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Tile Drainage in Wisconsin: Managing Tile-Drained Landscapes to Prevent Nutrient Loss

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Subsurface drainage of agricultural land has the ability to improve yields and reduce surface runoff and erosion losses. However, with a reduction in surface runoff, more water infiltrates the soil and percolates through the soil profile. This is of particular importance to farmers, as this water can also transport essential plant nutrients, specifically nitrogen and phosphorus, out of the root zone. Once nutrients reach the tile drain, they have a direct conduit to surface waters.

Tile-drained agricultural land must be well-managed to reduce the loss of nutrients to surface waters. Nutrient management practices must be carefully followed to minimize the risk of nutrient loss and to maximize fertilizer use efficiency. Additional considerations need to be taken with manure applications on tile-drained land to both minimize nutrient loss and prevent manure entry into tile drains.

The purpose of this publication is to:

- ✓ provide information on nutrient management concerns in tile-drained agricultural landscapes, and
- ✓ present management and treatment practices to reduce the loss of nutrients from tile systems to surface water.

"Proper management of crop nutrients on tile-drained landscapes is the key to reducing nutrient loss and maximizing nitrogen use efficiency."

Tile Drainage and Preferential Flow

One of the key factors in nutrient loss to tile drains is preferential flow through the soil profile, which is also referred to as macropore flow. Preferential flow paths are direct conduits from the soil surface to deeper depths in the soil profile. Preferential flow paths are formed by earthworm burrows, channels resulting from decayed roots, cracks created by soil shrinkage and other structural porosity in the soil.

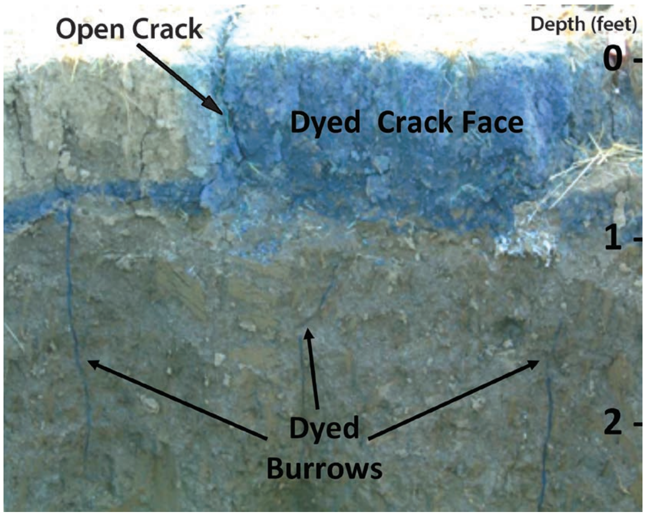


Figure 1. Methylene blue dye flowing through preferential flow paths in the soil.

As water percolates through the soil, it travels through preferential flow paths and rapidly transports soluble nutrients below the root zone. As observed with methylene blue dye applied to the surface of the soil in figure 1, the dye moved through the soil by a combination of preferential flow pathways. Most of the dye entered the soil through shrinkage cracks in the soil surface, then moved laterally along a plow pan and finally moved deeper in the soil profile through earthworm burrows. Water and nutrient transport through the soil matrix is much slower than through macropores, and water moving within the soil matrix allows more opportunities for nutrients to be absorbed by the soil. Figure 1 clearly illustrates that macropores in subsurface can cause rapid nutrient leaching losses.

The development of preferential flow paths in soil varies significantly with soil type and management. Long-term no-till typically results in increased macropore development as a result of lack of tillage to disrupt preferential flow paths. Soils with greater amounts of clay often develop large shrinkage cracks that occur as soil dries, and these cracks can go deep into the soil profile. Nutrients and organic material can be transported rapidly through these shrinkage cracks. For example, plant debris has been observed in well-developed shrinkage cracks down to 17 feet in Fond du Lac County *(Fred Madison, personal communication)*.

Earthworm activity results in considerable macropore development in soil, and earthworm activity tends to be greater in fields under no-till than in fields that are annually tilled. Results from several studies have shown that earthworm populations in no-till fields were approximately twice that of tilled fields (Kladivko et al., 1997; Kemper et al., 2011). The area over tile drains also creates a prime habitat for earthworms because this area is less frequently saturated. Earthworm populations over tile lines can be double that of those between tile lines (Shipitalo et al., 2004). This is important because earthworm burrows that exist within two feet of a tile drain cause direct drainage from the burrow to the tile outlet (Smetler, 2005).

Manure Management

When applying manure on tile-drained landscapes, additional precautions are needed because of the presence of preferential flow paths which can lead to direct transport of manure to tile drains. The application method, specifically for liquid manure, can have a large effect on the potential to transmit manure to tile drains. The key to preventing applied manure from leaching is to disrupt the macropores around and below the application area.

