural & Biological Engineers.*

Kim, E. K., Kang, Y. W., Christy, A. D., and J. Weatherington-Rice, submitted, Ternary Diagram Modeling of Soil Texture Data for Predicting Subsurface Fracturing in Glacially Related Fine-Grained Materials, *Transactions of the American Society Agricultural & Biological Engineers.*

FIELDS OF SPECIAL COMPETENCE

Geomorphology, stratigraphy and hydrogeology and mapping (both soils and geologic) with special emphasis on Pleistocene geomorphology, physical and chemical properties of materials (both soils and parent) and ground water movement investigations with GIS systems applications; Ground-Water Protection; Aquifer Characterization and Modeling; Wellfield Development; Solid, Hazardous, and Radioactive Waste Landfill Siting studies. Land Use Planning, including River Basin and Watershed Evaluations and Riparian Corridor Evaluations and Restorations; Sole Source Aquifer Designations; Wellhead Protection; Regional Planning; Stormwater Management; Landslide and Sedimentation Evaluations; Strip-Mine Reclamation. Presentations and training sessions on Ohio Geology; Ground Water Protection; Landfill Siting Criteria, Fractured Till, Stormwater Delivery and Management, Applications of GIS (data and mapping) to Water and Land-Use Planning Projects, Earth Science and Water Education, and related subjects.

EXPERIENCE

Typical Projects with Responsible Charge:

Bryan, Ohio

Review of a proposed large-scale Dairy operation (Confined Animal Feeding Operation – CAFO) Permit to Install (PTI) Application to be located near the City's main well field. Manure applications were scheduled for lands surrounding the wellhead protection area. Review included general comments on the application and loading rate limitations of manure on Ohio's soils, as well as complete individual analyses of the PTI from soils, geological, hydrogeological and engineering perspectives. Efforts included a written report submitted to Ohio EPA, presentations at public meetings and the public hearing and representation of the City at a meeting with the Governor's staff regarding the needed modifications to Ohio's CAFO program.

This project has evolved into an analysis of the City's current well fields, including the completion of a ground water model to redefine the five-year wellhead protection zone and the upgrading of the wellhead protection program and the identification of potential new well fields for the City. The City coordinated a proposed tri-state, five county Sole Source Aquifer Petition to US EPA.

Lake Township, Stark County, Ohio

Ongoing efforts to resolve the cleanup and closure of the Uniontown Industrial Excess Landfill Superfund site in Lake Township. Clients have included local citizens in class action suits in Start County Court of Common Pleas, resulting in a determination of damages to the surrounding community; litigation support to local attorneys in a private civil litigation (now settled and pending); and ongoing assistance to the Lake Township Trustees in their continued comments and reviews of Ohio and US EPA decisions and documents when requested. This case was also used for four years as a classroom training exercise for the combined Soil and Water Engineering class and the Biological Engineering class or just the Biological Engineering class, depending upon year, in the Department of Food, Agricultural and Biological Engineering, The Ohio State University, which includes a site visit and some monitoring of the surrounding region. Efforts have included a full geologic, hydrogeologic and engineering analysis of the site and surrounding region, a review of historic documents relating to the case, preparations of written comments for US EPA and numerous presentations in court, at public meetings and in the classroom.

Northern Clark County Ohio

Extensive evaluation of the soils, glacial materials and routes for surface and ground-water contaminant migration from the proposed Clarkco Solid Waste Landfill into the underlying 100+ gpm sand & gravel aquifer and the adjacent Mad River Buried Valley Aquifer, part of the Great Miami Buried Valley Sole Source Aquifer. Evaluation included review of the proposed siting and design as it relates to Ohio's Solid Waste Siting Criteria; construction of an observation pit and identification of springs and seeps in the surrounding surface waterways; development of a GIS presentational format for agency, court and public education presentations; successful presentation of the site's limitations to the Environmental Review Appeals Commission (PTI remanded back to Ohio EPA). Preliminary investigation of the neighboring closed, failing and in remediation Tremont Landfill and the adjacent closed hazardous waste barrel fill as they relate to the proposed Clarkco Solid Waste Landfill and to regional surface and ground water contamination. Clients and cooperating agencies for this effort included the Clark County Commissioners, the City of Springfield, the Clark County Health Department, the Clark County Solid Waste District, the Clark County Prosecuting Attorney's Office, the German Township Trustees and local citizens.

Canal Winchester, Ohio

Surface water, stormwater runoff, ground water, public water supplies, and soils evaluation as they relate to land-use planning for Canal Winchester's new long range planning effort. Relationship of stormwater runoff to changes in land-use and disruption of soils. Impacts of land-use changes to down stream flooding frequencies and elevations. Current locations for ground-water recharge, maintaining the sustainability for well fields by managing stormwater detention/retention to augment ground-water recharge, targeting new development areas to preserve recharge capabilities. Identification of future well fields and planning for their preservation. Federal, State and local rules, programs and regulations that affect these issues. Identification of watershed partners, shared benefits, and non-traditional funding structures.

Franklin Soil & Water Conservation District

Systems analysis, systems design, coordination of funding, purchase specifications for hardware and software, staff hiring and training, data layer acquisition and creation, interagency coordination and ongoing oversight of the District's new GIS system. District representation and coordination for the Franklin County Greenways Project including involvement on the steering, technical, GIS subcommittee, and appropriations committees, contractual arrangements and oversight of the ODNR Nature Works grant portion of the project.

Ongoing responsibility for or coordination of special ground water, surface water, sediment and erosion controls and soils investigations and training sessions in the county. Projects have been as diverse as the 1993 Drought inventory for portions of Plain and Jefferson Townships; an analysis of surface and ground water and soils and land-use development impacts on Pickerington Ponds (earned Cooperator of the Year Award for this work); and coordination with and technical support for the City of Columbus on soil and water issues for their long-range planning program (earned Assoc. of Ohio Pedologists Distinguished Service award for this work). Periodic training sessions on USDA's TR#55 Urban Hydrology for Small Watersheds.

East Central Ohio

Solid Waste District Management plan for a four-county area (Licking, Fairfield, Perry and Coshocton). Evaluation of the current solid waste management needs and capabilities of the district. Identification of future facility shortfalls. Establishment of facilities siting criteria through group decision mechanisms. Presentation of plan in public meetings and hearings. Additional independent evaluation of the existing conditions and management efforts at one of the landfills in the District.

Dayton, Ohio

Ground Water Management plan for a five-county area (MVRPC). Evaluation of ground-water resources throughout five counties, including assessment of pollution potential, ground-water use and availability, land-use planning, and geologic mapping. Development of database for management of ground-water resources use and protection. Numerous additional independent mapping, land-use suitability, surface, and ground water contamination studies in the region for local government and private clients.

Cincinnati, Ohio

Ground Water Management plan for a four county area (OKI). Evaluation of ground-water resources throughout four counties, including assessment of potential sources of pollution; status of ground-water resources throughout four counties, including assessment of potential sources of pollution; status of ground-water monitoring; and development of a master plan for the implementation of the regional ground-water protection strategy. Additional independent mapping, land-use suitability, surface and ground water contamination studies in the region for local governments.

Allen County, Ohio

Geologic and hydrogeologic evaluation of the suitability of proposed solid waste landfill site overlying the wellhead protection area for the local community. Presentation of findings to Ohio EPA. Preparation of a successful Sole Source Aquifer Designation Petition for portions of five counties in the region. Continued support of SSA in local and regional land-use issues.

Oregon, Ohio

Geologic investigations (geologic mapping and the identification of surface and subsurface routes for contaminant migration, analysis of contaminant parameters) of the Envirosafe Hazardous Waste Landfill site and the surrounding region for the City of Oregon. Presentation of the geologic findings to the Hazardous Waste Siting Board of

Ohio, Ohio EPA and US EPA., continued involvement and support to Central Michigan State University during the US EPA RIFS efforts at the site.

Madison County Ohio

Glacial and hydrogeological evaluation of stratified glacial valley deposits (Teays River Valley) over an 85 square-mile area, including one of the first non-agency applications of computer-flow modeling (Modflow) in Ohio for the development of a major wellfield. Field collected data became the core for the first Groundwater Pollution Prevention Map (DRASTIC) created in Ohio. This area is being revisited 17 years later for the Wellhead Protection Programs for the London Correctional Institute and Lake Choctaw.

Columbus, Ohio

Geologic and hydrologic evaluation of the southern portion of Franklin County for a variety of projects. These include evaluation of the Southerly Wastewater Treatment Plant construction dewatering of the water supply for the community of Shadeville, Ohio; Pleistocene depositional sequence identification, mapping and evaluation for the City of Columbus South Wellfield to help determine the sustainable yield for the wellfield; Pleistocene depositional sequence identification, mapping and evaluation to develop the input code for a regional ground-water model.

Franklin, Fairfield, Licking and Ross Counties Ohio

Drilling, surface soils and subsurface geologic, and hydrogeologic investigations of a number of locations in the four counties over the buried Teays River Valley mainstem in Ross County to southern Franklin County and Teays age tributaries including the Newark River located in southern Licking County, northern Fairfield County and southern Franklin County. Investigations have centered on locating and developing new well fields, installing new wells in existing well fields and developing wellhead protection programs for both new and existing well fields. All are public water supplies but ownership ranges from rural water supplies to county-owned water supplies to municipal water supplies with more limited distributions.

Miami-Erie Canal

Land-use and surface-water drainage evaluation of a 40-mile stretch of canal, including historical research and public works planning. Continuing involvement as canal lands have transferred to ODNR and have been prioritized for reconstruction and maintenance.

Maumee Watershed Conservancy District

Assistance with a variety of projects including evaluation and guidance in the preparation of a sub-district petition for the West Branch St. Joseph River in Williams County and the investigation of a private well contamination complaint in Van Wert County.

Reily, Ohio

Geologic and hydrogeologic evaluation of the suitability of a proposed solid waste landfill site for the local community, including observation of site drilling; pumping test; and presentation of findings to Ohio EPA hearing panel.