Although manure transmission can occur with all application methods (e.g., irrigation, surface spreading and subsurface injections), the two application methods that have the highest potential to lead to leaching of nutrients via preferential flow are knife injection and application using horizontal sweeps. For each of these application methods, there are specific conditions that lead to the high risk of manure leaching. Knife injection can be problematic if sufficient tillage is not performed before application. As shown in figure 2, as the knife passes through the soil, it leaves a column of manure behind the knife. If sufficient tillage has not been performed prior to injection, the fluid pressure forces the manure down earthworm burrows, shrinkage cracks or other preferential flow paths. However, if sufficient tillage has been performed the tillage and the resulting breakup of macropores decrease the likelihood that the applied manure will leach.

Similarly, horizontal sweep injection can be problematic if sweeps are placed too close together or if the implement is pulled through the soil too rapidly. This results in lifting the soil above the sweep, resulting in infill of the void with manure. As the weight of the soil comes down on the manure, it may be forced into preferential flow

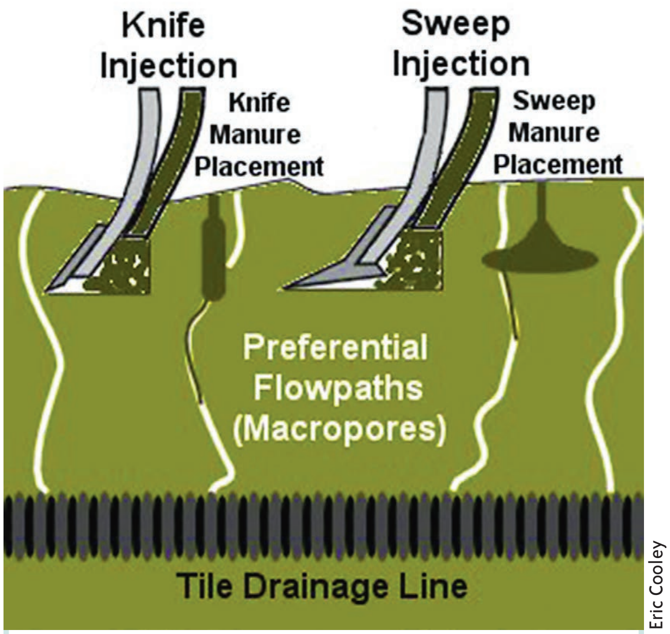


Figure 2: Knife injection and horizontal sweep injection can transmit manure to tile drains if done incorrectly in tile-drained landscapes.

paths and eventually into the tile drains (figure 2). Increasing the spacing/distance between knife and sweep injectors increases the loading of manure in a localized area near the injection zone. For example, an 8,000 gallon/acre application made using a horizontal sweep injection toolbar with 10-inch sweeps and 30-inch spacing would result in an effective rate of 24,000 gallon/acre in the area above the sweep (figure 2). The soil loading in the localized application area would be three times greater than a uniformly distributed load. Localized soil loading for knife injection is typically greater than the example used. Emerging technologies for manure injection may disrupt preferential flow pathways and reduce the potential for nutrient leaching.

The consistency and rate of liquid manure applications also factor into the potential for manure transport into tile drains. Manure consisting of greater than 5% solids has enough particulate matter to decrease the probability of preferential flow. Application of manure containing less than 2% solids has a greater probability of moving via preferential flow and has been observed in fields *(Frank Gibbs, personal communication).* The greater the application rate, the greater the volume of water that is added to the soil, thus increasing the potential risk to transmit manure to tile drains. An application of 13,000 gallons of liquid manure per acre has the same amount of water applied to the soil as a half-inch rainfall.

Soil moisture is an important factor in the potential to transmit manure to tile drains. Both high and low soil moisture can greatly increase this potential. When soils are near saturation, additional water added by liquid manure applications can initiate tile flow, thus facilitating manure entry into tile drains. In general, liquid manure should not be applied to tile-drained cropland if the drains are flowing. However, the University of Wisconsin Discovery Farms Program has monitored tile outlets that have flowed up to 365 days a year. Tile drains with continual flow indicate that the tile drain is placed below the water table and is actively transporting groundwater. In these situations, there are times when the tile flow is not exporting surface water and surface hydrology is uncoupled from the tile flow. Therefore, it is important for producers to know their tile system characteristics and evaluate soil moisture levels prior to application. Additionally, avoid manure applications when rainfall is predicted, especially when soil moisture levels are high; manure transmission to tile drains has occurred days to weeks after application. Research in Ohio identified manure applications to high moisture content soils or heavy rainfall after manure application as the most common factors contributing to manure entry into tile drains *(Hoorman and Shipitalo, 2006).*

Figure 3: Cracks in clay soils with high shrink-swell capacity.

Alternatively, clay soils with shrink-swell capacity (figure 3) will have an elevated potential to transmit manure when soil moisture is low. As previously mentioned, soil cracks can extend deep into the profile, especially during periods of drought. If feasible, pre-tillage (tillage conducted immediately before a manure application) should be performed to disrupt cracks and other macropores. If manure applications are to be made to growing crops or areas under no-till during very dry soil moisture conditions, decrease the initial application rate to add moisture to the soil and facilitate closing of the cracks.

Best Management Practices on Tile-Drained Agricultural Land

There are a variety of best management practices customizable to fit individual cropping systems and various tile-drained landscapes. We have identified twelve key elements that will lead to proper nutrient management on tile-drained land and thus minimize the potential to transmit manure to tile drains.

- ***Understand and locate tile drainage system features:*** A working knowledge of tile drainage systems and identification of tile outlets, surface inlets, vents and other components of tile drainage systems can reduce the potential of inadvertent entry of manure, pesticides, fertilizer and other soil amendments into the tile. Further information can be found in *Tile Drainage in Wisconsin: Understanding and Locating Tile Drainage Systems* (Ruark et al., 2009).

- ***Maintain tile drainage systems:*** Proper inspection and maintenance of tile drainage systems ensures that the tile system is functioning properly and reduces the potential of inadvertent entry of manure, pesticides, fertilizer and other soil amendments into tile drainage systems. Annual inspections should be performed to identify tile blowouts and outlet blockages. Further information can be found in *Tile Drainage in Wisconsin: Maintaining Tile Drainage Systems* (Panuska et al., 2009).

- ***Assess soil conditions prior to liquid manure applications:*** Both high and low soil moisture contents can be problematic for liquid manure applications to tile-drained land. Flowing tiles are often a good indicator of high soil moisture conditions and well-developed soil surface cracks are an indicator of low soil moisture conditions in clay soils with high shrink-swell capacity. Manure applications should be avoided during high soil moisture conditions. If manure applications are made during dry soil conditions with surface cracks apparent in the soil, either utilize pre-tillage before application or reduce initial application rate to slowly add moisture to the soil to facilitate closing of the cracks.

- ***Review forecasted weather prior to liquid manure applications:*** Avoid applications when rainfall is predicted to occur after application. Soil moisture levels are increased by liquid manure applications, and subsequent rainfall can result in tile flow and release of manure to tile drains. Also avoid applications soon after rainfall events because soil moisture levels are typically elevated.

- ***Monitor tile outlets when applying liquid manure:*** Tiles should be monitored before, during and after liquid manure applications for potential discharge of manure. Tiles flowing before applications are an indication of high soil moisture conditions, in most circumstances, and applications should be avoided. Monitor during applications because water from the liquid manure increases soil moisture content and can result in a flow event. Tile outlets should also be monitored up to a few weeks after application, especially after subsequent precipitation that may cause tile flow.

- ***Restrict tile discharge prior to manure application if possible:*** If water level control structures are installed in tile systems, insert stoplogs (devices inserted to control water level) to prevent flow from tile drains before application. Subsequent to application, remove stoplogs and check for flow. If flow is present after application, reinsert stoplogs to prevent discharge. Stoplogs should also be reinserted if a large rainfall is predicted to occur within a few weeks of application. Tile plugs can also be used in systems without water level control structures, but they have been shown to fail 50% of the time *(Hoorman and Shipitalo, 2006).*

- ***Use tillage to break up preferential flow paths prior to or concurrent with application:*** Pre-tillage for surface and injected liquid manure applications or application methods that concurrently disrupt preferential flow paths below the manure injection depth should be utilized to prevent manure entry to tile drains. Soils should be tilled at least three inches below the injection depth to adequately disrupt preferential flow paths.

- ***Take precautions when surface applying liquid manure to land under no-till or perennial crops***: Preferential flow paths are more developed in no-till systems and in later years of perennial crops. Split applications or reduced rates should be considered for liquid manure applications. Additionally, manure can be transported along growing or decayed roots of deep tap root crops like alfalfa.

- ***Ensure precautions are taken for manure and pesticide applications in fields with surface tile inlets:*** Surface inlets are commonly used in fields with closed depressions, that is areas without an outlet for surface water. Extra precautions need to be taken in proximity of surface tile inlets because they are a direct conduit to tile drainage systems. Check state and local setback requirements for surface tile inlets before applying manure and pesticides.

Eric Cooley

Figure 4: Water level control structure for tile drains.