Westerville, Ohio

Stormwater management demonstration program, including hydrologic modeling and recalibration of rainfall volumes for storms of record for development of stormwater plan for City.

Central, Ohio

Glacial and hydrogeological evaluation and deposition for the plaintiff in Cline vs. American Aggregate, the landmark case regarding ground-water rights in Ohio.

Scioto River Basin

Evaluation on non-point source sedimentation and nutrient enrichment due to agricultural practices, including 208 planning study.

State of Ohio

Evaluation of several surface-mine reclamation sites, including geologic evaluation, landslide analysis and evaluation of microbiological treatment of acid seeps, ponds and spoil materials.

Private Clients

Evaluation of geologic and hydrogeologic conditions regarding brine contamination of residential wells resulting from oil and gas brine disposal.

Public and Private Clients

Site specific geologic investigations of existing solid waste landfills to determine nature and age of deposits on site, to determine suitability for continued use as solid waste landfills, to determine locations and types of monitoring well installations.

State of Ohio Agencies

Development of presentations and training sessions on Ohio's Geology, Soils, and GIS Applications including the following:

> "Taking First Cut at Landfill Siting" for the Ohio Federation of Soil and Water Conservation Districts;
>
> "Ground Water - Ohio's Buried Treasure" for the Ohio Cooperative Extension Service;
>
> "Ground-Water Quantity and Quality, It's Relationship to Ohio's Geology" for the Ohio Department of Health;
>
> "Is There Any Good Way to Site a Landfill-A GIS Approach" for multiple agencies;
>
> "Summer Field Workshop on Joints and Fractures in Ohio Tills: Site Investigation Techniques and Field Hydraulic Measurements" Molly Caren Farm Science Review, Madison County, August 1997, for The Ohio State University (Cooperative Extension), Ohio Dept. of Natural Resources and USDA (Natural Resources Conservation Service and Agricultural Research Service). Additional Fracture Field Days Franklin County, May 2000, WMAO Spring Meeting, Defiance County, Sept. 2001, Ohio Fracture Flow Working Group, ATI and Wayne County, Sept. 2003, Firelands College and Erie County, August 2006, Ohio Fracture Flow Working Group;

"TR# 55, Urban Hydrology for Small Watersheds", USDA Natural Resources Conservation Service's stormwater evaluation system for the Franklin Soil & Water Conservation District.

"GIS Applications for Environmental Planning, Assessment and Decision Making" for Ohio Department of Transportation, Environmental Section.

Guest Lecturer

The Ohio State University, School of Natural Resources and Dept. of Food, Agricultural and Biological Engineering; Wright State University, Department of Geological Sciences; University of Cincinnati, Institute of Environmental Health.

PROFESSIONAL ORGANIZATIONS

Association of Ground Water Scientists and Engineers.
Association of Ohio Pedologists, Distinguished Service Award, 1998.
American Institute of Professional Geologists, Past National Chair, Public Education Comm., Certified Professional Geologist
Ohio Academy of Science, Fellow, 1994, Co-coordinator Ohio Fracture Flow working Group, Co-editor special issues on fractures Ohio Journal of Science.
Ohio Alliance for the Environment, Past Board Member.
Ohio Citizen Action; Howard M. Metzenbaum Scientific Leadership Award and Ohio Senate 125th General Assembly of Ohio Certificate of Honor, 2003.
Ohio Environmental Council, Past Board Member, Technical Advisor.
Soil Science Society of America, ARCPACS Certified Professional Soil Scientist, 2008.
Soil and Water Conservation Society, Past Chair Environmental Education Committee, State and National levels.
Water Management Association of Ohio, R. Livingston Ireland Award, 1994, Past Officer, Past GIS Liaison to the Ohio GIS Conference.

APPOINTED AND ELECTED MULTI STATE, OHIO & COUNTY POSITIONS

Franklin Soil and Water Conservation District Board of Supervisors 1989-1997; District Representative to the Franklin County Greenways Committee, 1994-1997; Associate District Board of Supervisors and Technical Advisor, 1998 – present; Franklin SWCD Goodyear Cooperator of the Year Award, 1998 for the Franklin County Metro Parks Pickerington Pond Project.
Freshwater Foundation/Kellogg Foundation, Ground Water Information System (GWIS) to the Great Lakes Region, Ohio Representative, 1992-1995.
Mid-Ohio Regional Planning Commissions Local Government Committee Member 1992-1997.
NASA Mission to Planet Earth, Technology Transfer Coordinator, Ohio Grant, 1994-1997.
Ohio Academy of Science, Lake Plains Working Group (Ohio Fracture Flow Working Group, Co-Coordinator, 1993-present), co-editor, Ohio Journal of Science Special Issue, *Fractures in Ohio's Glacial Tills,* June/September 2000, Vol. 100 No. 3 / 4, 80 pages; Ohio Journal of Science Special Issue *Fractures in Ohio's Glacial Tills: Further Explorations,* April 2006, Vol. 106 No. 2, 76 pages. Ohio Academy of Science member to the Ohio EPA Lake Erie Phosphorus Task Force, 2007-present, OAS symposium convener, "Declining Water Quality in the Western Lake Erie Basin: Increasing Invasion of Blue-Green Algae (Cyanobacteria), and Increasing Levels of Soluble Reactive Phosphorus, April 2008.
Ohio Dept. of Health Private Water Supply Advisory Board 1983-1991.

Ohio Environmental Protection Agency Lake Erie Phosphorus Task Force, 2007 – present.

Ohio Federation of Soil and Water Conservation Districts Board Member to the Ohio Environmental Council 1993-1997.

Ohio Federation of Soil and Water Conservation Districts Prime Farmland Preservation Task Force 1996-2000.

Ohio Federation of Soil and Water Conservation Districts Urban Comm. 1989-1997.

Ohio Inter-Agency Ground Water Advisory Council, Executive Committee 1987-1994.

Ohio Oil and Gas Regulatory Review Commission 1986-1987.

Ohio State University Dept. of Agricultural Engineering Industry and Professional Advisory Group Member 1992-1996.

Walnut Grove Cemetery Advisory Board, City of Worthington and Sharon Township, 1997-present.

Water Management Association of Ohio GIS Liaison to the Ohio GIS Conference, 1996-2000.

REGISTRATION AND CERTIFICATIONS

American Institute of Professional Geologists - #7433, Certified Professional Geologist, geomorphology, stratigraphy and water resources.
Association of Ohio Pedologists – #1015 Certified Soil Scientist.
Commonwealth of Kentucky # 2142 Registered Geologist
Ohio Facilitator, Project Wet (first training class in Ohio)
Soil Science Society of America, #206059, ARCPACS Certified Professional Soil Scientist.

PUBLICATIONS, POSTERS AND AUDIO/VISUAL PRESENTATIONS

"Monitoring Landfills", Water Well Journal, July, 1979, Volume 33, No. 7, pp. 49-51.

"A 3-Dimensional Ground-Water Modeling Study for Development of the New Well Field at London Correctional Institute in Madison County, Ohio", Proceedings of the National Water Well Association Conference on Practical Applications of Ground Water Models, August 10-20, 1985, The Ohio State University, Fawcett Center for Tomorrow, Columbus, Ohio, pp. 197-211.

“Regional Ground-Water Management Planning in Ohio” with Truman Bennett, Nora Lake, Ann Shafor, and Ronald Schmidt, 32nd Annual Midwest Ground-Water Conference, Madison, Wisconsin, Oct. 28-30, 1987, Program Abstracts, p. 18.

"Ground Water-Ohio's Buried Treasure" A 45 minute slide-tape presentation for the Ohio Cooperative Extension Service, 1987.

"A Hypothesis for the Deposition of the Lockbourne Sand and Gravel", with Don Clabaugh and Truman Bennett, The Ohio Journal of Science, April Program Abstracts, 1988, Volume 88, No. 2, P.14.

"Establishing a Regional Ground-Water Monitoring Network for Buried Valley Aquifers", with Margo Lindahl and George Roadcap, The Ohio River Basin Consortium for Research and Education, Fifth Annual Scientific Symposium Abstracts, September 6 - 8, 1989, Ohio University, Stocken Center, Athens, Ohio, pp. 30-31.

"Beyond a State Ground-Water Protection Strategy; Where do we go from here?", with Ava Hottman, Proceedings of the National Water Well Association/Association of Ground Water Scientists and Engineers Cluster of Conferences, Ground Water Management and Wellhead Protection Section, February 20-22, 1990, Kansas City Convention Center, Kansas City, Missouri, pp 529-544.

"Taking a First Cut at Landfill Siting" a 30-40 minute slide script presentation for the Ohio Federation of Soil and Water Conservation Districts, Urban Committee.

"Pleistocene Stratigraphy of the Knox County Landfill," Karen Voisard and Julie Weatherington-Rice, The Ohio Journal of Science, April Program Abstracts, 1990, Volume 90, No. 2, p. 12.

"Is There Any Good Way to Site a Landfill", Four regional, one day training seminars on landfill siting criteria. January & February 1991, co-sponsored by Ohio Federation of Soil & Water Conservation Districts, ODNR Divisions of Soil & Water Conservation, Miami University, Ohio EPA, Ohio Environmental Council, Ohio Citizen Action, Franklin, Athens, Hancock, Montgomery and Portage Soil and Water Conservation Districts, Miami Valley Regional Planning Commission, Portage Co. Solid Waste District and Bennett & Williams, Inc., Athens, Findlay, Trotwood and Rootstown, Ohio.

"A Geologic, Hydrogeologic and Soils Survey as it Relates to Land Use Development in German Township, Montgomery County, Ohio", with Marc Racine, Peter Lurker and Stephen Dourson, The Ohio Journal of Science, May program Abstracts, 1992. Vol. 92, No. 2, page 20.

"Allen County Area Combined Aquifer System Sole Source Aquifer Proposed Designation", The Ohio Journal of Science, May Program Abstracts, 1992, Vol. 92, No. 2, page 20.

"Ohio's Lake Plains, Their Pleistocene Origin, Post Depositional History and Geotechnical Limitations", with Douglas Hunter and Ronald Trivisonno, The Ohio Journal of Science, April Program Abstracts, 1993, Vol. 93, No. 2, page 38.

"Fracture Flow in Fine-Grained Materials in Northern Ohio - Two Site Investigations", with Michael P. Angle, The Ohio Journal of Science, April Program Abstracts, 1994, Vol. 94, No. 2, p. 7.

"GIS for Land-Use and Water Planning Projections; A Demonstration Project", with John Bateman, Ayman Ismail and Todd Jackson, Geographic Information Systems Applications for Water Resources Conference Abstracts, page 29, May 12, 1994, Holiday Inn, I-670 Conference Center, Fairborn, Ohio, Water Management Association of Ohio, Ohio Section AWRA and NASA.

"How Deep are the Fractures in Ohio's Fine-Grained Materials?", The Ohio Journal of Science, April Program Abstracts, 1995, vol. 95, No. 2, P. A-42.

"Greenways: Bootstrapping Franklin County's GIS System through a County-Wide Waterways Inventory and Preservation Project", Geographic Information Systems Applications for Water Resources; Data, New Applications and Projects Conference Abstracts, page 18, May 16, 1996, Akron Hilton at Quaker Square, Akron, Ohio, Water Management Association of Ohio, Ohio Section of AWRA and NASA.

"Updating Ohio's Landuse/Landcover Data Base: NASA's Grant to Ohio", Gary Schaal, Bruce Mutsch, Ralph J. Haefner and Julie Weatherington-Rice, Geographic Information Systems Applications for Water Resources; Data, New Applications and Projects Conference Abstracts, page 20, May 16, 1996, Akron Hilton at Quaker Square, Akron, Ohio, Water Management Association of Ohio, Ohio Section of AWRA and NASA.

"Fracture Flow in High Clay Content Glacial Materials - Applying the FRACTRAN Model", The Ohio Journal of Science, April Program Abstracts, 1996, Vol. 96, No. 2, pages A-29 to A-30.

"*Summer Field Workshop on Joints and Fractures in Ohio Tills: Site Investigation Techniques and Field Hydraulic Measurements*" August 1997, Molly Caren Farm Science Review, Madison County, for The Ohio State University (Cooperative Extension), Ohio Dept. of Natural Resources and USDA (Natural Resources Conservation Service and Agricultural Research Service). This was the First Ohio Fracture Flow Working Group Field Day. Subsequent Ohio Fracture Flow Working Group Field Days have been held in Franklin County, May 2000, Defiance County, September 2001, and at ATI, Wayne County, Sept. 2003.

"Boston Till Identified as Lower Till of Uplands, West Side of Mad River, Northern Clark County Ohio", The Ohio Journal of Science, Program Abstracts, 1998, Vol. 98, No. 1, Page A-21.

Fractures in High Clay Content Unlithified Glacial Materials in Ohio; Where They are Found, How They are Formed and Why They Persist", with Linda Aller, Truman Bennett, Ann Christy, Jerry Bigham, George Hall, Mike Angle, Scott Brockman, Ed Miller, Larry Tornes, Norm Fausey and Jon Gerken, in Mass Transport in Fractured Aquifers and Aquitards Abstracts, pages 66-69, May 14 to 16, 1998, Geoscience Center, Copenhagen, Denmark, Sponsored by the Geological Institute University of Copenhagen, Geological Survey of Denmark and Greenland, the Danish Geotechnical Institute , Groundwater Group Danish Environmental Research Programme, and GRUNDFOS.

"Research and Educational Outreach Efforts Relating to Fracture Formation and Water/Contaminant Transport in Ohio" with Linda Aller, Truman Bennett, Ann Christy, Jerry Bigham, George Hall, Mike Angle, Scott Brockman, Ed Miller, Larry Tornes, Norm Fausey and Jon Gerken, in Mass Transport in Fractured Aquifers and Aquitards Abstracts, pages 101 to 104, May 14 to 16, 1998, Geoscience Center, Copenhagen, Denmark, Sponsored by the Geological Institute University of Copenhagen, Geological Survey of Denmark and Greenland, the Danish Geotechnical Institute , Groundwater Group Danish Environmental Research Programme, and GRUNDFOS.

"The Use of GIS to Manage, Analyze and Visualize Data Collected During an Investigation of a Proposed Landfill", Anthony Catalano, Ming Zhang and Julie Weatherington-Rice, in Eighteenth Annual ESRI International User Conference Proceedings, Redland, California, 1998, CD ROM.

"Field Workshop on Till Fractures and their Environmental Implications: Research and Educational Outreach on Subsurface Fracture Formation, Water Flow, and Contaminant Transport in Ohio", with Ann Christy, The Ohio Journal of Science, Program Abstracts, 1999, Vol. 99, No. 1, A-15.

Also presented 45th Annual Midwest Ground Water Conference, October 17-19, 2000, Columbus, Ohio, Program Abstracts, p. 38.

"Developing Field Mapping Techniques for Fracture Identification and Spacing in Naturally Occurring Outcrops – An Educational Experience", with Ann D. Christy and Garry McKenzie, The Ohio Journal of Science, Program Abstracts, 2000, Vol. 100, No. 1 A-10.
Also presented 45th Annual Midwest Ground Water Conference, October 17-19, 2000, Columbus, Ohio, Program Abstracts, p. 37.

"*The Use of Long Term, Large Scale Pumping Data to Determine the Regional Recharge Rates Through Fractured Till and Lacustrine Materials",* with Linda Aller, Truman Bennett, Doug Hunter, Norman Fausey, Barry Allred, Larry Tornes, Scott Brockman, Mike Angle, George Hall, Ann Christy, John Szabo and Brenda Lloyd-(Hite), in Ground Water 2000 Conference (International-European led), Program Abstracts, June 12-14, 2000, Copenhagen, Denmark.
Also presented 45th Annual Midwest Ground Water Conference, October 17-19, 2000, Columbus, Ohio, Program Abstracts, p. 39.

"*Use of a Superfund Site as a Hands-On Learning Laboratory for Engineering Design Students"* with Ann D. Christy and Andy Ward, The Ohio Journal of Science, Program Abstracts, 2000, Vol. 100, No. 1 A-27.

Weatherington-Rice J, Christy AD, McKenzie G. 2000. Developing field mapping techniques for fracture identification and spacing in naturally occurring outcrops – An educational experience. Ohio J Sci 100(1):A-10.

Weatherington-Rice J, Christy AD, McKenzie G. 2000. Developing field mapping techniques for fracture identification and spacing in naturally occurring outcrops – An educational experience. In: 45th Annual Midwest Ground Water Conference Proceedings; 2000 Oct 17-19; Columbus, Ohio. Columbus (OH): Division of Water, Ohio Department of Natural Resources. 74 p.

Christy, A.D., and J. Weatherington-Rice. 2000. Field workshop on subsurface fractures in glacial till and their environmental implications: An educational experience for professionals and decision-makers. *Ohio Journal of Science* 100(3/4):94-99.

Weatherington-Rice, J., A.D. Christy, and J. L. Forsyth. 2000. Ohio's Fractured Environment. *Ohio Journal of Science* 100(3/4):36-38.

Christy, Ann D., and Julie Weatherington-Rice. 2001. Fractured glacial till sites and soils in central Ohio. *Ohio Journal of Science* 101(1): A-24.

Weatherington-Rice, Julie, Carol Moody, Diane Yagich, and Ann Christy. 2001. Filling in the gaps: Using mini-courses to teach earth sciences needed for students' successful completion of interdisciplinary engineering design projects. *Ohio Journal of Science* 101(1): A-30-31.

Weatherington-Rice, Julie and Anne Christy. 2001. *"Ohio's Natural Settings & Animal Manure Management"*. A 30-60 minute power point presentation developed for an OSU Extension Manure Management Training Day, Nov. 2001 and a Bowling Green State University Town-Gown Colloquium Nov. 2001. Subsequently updated and presented in 2002 to the Harden County Health District and in 2004 at a public meeting in Greene County.

Malone, R.W., S. Logsdon, M.J. Shipitalo, J. Weatherington-Rice, L. Ahuja, L. Ma. 2003. Tillage effect on macroporosity and herbicide transport in percolate. *Geoderma* 116:191* 215.

Malone, R.W., J. Weatherington-Rice, Shipitalo, N. Fausey, L. Ma, L. Ahuja, R. D. Wauchope, and Q. L. Ma. 2004. Herbicide leaching as affected by macropore flow and within-storm rainfall intensity variation: a RZWQM simulation. *Pest Management Science*. 60:277-285.

Weatherington-Rice, J. 2005. Beyond raw wastewater lagoons: Visiting new technologies and re-visiting traditional approaches to animal manure management. Ohio Academy of Science annual meeting special symposium on CAFOs, April 2005, Bowling Green. Ohio. This presentation has been given numerous times subsequently.

Weatherington-Rice, J. Dec. 2005. Local & regional mechanisms for protecting ground water resources. Presented at the Southwest Ohio Planning Conference, Dayton, Ohio. Subsequently modified and presented again to the Tuscarawas Buried Valley Aquifer Watershed Committee, Bolivar, Ohio, April 2006.

Weatherington-Rice J, Angle MP, Christy AD, Aller L. 2006. DRASTIC Hydrogeologic Settings Modified for Fractured Till: Part I. Theory. *Ohio J Sci* 106(2):45-50.

Weatherington-Rice J, Angle MP, Christy AD, Gerhing R, Aller L. 2006. DRASTIC Hydrogeologic Settings Modified for Fractured Till: Part II. Field observations. *Ohio J Sci* 106(2):51-63.

Weatherington-Rice J, Bigham J. 2006. Buried Pre-Illinoian-Aged lacustrine deposits with "green rust" colors in Clermont County, Ohio. *Ohio J Sci* 106(2):35-44.

Weatherington-Rice J, Hall G. 2006. Fracture and gully formations in glacial fill: Field observations at the WillowCreek Landfill, Portage County, Ohio and at historic earthen dam failure sites in the US. *Ohio J Sci* 106(2):27-34.

Weatherington-Rice, J., Hottman, A., Murphy, E. F., Christy, A.D., and M. P. Angle. 2006. Fractured tills, Ohio's ground water resources, and public policy considerations addressed by DRASTIC maps. *Ohio J Sci* 106(2):64-73.

Weatherington-Rice, J. 2006. Introducing the Ohio Fracture Flow Working Group, their research, educational, and outreach efforts. GSA North-Central Meeting, April 2006, Akron , Ohio, Abstracts.

Christy, A. D. and J. Weatherington-Rice. 2006. Fractures in glacial till: How quickly can they form and how long can they persist. GSA North-Central Meeting, April 2006, Akron, Ohio. Abstracts.

Christy, A. D., Weatherington-Rice, J., and M. Angle. 2006. Modifications of DRASTIC maps for fractured till. *Ohio J Science* 106(1): A 48.

Weatherington-Rice, J. 2008. Declining Water Quality in the Western Lake Erie Basin: Increasing Invasion of Blue-Green Algae (Cyanobacteria), and Increasing Levels of Soluble Reactive Phosphorus. *Ohio J Science* 108(1):A5-7.

Weatherington-Rice, J. 2008. Introduction to the "Declining Water Quality in the Western Lake Erie Basin" Symposium. *Ohio J Science* 108(1):A8.

Weatherington-Rice, J. 2010. Water Quality of Ohio's Lakes: Inland and Erie. *Ohio J Science* 111(1):A4-6.

Weatherington-Rice, J. 2010. Introduction to the "Water Quality of Ohio's Lakes: Inland and Erie" Symposium. *Ohio J Science* 111(1):A7.

Ohio Lake Erie Phosphorus Task Force. April 2010. Ohio Lake Erie Phosphorus Task Force Final Report. Ohio EPA Div. Surface Water (Task Force Member & co-author). On-line (http://www.epa.state.oh.us/portals/35/lakeerie/ptaskforce/Task_Force_Final_Report_April_2010.pdf) 109 pages.

Kim, E. K., Kang, Y. W., Christy, A. D., and J. Weatherington-Rice, in press, Laboratory Method for Predicting Boundary Conditions of Soil Textures that Support Fracture Development, *Transactions of the American Society Agricultural & Biological Engineers.*

Kim, E. K., Kang, Y. W., Christy, A. D., and J. Weatherington-Rice, submitted, Ternary Diagram Modeling of Soil Texture Data for Predicting Subsurface Fracturing in Glacially Related Fine-Grained Materials, *Transactions of the American Society Agricultural & Biological Engineers.*

Weatherington-Rice, J, Kim, E. K., Kang, Y, and A.D. Christy, October 2010. Predicting Subsurface Fractures in Glacial Tills & Unconsolidated Materials by Soil Texture Analysis. 55th Annual Midwest Ground Water Conference Abstracts, Concurrent Session E "Ground Water Movement Along Short Circuits" (invited presentation) October 4-7, 2010 Columbus, Ohio. P. 36.

Kim, E. K., Kang, .Y, Weatherington-Rice, J. and A.D. Christy, October 2010. Expanding the Fracturing Range by Laboratory Experiment & Midwest Soil Texture Analysis Data. 55th Annual Midwest Ground Water Conference Abstracts, Concurrent Session E "Ground Water Movement Along Short Circuits" (invited presentation) October 4-7, 2010 Columbus, Ohio. P. 37.

KERRY HUGHES ZWIERSCHKE, Ph.D., P.E.

Bennett & Williams Environmental Consultants, Inc.

EDUCATION

BSc– The University of Natal, South Africa, April 1998.
BSc (Hons) MICROBIOLOGY – The University of Natal, South Africa, April 1999.
MSc MICROBIOLOGY – The University of Natal, South Africa, April 2001.
Ph.D. FOOD, AGRICULTURAL AND BIOLOGICAL ENGINEERING – The Ohio State University, Columbus, OH, March 2009.

CERTIFICATION

Registered Professional Engineer - State of Ohio (License # 76394)
Registered Professional Engineer - State of Missouri (License # 2013038979)
Registered Professional Engineer - State of West Virginia (License # 21161)

SUMMARY OF EXPERIENCE

For more than fifteen years, Dr. Zwierschke has been actively involved in environmental science and engineering, with a focus on pollution prevention, monitoring and remediation. As part of her experience, Dr. Zwierschke has been involved in permitting requirements relating to surface water, stormwater pollution prevention, and wetlands and assists clients with compliance-related issues. Dr. Zwierschke uses state-of-the-art GIS data from utilities (water, wastewater and stormwater) to develop hydraulic models that allow utilities to maximize efficiencies. Her use of GIS also provides valuable insights in contamination and remediation projects especially at complex or large sites, allowing efficient visualization of data to facilitate decision making. She has also used GIS data to create models for groundwater flow and contaminant transport. Dr. Zwierschke has extensive experience with different forms of non-point source pollution-leachate from lined and unlined landfills; runoff from turfgrass systems; and tile discharge from fields in Ohio, and has expertise in surface and groundwater and the interactions between these media. She has designed wetland treatment systems that treat leachate from landfills and runoff and tile drainage from agricultural fields. She has provided expert opinions in cases dealing with impacts from solid waste and hazardous waste landfills and disputing the safety of disposing drilling cuttings in landfills. Dr. Zwierschke also has experience sampling soil, water and air and interpreting the results to provide actionable recommendations to protect human health and the environment. Dr. Zwierschke has over twenty years of experience in environmental research and education in both the United States and South Africa and currently serves as a mentor at The Ohio State University in the AWARES (Aspiration for Women's Advancement and Retention in Engineering and Sciences) in the Department of Food, Agricultural and Biological Engineering.

RELATED PROJECT EXPERIENCE

Canton, Ohio	Performed assessment and updates for potential pollution sources within the one- and five-year time of travel, inputted this data into ArcGIS for spatial display. Performed groundwater modeling to re-define the one- and five-year time of travel for the three wellfields. Assisted with the development of a comprehensive database system to collect, store and output all water quality data collected by the water system, including data necessary to meet regulatory requirements. Assisted with preparation of a management plan. Consulted with Client about strategies to minimize groundwater pollution due to the disposal of two millions of bentonite drilling fluid from oil and gas drilling adjacent to a wellfield.
Confidential Client Williams County, Ohio	Supervised the development of plans and permit applications for two wetlands providing initial treatment of tile drainage and surface runoff from agricultural fields.
Utility Madison County, Ohio	Developed documentation and programs for compliance with federal and state regulatory programs.
Confidential Client Montgomery County, Ohio	Investigated groundwater-surface water interactions and monitored runoff volume at a site slated for development to assess the downstream impact.
Westerville, Ohio	Mediated stormwater management discussions for the City during the development of a Stormwater Management Plan.
Le-Ax Water District, Ohio	Project manager for the development of a groundwater flow model to develop emergency response plans in case of a spill within the source water protection area.
Adams County Regional Water Adams County, Ohio	Developed a comprehensive GIS system for the water utility, including online access for field personnel, data collection for regulatory compliance and development of documentation and programs for compliance with federal and state regulatory programs.
Mahoning Valley Sanitary District Trumbull County, Ohio	Served as a technical advisor and evaluator for the Mineral Ridge Dam, including recommending maintenance and repair activities and providing communication strategies for stakeholders.

North Canton, Ohio	Performed groundwater modeling to re-define the one- and five-year time of travel for multiple wellfields. Consulted with Client about strategies to minimize groundwater pollution due to a leaking above ground storage tank adjacent to a municipal wellfield.
Northern Ohio Rural Water Ohio	Project manager for the development of a WaterGEMS hydraulic model for over 10,000 service connections. Used model to identify areas with high water loss rates.
Highland County Water Ohio	Developed an EPANet hydraulic model for over 11,000 service connections that was used to assess system improvements. Provided ongoing GIS development and training. Performed lead mapping to meet regulatory compliance requirements.
Ross County Water Company Ohio	Project manager for the development of an Online GIS system including training of field employees and development of methods to manage increased data collection. Developed documentation and programs for compliance with federal and state regulatory programs.
Western Water, Southeast Ohio	Project manager for the development of a hydraulic model of a 3,000 pipe water distribution system using InfoWater in ArcGIS. Used model to optimize pumping scenarios to minimize water waste. Implemented ArcGIS Online system. Performed lead mapping to meet regulatory compliance requirements.
Sole Source Aquifer Petition Eastern Ohio	Prepared a petition for the designation of a sole source aquifer in 13 counties in eastern Ohio. Petition included an analysis of public water supplies in the area, provision of alternate water supplies to replace groundwater and documentation of the dependence on groundwater in this area.
Fairfield County, Ohio	Environmental sampling of soil, groundwater, soil gas, sub-slab vapor and ambient air to assess exposure pathways including vapor intrusion, dermal, inhalation and ingestion from inorganic and organic contaminants. Risk assessments of all possible exposure pathways including use of the VISL and the EPA Adult Lead Methodology. Analysis of air sampling results to assess the necessity for on-site lead monitoring and mitigation during construction. Performed assessments of multiple chemical interactions and limitations of risks assessment results.

Clermont County, Ohio	Project manager for a litigation support project at a closed hazardous waste landfill. Work included analysis of submissions to OEPA, review of chemical analytical data for surface and groundwater, design of monitoring well networks, review and analysis of leachate data, review of leachate collection and treatment system operation and liner systems, preparation of technical comments on all aspects of landfill design components and monitoring, including liners, leachate collection, leachate quality, leak detector water quality, groundwater quality, underdrain water quality; and preparation of expert report on post-closure deficiencies. Negotiated with the owner/operator on behalf of the client to enhance aspects of the post-closure monitoring including groundwater and surface water monitoring.
Confidential Client Wetzel County, West Virginia	Provided expert testimony relating to the disposal of wastes from oil and gas drilling in a solid waste landfill. Testimony for litigative purposes included operational considerations for landfills accepting large amounts of oil and gas drilling cuttings.
Fairfield County, Ohio	Performed environmental sampling of soil, groundwater, soil gas, sub-slab vapor and ambient air to assess exposure pathways including vapor intrusion, dermal, inhalation and ingestion from inorganic and organic contaminants. Risk assessments of all possible exposure pathways including use of the VISL. Performed assessments of multiple chemical interactions and limitations of risks assessment results.
Stark County, Ohio	Provided litigation support at an operational landfill which had accepted aluminum dross waste, including the assessment of odor suppression/neutralization systems, design features of the leachate collection and recirculation systems, assessment of leachate generation, assessment of gas collection efficiency, design of the gas collection system, radius of influence and temperature effects relating to landfill gas control and preparation of expert report on design deficiencies and operation of landfill facilities.
Steubenville, Ohio	Project manager responsible for environmental monitoring and regulatory compliance at a closed city landfill. Performed semi-annual groundwater monitoring, quarterly gas monitoring and

	prepared all required regulatory submissions. Prepared closure plans for the facility including gas vents and capping plans. Coordinated all aspects of installing wetland treatment systems for the treatment of leachate, including preparation of plans and technical specifications, NPDES permit submission, preparation of the stormwater pollution prevention plan (SWP3), co-ordination of the bid process, awarding the bid, contract co-ordination and project management during construction. Preparation of corrective measures plan, including risk assessment.
Private Client Franklin County, Ohio	Assessment of BUSTR Tier I results and performed preliminary risk assessments to assess the exposure pathways at the site.
Private Foundry Ohio	Prepared and submitted Toxic Release Inventory and Ohio State Emergency Response Commission Reports for regulatory compliance.
Knox County, Ohio	Project manager responsible for environmental monitoring and regulatory compliance at a closed county landfill. Performed semi-annual groundwater monitoring, surface water monitoring, leachate collection system inspection, quarterly facility inspections, annual reporting requirements and prepared all required regulatory submissions.
Chillicothe, Ohio	Project engineer for post-closure activities and regulatory compliance at a closed city landfill. Work included quarterly site inspections, semi-annual explosive gas monitoring, semi-annual groundwater monitoring, quarterly cap inspections, installation of explosive gas monitoring wells, certification of gas wells and submission of reports to regulatory agencies.
Hamilton County, Ohio	Technical review of historic and current license applications for seven construction and demolition debris landfills to determine compliance with regulations. Reviewed and commented on issues such as operations, deficiencies in hydrogeology, plan drawings, groundwater monitoring and well locations. Provided ongoing review of technical aspects of proposed exemptions and modifications. Performed review of groundwater monitoring data, statistical analysis and groundwater flow directions.

Bryan, Ohio	Performed groundwater modeling to re-define the one- and five-year time of travel. Performed assessment and updates for potential pollution sources within the one- and five-year time of travel, inputted this data into ArcGIS for spatial display. Provided assistance with NPDES renewal and permitting assistance for well abandonment.
Kingdom of Jordan	Provided internationally acceptable pumping test protocols and methods of safe yield determination for a groundwater supply project.
Accra, Ghana	Provided internationally acceptable pumping test protocols and methods of safe yield determination for a groundwater supply project.
Confidential Client Washington, DC.	Performed analysis of amount of water available for recharge in aquifers, sources of recharge and total water budget.
Little Hocking, Ohio	Performed analysis of water levels and recharge in existing municipal wellfield. Researched technical information about unregulated contamination in the wellfield. Reviewed NPDES permits. Project manager for creating the water distribution GIS program that identifies all capital investments and spatially locates critical components. Conducted training of office staff on ArcGIS Online. Developed data collection and coordinated the updating of GIS data. Developed documentation and programs for compliance with federal and state regulatory programs. Developed an EPANet hydraulic model for the water distribution system in two counties and developed potential improvements to reduce system concerns with low pressure zones.
Richland County, Ohio	Performed groundwater monitoring at a facility with an abandoned underground storage tank and submitted reports to regulatory agency.

RELEVANT TRAINING

OSHA Certification: Health and Safety for Hazardous Waste Site Operations (40-hour) – 2001 and annual 8-hour updates through the present.

Best Practices for Vapor Intrusion Investigations Webinar, April 16, 2021.

AWWA Webinar: Final Lead and Copper Rule Revisions – What it Means for Water Systems. January 28, 2021.

Ohio Statewide Floodplain Management Virtual Conference Webinar Series, December 8 & 15, 2020.

Stormwater Permitting Requirements for Industrial Activity, October 6, 2020.

TPH Risk Evaluation at Petroleum Contaminated Sites, June 9, 2020.

Small System Risk and Resilience Assessments under AWIA, June 4, 2020.

Optimizing Injection Strategies in Site Bioremediation Performance, May 21, 2020.

Bioavailability of Contaminants in Soil: Considerations for Human Health Risk Assessments, May 19, 2020.

Managing LNAPL Sites, Conceptual Site Models, and Using Science to Select a LNAPL Remedial Technology. April 7, 14, and 28, 2020.

Midwest PFAS Webinar. January 29, 2020.

Environmental Forensic Techniques: Applications for Classic and Emerging Contaminants. November 14, 2019. Columbus, Ohio.

PFAS and Due Diligence: Practical Information for Managing the Emerging Risk. June 19, 2019.

PFAS Basics: An Introduction to the Chemistry, Sources, Regulation and Analysis. March 26, 2019.

Workshop on Elevated Temperature Landfills. November 7, 2018. Columbus, Ohio.

Missouri MWEA/AWWA Joint Conference. March 26, 2018. Osage Beach, Missouri.

Northwest Ohio Section AWWA. March 22, 2018. Bucyrus, Ohio.

Ohio GIS Conference. September 25-26, 2017. Columbus, Ohio.

Northeast Section AWWA. August 17, 2017. Canton, Ohio.

ESRI Water Conference. February 6-8, 2017. Orlando, Florida.

Practical Guide to Vapor Intrusion. May 10-11, 2016. Hartman Environmental Geoscience, Columbus, Ohio.

Remediation Workshop. September 10, 2015. Various sponsors, Columbus, Ohio.

AWWA Asset Management Workshop. May 19, 2015. Columbus, Ohio.

VISL Webinar. May 12, 2015. Ohio EPA, Columbus, Ohio.

Interpreting VAP Certified Laboratory Data. January 29, 2015. Ohio EPA, Columbus, Ohio.

Advanced Tools for In-situ Green Remediation. December 2014. Ohio EPA, Columbus Ohio.

Aquifer Analysis Course. August 2013. E. Scott Bair and T. Naymik. National Groundwater Association.

2013 Vapor Intrusion Training Course. May 14, 2013. Presented by Ohio Environmental Protection Agency, Reynoldsberg, OH.

GSE Technical Seminar, Geosynthetics Success, October 14, 2010, Powell, Ohio. Speakers included Dr. J.P. Giroud and Dr. George Koerner.

2010 North American Environmental Field Conference & Exposition, January 12-15, 2010, Tampa FL.

Sanitas Technologies, Applied Groundwater Statistics Short Course, 2007, Dublin Ohio. Presented by Dr. Kirk Cameron.

PUBLICATIONS

Aller, Linda, Kerry Zwierschke, Julie Weatherington-Rice, Melanie Houston, Trent Dougherty and Jack Shaner. 2013. Shale Gas Development in Ohio. The Ohio Environmental Council, Columbus, Ohio. 12 pp.

Zwierschke, K.H. and Christy, A.D. 2010. Anaerobic Bioreactor Landfills. In: *Encyclopedia of Agricultural, Food, and Biological Engineering, Second Edition* (editors Dennis R. Heldman and Carmen I. Moraru). Taylor and Francis, 5 pp (*In press*).

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Hughes, K.L., Ward, A.D., and Christy, A.D. 2002. A new engineering course closes the gap in applying natural channel concepts to engineering design. *Ohio Journal of Science* 102(1), A-34.

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Hughes, K.L., Daneel, R.A., and Senior, E. 2002. Physiological and molecular characterization of a methanol-oxidizing microbial association isolated from landfill covering soil. *South African Journal of Science* 98 (9/10), 434-436.

TEACHING

Department of Food, Agricultural and Biological Engineering, The Ohio State University:

- Instructor for Construction Systems Management (Professional Development and Business Communication) (2007)

- Teaching Assistant for Agricultural Systems Management and Construction Systems Management (courses in Professional Development and Safety, including OSHA standards) (2006-2007)
- Teaching Assistant for Material and Energy Balance (2006)
- Graduate Resident Instructor for Study Abroad in South Africa (June 2006)
- Graduate student advisor for Capstone Engineering Design Group (2005-2007)
- Static modeling of biological systems using MatLab, senior level engineering course (2003-2006)
- Assisted with Biological Engineering and Waste Management classes (2001-2004)

PRESENTATIONS

April 26, 2021. Member of GIS Professional Panel answering questions from students and professionals. URISA Monthly Meeting, Ohio Chapter of Urban and Regional Information Systems.

March 29, 2021. Survey123 in Water and Wastewater Utilities-Application and Integration. URISA Monthly Meeting, Ohio Chapter of Urban and Regional Information Systems.

October 20, 2020. Using Technology to Adapt to Unexpected Challenges. Ohio Rural Water Association Operator Expo.

October 13, 2020. Mobile Work Orders and Other GIS Applications – Using Technology to Adapt to Unexpected Challenges. Software Solutions Annual Conference.

September 29, 2020. Using Technology to Adapt to Unexpected Challenges. 2020 Kentucky GIS Virtual Conference – Above, Below and Beyond. Kentucky Association of Mapping Professionals.

October 15, 2019. Integrating Asset Management into Daily Operations. Ohio Rural Water Association Fall Expo.

September 12, 2019. Using Technology to Improve Communication – Case Studies. Ohio AWWA Annual Conference 2019.

August 26, 2019. Using Technology to Improve Communication in Rural Water Utilities.
Kentucky Rural Water Conference 2019.

May 15, 2019. Integrating Asset Management into Daily Operations. Tools for Asset Management Workshop. Ohio Training Committee of Ohio.

May 8, 2019. Case Study: Using Technology to Improve Communication – Rural Water Utilities. Ohio Rural Water Annual Conference.

February 4, 2019. Billing System Integration with WorkForce: Software Design and Deployment. ESRI Water Utility Conference, Nashville, TN.

October 25, 2018. The City of Canton's Dynamic Source Water Protection Plan – From Delineation to Implementation. Mid-Ohio Regional Planning Commission Annual Conference.

October 24, 2018. Mobile Work Order Development in Water and Wastewater Utilities. 2018 Kentucky GIS Conference. Kentucky Association of Mapping Professionals.

August 29, 2018. Implementing a Dynamic Source Water Protection Management Plan for the City of Canton. One Water Conference, Ohio.

May 9, 2018. Going Mobile with Work Orders. Ohio Rural Water Association Annual Conference 2018.

January 29, 2018. An Innovative Approach: Integrating Billing Software with ESRI WorkForce to Create Operational Efficiencies. ESRI 2018 Water Utility Conference, San Diego, CA.

October 2017. Mobile Work Order Development in a Rural Water Utility. Ohio Rural Water Operator Expo.

October 2017. Putting GIS to Work: Data Collection and Asset Management. Ohio Rural Water Fall Quarterly Meeting.

September 2017. Beyond GIS: Integrating GIS With Billing Software to Create Operational Efficiencies. Ohio GIS Conference.

August 2017. Creating a Dynamic Source Water Protection Management Plan for the City of Canton. AWWA Northeast Section Meeting.

May 2017. Innovations in Mobile GIS Technologies for Comprehensive Rural Water Utility Management. Ohio Rural Water Conference.

February 2017. Source Water Protection Program-Using ArcMap Desktop and ArcGIS Online. Co-presented with the City of Canton, Ohio. ESRI Water Conference, Orlando, Florida.

May 2016. How Best to Use GIS-based Management Systems to Improve Daily Operations and Budgetary Planning. Co-presented with Western Water Company. Ohio Rural Water Conference.

2013-2023. Mediator and presenter at quarterly user group meetings hosted by Bennett & Williams.

Attachment B
Research History
Water Movement in Soils in Ohio and Internationally

The identification of macropores was undertaken in at least the middle of last century, if not before, by the soil scientists who were charged with soils mapping of the state of Ohio. These soil scientists worked for the USDA SCS, later NRCS; for the Ohio Department of Natural Resources (ODNR) Division of Lands and Soils, later Division of Soil and Water Conservation (DSWC) and now the Ohio Department of Agriculture (ODA) DSWC; The Ohio State University (OSU) Department of Agronomy, later Department of Soil Science and now School of Environment and Natural Resources (SENR), and the Ohio Agricultural Research and Development Center (OARDC) headquartered at Wooster, Ohio. The OSU/OARDC soil scientists also support the OSU Cooperative Extension Program. Often, soil scientists were accompanied by the Pleistocene geologists of Ohio from ODNR Division of Geology Survey (DGS) and/or various colleges and universities. These teams have consisted of more than 100 soil scientists and geologists over several generations of field teams and researchers (Weatherington-Rice, 2022b). A photograph of these secondary fractures being exposed along a stream can be found in Figure B-1. A second photograph from near Defiance, Ohio on the Auglaize River can be seen in Figure B-2.

The team of soil scientists studying biopores is a much smaller group in Ohio. The work, for the most part, was carried out by the USDA Agricultural Research Service (ARS) at the North Appalachian Experimental Watershed Research Station near Coshocton, Ohio. That facility is now closed. Bill Edwards, the Team Leader at the facility began his research on biopores created and/or filled by earthworms the latter half of the 20th century. The Research Station was uniquely equipped for these studies. Martin Shipitalo, Rob Malone and Lloyd Owens trained under Bill Edwards and when Edwards retired, Owens took over the management of the facility and the biopore research. With the closing of the facility, Malone and then Shipitalo transferred to the Soils Tilth Lab in Ames, Iowa. There was another member of the Ohio team who also made significant contributions to the research, Frank Gibbs, USDA NRCS (retired) who was the Soil Scientist assigned to the Findlay Area Office. Gibbs developed the equipment used to smoke field tiles and worked as a close collaborator with Shipitalo (Figures B-3 and B-4). They were classmates at OSU and Gibbs had been studying macropore formation since he was a child on the family farm north of Lima, Ohio (Weatherington-Rice, 2022b).

Bedrock public water supply wells in northern Ohio recharge more rapidly and at higher volumes than matrix laboratory analyses of the overlying glacial and lake deposits would have predicted. In the summer of 1992, Gibbs and Weatherington-Rice were investigating a backhoe pit in Putnam County and encountered a series of vertical fractures in the underlying glacial materials that appeared to remain open permanently and control the migration of water from the surface to underlying bedrock aquifers (Figure B-5). Gibbs had studied under George Hall, the OSU Cooperative Extension Soil Scientist and Weatherington-Rice was currently his PhD graduate student so they brought their findings to Dr. Hall who immediately recognized the importance of the discovery.

After much discussion between soil scientists, geologists/hydrogeologists and agricultural engineers, Dr. Hall and Truman Bennett, founder of Bennett & Williams, convened the Ohio Fracture Flow Working Group in the spring of 1993 to coordinate the research efforts into macropores. The original research group consisted of members from NRCS, ARS, the US Geological Survey (USGS), ODNR, ODA, Ohio EPA, OSU/OARDC, several Ohio university and colleges' geology departments, local communities who were interested because of their public water supplies, and private firms. Since most of these organizations were members of the Ohio Academy of Science, it was decided to house the Working Group under their umbrella but to staff it at OSU. Research topics were identified; agencies, universities and private firms were assigned topics. The group decided to model the program after the Cooperative Extension process of simultaneous research, outreach and publication.

By 1997, enough research had been collected to hold a field day. A field day was held in August 1997 at OSU's Farm Science Review-Molly Caren Farm in Madison County. More than 175 people attended the all-day event which was staffed by representatives from Federal and State agencies, OSU, private firms and the Indiana Geological Survey. The field day was documented in "*Field workshop on subsurface fractures in glacial till and their environmental implications: An educational experience for professionals and decision-makers"* (Christy and Weatherington-Rice, 2000). If memory serves, Ohio EPA was in attendance. After the success of the field day, the Working Group decided to write papers capturing everything known at that time about macropore formation and their role in water and contaminant transport. These nine papers were published in a Special Edition of the Ohio Journal of Science, June/September 2000, volume 100, numbers 3 /4 (Ohio Journal of Science, 2000).

Research continued and more field days and conferences were held. The Ohio Groundwater Pollution Potential Mapping Program was modified to incorporate the importance of the secondary porosity macropore impacts on contaminant transport to underlying aquifers. The mapping process as a whole does not include transport to field tile and stream baseflow which would be included in the soils (S) layer. They do include a classification of "Clay shrink-swell" that refers to clays that "shrink and crack when dried, thereby increasing flow through the soil profile" (Nelson and Valachovics, 2022). In 2006, a second Special Issue of the Ohio Journal of Science was published. This issue contained 11 articles (Ohio Journal of Science, 2006). By this time, the Working Group was aware that the physical/chemical controlling factors for macropore fractures were grain sizes and clay mineralogy. This issue carried an early version of Dr. Eun Kyoung Kim's dissertational research detailing areas of the USDA textural triangle that support secondary porosity macropore fractures (Kim and Christy, 2006). This dissertation provided a method to determine if soils would fracture based on the widely-used textural triangle.

The Working Group chose publication in the Ohio Journal of Science because of its multidisciplinary audience and its broad Ohio distribution. While internationally abstracted and available on line, physical copies are distributed to all Depository Libraries of member agencies and academia. In addition, all members of the Ohio House of Representatives and Senate receive a hard copy, as does the Governor and all State agencies. Copies also go to all County Engineers. These special issues were further distributed to Soil and Water Conservation Districts, County Health Departments, a number of local planning departments and others that the Working Group thought would benefit from this information. The goal was to make certain that any and all decisions that could be affected by contaminant migration from the surface to underlying waters, would be able to factor in the importance of macropore systems to subsurface transport of water and contaminants. This includes the policies behind the application of liquid manures on agricultural fields. While the Working Group continued to undertake research, hold field days and conferences, speak at meetings, serve on the Ohio Lake Erie Phosphorus Task Force and publish peer reviewed papers, all the base knowledge needed to predict the migration of dissolved nitrogen and DRP to field tiles, stream baseflow and underground aquifers was in the hands of decision makers by 2006.

This topic is also understood and investigated by scientists beyond Ohio. Scientists all over the world are writing peer reviewed papers, theses and dissertations on this broad topic. Hundreds of papers are available. Just the papers where Weatherington-Rice is listed as one of the co-authors have been cited more than 175 times around the world. The last paper on the topic published by the research team was in the international *Journal of Engineering Geology* (Kim et al., 2017). It is, therefore, difficult to understand how these basic scientific principles could have been overlooked when developing the liquid manure spreading protocols for Ohio.

Figure 3.4. Fractures intersected by a stream cut in Hamilton County, Ohio (Source: Ohio Fracture Flow Working Group photo files). Photo was taken by C.S. Brockman.

Figure B-1: Secondary fractures intersected by a stream cut. These secondary fractures channel water and condiments moving with water to the baseflow of the stream (Kim, 2007).

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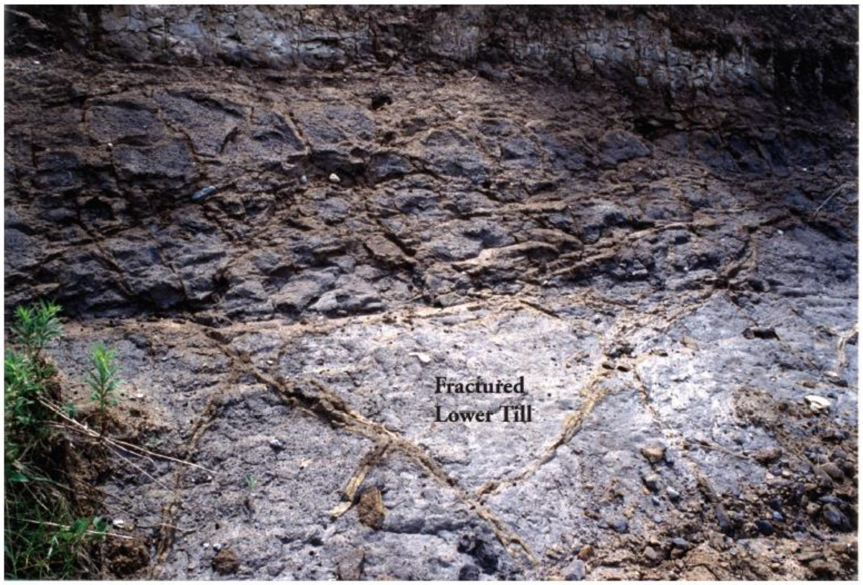

FIGURE 7: Two fractured tills with possible paleosol in between, east bank Auglaize River cut just downstream from the city of Bryan hydroelectric dam. Close-up of possible paleosol and lower till. Note more resistant remineralization infilling in the lower till and paleosol. Fractures are still hydraulically active. (Photo by L Aller 2003)

Figure B-2: This streambank cut on the Auglaize River, just upstream from Defiance, Ohio, documents fractured glacial tills which still are hydraulically active transporting baseflow recharge to the Auglaize River. If that baseflow was contaminated with DRP, the DRP would also enter the river through this transport system (Weatherington-Rice et al., 2006).

Figure B-3: Photo of Frank Gibbs and Martin Shipitalo smoking a tile line in northwest Ohio. Smoke is emanating from earthworm burrows that are connected to the surface (Shipitalo and Gibbs, 2000).

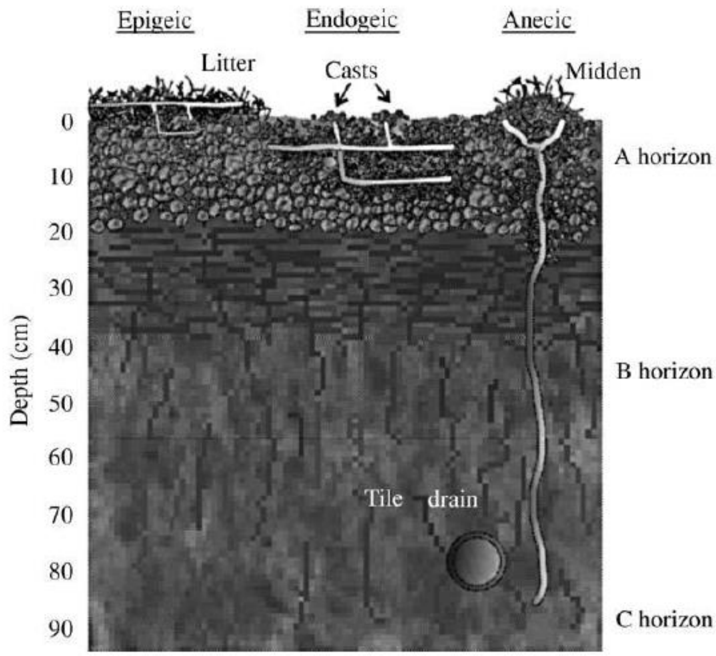

Fig. 1 Diagrammatic representation of the burrows made by the three ecological groups of earthworms as defined by Bouché.

Figure B-4: A representational sketch of the Anecic earthworms found in Ohio who advance their burrows to tile drains and below, often following biopores formed by roots and fractures formed by physical/chemical properties of the soil and underlying fine-grained glacially related materials (Shipitalo, 2002).

Figure 3.6. Fractured glacial lacustrine materials removed from the bottom of a backhoe pit north of the Miller City landfill, Putnam County, Ohio (Source: Ohio Fracture Flow Working Group photo files. Photo by J. Weatherington-Rice, June 2002). Fractures are approximately 30 cm apart. Oxidation rinds are approximately 10 cm in width each side of the fracture.

Figure B-5: Fractures found in the Putnam County backhoe pit investigated by Gibbs and Weatherington-Rice in 1992 (Kim, 2007).

Attachment C
State Line Observer Article
August 20, 2006

STATE LINE Observer

Frank Gibbs: Liquid manure is too wet

Written by David Green. Aug. 20, 2006

By DAVID GREEN

Don’t blame tile lines for discharges of liquid manure into drains, says soil scientist and farmer Frank Gibbs, and don’t blame the rich soil with its worm holes leading to the tile.

Put the blame on the watered down manure. That’s where the problem lies.

Gibbs, from the National Resources Conservation Service office in Findlay, Ohio, spoke to farmers last Wednesday at the annual Center for Excellence Field Day at Bakerlads Farm north of Clayton.

Gibbs told how he came to this conclusion several years ago, after he got a call from a producer in Ohio who had a problem. He was applying manure from his swine operation at only about half the recommended rate, but it was still finding its way into tile and drains.

A DNR officer told the farmer that he wouldn’t cite him for discharges this time, but it had to be stopped.

“I went down there thinking I’d see big cracks in the ground,” Gibbs said, “but the soil moisture was ideal. Impeccable shape. I saw lots and lots of night crawler holes and I thought, ‘My God, could this be what’s going on here?’”

Gibbs got ahold of some dye—similar to the kind used to check for leaks in a toilet tank—dumped it into the manure lagoon and agitated the mixture. After he dug down to a six-inch tile, manure was injected into the soil with a drag line. The tile was dry when the experiment began.

“We wondered how long it might take to percolate down to the tile lines. Twenty minutes? Should we go to lunch?”

There was no time for lunch, Gibbs said. The dye was there within seconds, and every time a pass was made over a lateral tile line, another pulse of colored liquid came through.

Gibbs wondered if the pressure from the applicator pump was the cause, so they next tried a gravity-feed system. Same problem. One more idea came to mind. This time they avoided the watery manure from the lagoon and loaded some of the thicker slurry from the pit under the hog barn.

“It didn’t go anywhere,” Gibbs said. “It behaved like manure. We dug up some areas with a back hoe and it was laying right where it was shot.”

He knew then not to fault the tile nor the healthy soil.

“The problem is simple. We’re watering manure down to where it behaves like water. Let me repeat that. We’re watering manure down to where it behaves like water. You don’t need to be a rocket scientist to understand that.”

Gibbs has heard the suggestion that no-till soil is at fault. Get rid of the worm holes and there’s no conduit for the manure.

Not true.

“Preferential flow will occur in conventional tillage through cracks and around the soil structure,” he said. “We need to stop confusing the issue with tillage. The issue is that we’re adding too much water.”

This is a situation that needs to be addressed, Gibbs said.

“We need to keep on top of this. We really do. I think some basic research could solve the problem.”

Maybe the percentage of solids needs to be up to four or five percent, he said. Or, from what he learned in Europe, even higher.

The Dutch method

With so many Dutch farmers investing in this area, Gibbs decided to take a trip to the Netherlands to see how they farmed in that country. He was in for a surprise.

He didn't see any of the watered down manure that the large dairies are using here. The solid content was at about eight percent.

He noticed a plastic membrane spread over a storage lagoon with rain water waiting to be pumped from an overnight storm. Gibbs figured it was to keep the water out of the lagoon, but he was wrong. It was to control odor.

Gibbs watched as a farmer loaded his applicator with manure and inserted a paper form into equipment that recorded his position by GPS. Once in the field, additional data was stamped onto the form. A sample bag of manure was collected to send for analysis by a government agency.

If manure exceeds the allowable nitrate rates, Gibbs was told, the farmer receives a bill from the government.

The Dutch farmer joked about having one government official for every farmer, but it isn't the heavy regulation that's hurting agriculture in Holland, he said, it's simply a lack of space.

Gibbs returned home knowing that the practice of watering down manure didn't come from Europe.

"That's our technology," he said. "We're going to all the work of writing up Comprehensive Nutrient Management Plans and then where does it go? Into the tile. We just need a little bit of research to figure this thing out so we don't have to scrap the whole thing."

Gibbs said he's made attempts to urge agricultural agencies to study the issue, but it's never gone far.

"Everybody's going off in other directions," he said. "We need to work together. We don't have to destroy our soils. We don't need to rip our tile out.

"What we should do is look at solids. Eight percent isn't that much. I don't know why we can't tweak that."

- Aug. 30, 2006

Stop it in the root zone

A visit to Wisconsin gave soil scientist Frank Gibbs additional hope for the future.

“They have some really good things going on there,” he said.

For example, the custom manure applicators have formed an association. They have standards and training, for those who choose to join the group. They work closely with the EPA. They practice cleanup of spills for when something goes wrong.

Gibbs was impressed with the beautiful crops growing on rolling hills. The key was the soil.

“They’ve got hay and they’ve got alfalfa and they put manure on it,” he said.

In this area, it’s almost always corn and soybeans, year after year. It’s the root system of a plant such as alfalfa that breaks up the soil to prevent compaction.

Custom applicators have to work with what they’re given, Gibbs said, and sometimes control structures are in order. Gibbs has built shut-off valves at the property line to stop the flow of liquid manure. A catch basin is added to collect the flow—a septic tank will do the job—and the manure can be pumped out and applied in a safe area between tile lines.

It’s just a Band-Aid approach, Gibbs said, not a solution, but it’s better than using rubber tile plugs in which case a farmer has no idea if the manure has left the tile. Besides, he asks, do we know where all the tile is? And if we miss one, who’s fault is it?

That’s when the arguing and finger-pointing begins. When manure flows into a drain, who is at fault—the farmer who owns the animals, the owner of the land where it’s being applied, or the person in charge of the application?

“If we do it the wrong way,” Gibbs said, “it’s going to be a mess.”

Any time manure enters a tile line, it’s wasted. At that point, Gibbs said, the nutrient is too deep to be absorbed by plants.

“We have to stop it in the root zone,” Gibbs said.

Smoke test highlights no-till

As a long-time proponent of no-till farming, Frank Gibbs often tries to convince other farmers to give it a try.

One of his early attempts was to dig out a cubic foot of his no-till soil and place it next to a sample from his neighbor’s sugar beet field that suffered from a lot of compaction due to trucks. Then he would pour a bottle of water onto each and watch it soak into his soil and run off his neighbor’s.

“It was kind of hokey,” Gibbs said. “Farmers would say, ‘You’re from the government. You probably poked holes in it.’ I needed a different way to show the value of no-till.”

He remembered a blower contraption a friend created for planting beans—it never worked right—and as a fan of Red Green, Gibbs got out the duct tape to rig up a device for blowing smoke into a tile line.

“I could make smoke come out of millions of worm holes,” he thought.

The smoke test shows good soil conditions and at the same time, it shows the avenue that liquid manure takes to reach tile lines. It takes the easiest route, Gibbs said, the path of least resistance. Through worm holes and cracks in the glacial till, manure can quickly makes its way to tile.

To set up the Center of Excellence Field Day at Bakerlads Farm, Gibbs dug a hole to reach a tile line. He found two hand-laid tile lines, then a plastic line, then another older line. Tile is everywhere.

He set up his blower, dropped in a smoke bomb and watched for smoke to start rising out of a soybean field. Smoke started to run toward the bean field, but the line made a turn and headed back into the cornfield. That’s the trouble with tile lines, he said, you never know how many there are or where they end up.

Watching smoke rise out of the soil is a great demonstration, Gibbs said, and a real attention-getter.

“It’s hard for folks to deny this stuff happens when there’s smoke coming up under their feet.”

Attachment D
Photographs
Wooster, Ohio
September 4-5, 2003

Plate D-1. Soils pit.

Plate D-2. Soil pit cut back to bucket containing dye to visualize transport of dye in the soil.


Plate D-3. Smoker used in demonstration.

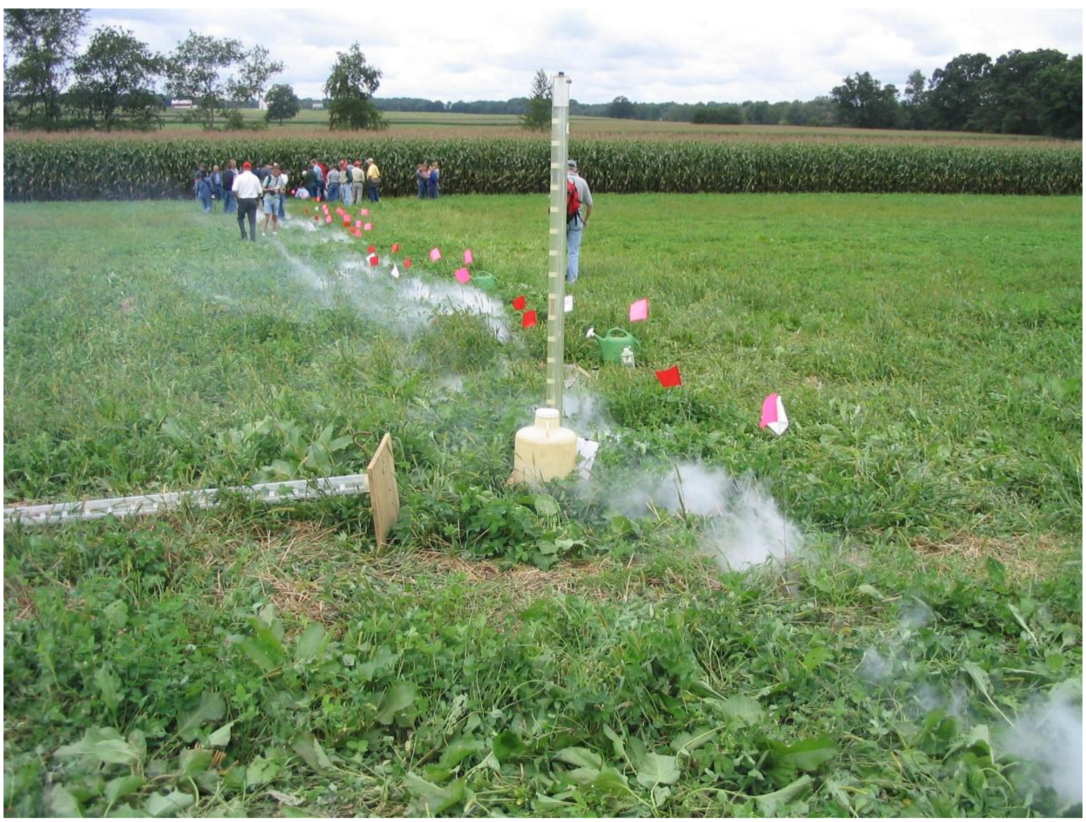
Plate D-4. Smoke from tile lines at the surface of a hay field.


Plate D-5. Smoke in adjacent (highly reworked corn field).

Attachment E
Western Lake Erie harmful algal bloom season projection

Western Lake Erie Harmful Algal Bloom Season Projection

03 August 2022, Projection 08

The Western Lake Erie HAB Early Season Projection gives an estimate of potential bloom severity based on measurements and forecasts of river discharge and phosphorus loads through July. The severity of the western Lake Erie cyanobacterial HAB depends on input of total bioavailable phosphorus (TBP) from the Maumee River from March 1-July 31. TBP is the sum of dissolved phosphorus and the portion of particulate phosphorus available for HAB development.

This updated forecast reflects measured July TBP loads, which were greater than the TBP forecast we used for the seasonal forecast. Therefore, we now expect a bloom with a severity of 4.5 with a range up to 5.5 due to model uncertainty. Locally generated rainfall was greater than normal in July. The bloom started in early July and can effectively use the TBP loads from July.

Blooms that do form will move with the wind and change over time; we will provide information on the presence and location of the bloom throughout the summer. The TBP loads are projected using Heidelberg University data and river forecasts from the National Weather Service Ohio River Forecast Center (through July).

R. Stumpf, J. Noel (NOAA), and L. Johnson (Heidelberg University) with assistance from E. Davenport, A. Hounshell, and M. Tomlinson (NOAA)

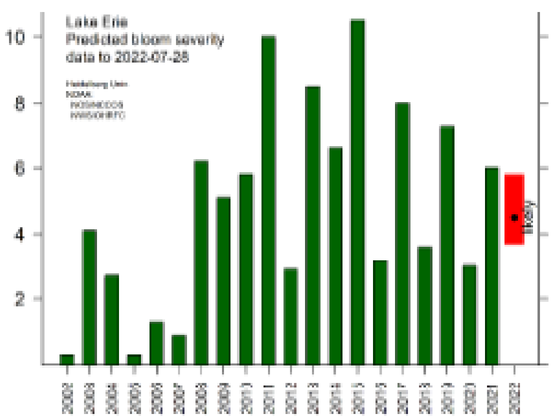

Figure 1. Projected bloom intensity as compared to previous years. The wide, bright red bar is the likely range of severity based on limits of model uncertainty.

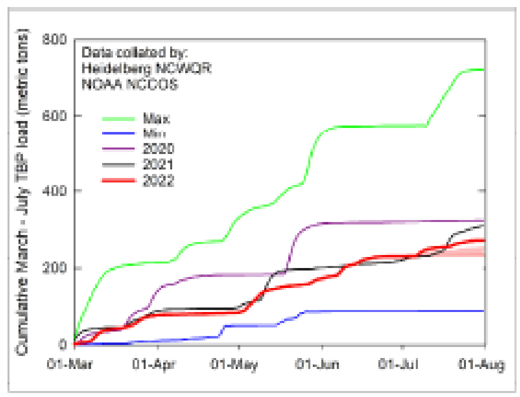

Figure 2. Cumulative total bioavailable phosphorus (TBP) loads for the Maumee River (based on Waterville, OH). Each line denotes a different year. 2022 is in red: the solid line is the measured load to July 31st; the pink area shows the likely range as forecasted on June 28th. Overall, there was greater TBP loading in July than expected from the end of June forecast.

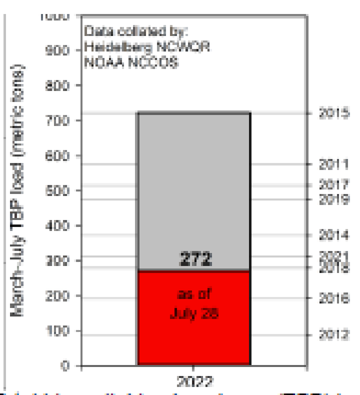

Figure 3. Total bioavailable phosphorus (TBP) load accumulated from the Maumee River near Waterville, OH to date. The right axis denotes the TBP load from selected previous years.

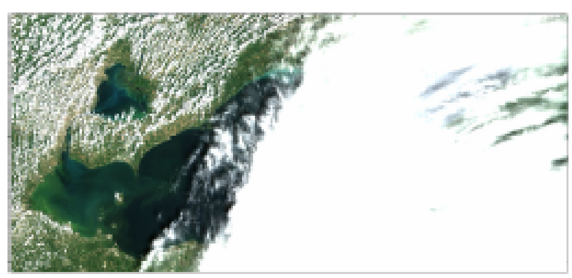

Figure 4. True color image of Lake Erie on 31 July 2022 derived from the Copernicus Sentinel-3b satellite. Greener waters in the western Lake Erie basin indicate a cyanobacterial bloom. Clouds obscure imagery in central and eastern Lake Erie.

For more information visit: http://www.ncwqr.org/ or http://coastalscience.noaa.gov/research/habs/forecasting/