- ✓ ***Use best management practices for fertilizer and manure management:*** This includes applying nutrients based on A2809 guidelines, *(Laboski and Peters, 2012)* delaying or splitting nitrogen fertilizer applications, and waiting to apply manure or anhydrous ammonia in the fall until soil temperatures are less than 50˚F. If applications are necessary when soil temperatures are above 50˚F, use nitrification inhibitors. Researchers in Indiana have shown that alternating the timing of liquid manure application from fall to spring can reduce nitrate leaching by 30% and that spring application of manure results in nitrate leaching losses similar to spring fertilizer applications *(Hernandez-Ramirez et al., 2011).*
- ✓ ***Utilize conservation management practices such as cover crops, conservation tillage, and planting of grassed waterways:*** This also includes any other management practice that increases nitrogen conservation in the soil and reduces erosion. These practices that reduce soil loss also reduce sediment-attached nutrient movement on the soil surface and will also help to reduce the potential of loss to tile drains.
- ✓ ***Have an emergency plan in place:*** If manure enters tile drains, take immediate steps to stop the flow and prevent discharge to fresh water systems. This can be performed by blocking or diverting the tile outlet, intersecting the tile system and digging a pit directly downstream of the spill site to collect manure. Contact the Wisconsin DNR Spills Hotline at **1-800-943-0003** to report the spill and get assistance with subsequent remedial actions.

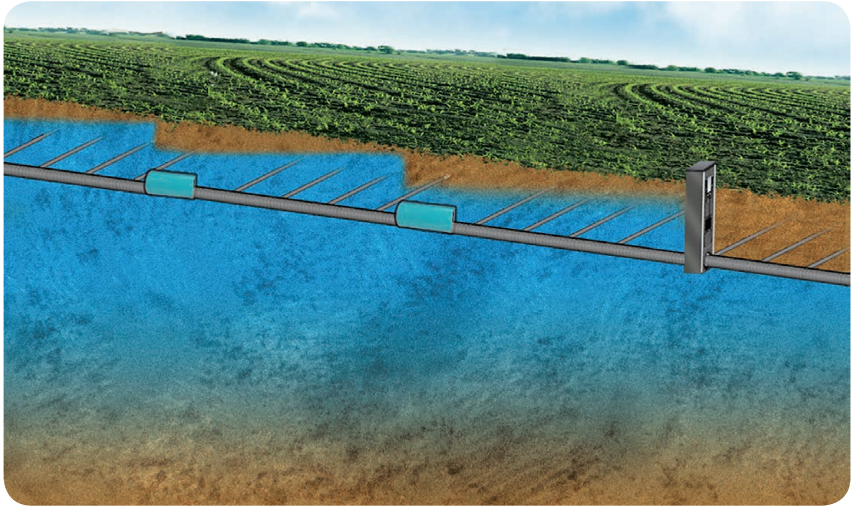


Image courtesy of AgriDrain, Adair, IA

Figure 5: Water Gates™ and Inline Water Level Control Structure "stair-step" water level.

Treatment practices

There are technologies available that can be used to retain water and nutrients in the soil profile. Drainage water management is the practice of controlling water table elevation to desired levels throughout the year. Water level control structures are used to maintain the water level higher in the soil profile after crops are removed to minimize nitrogen loss, predominantly in nitrate form, to surface water (figure 4). The control elevation is then lowered in the spring to remove excess water from the soil profile and to allow the soil to dry out for field access and planting. Once crops are planted, the control elevation is often raised to hold the water level closer to the root zone (a practice known as subsurface irrigation), especially for crops that are prone to drought stress. Once crops are removed, the control elevation is raised farther to store more water and to prevent nutrient loss until spring. Additional information on drainage water management can be found in *Drainage water management for the Midwest: Questions and answers about drainage water management for the Midwest* (Frankenberger et al., 2006).

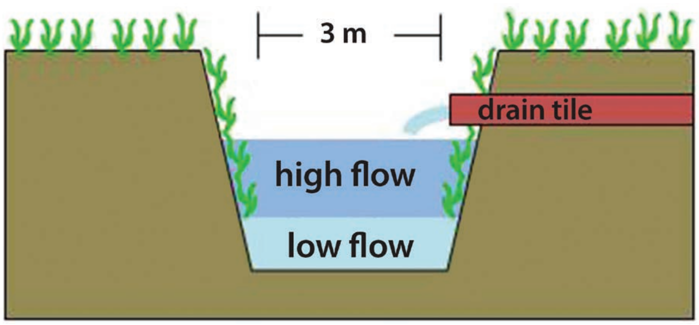
Water table management in many of Wisconsin's tile-drained landscapes is limited by the slope of the land. Slopes of less than ½% are suitable for drainage control structures to be practical. Slopes greater than ½% will only allow for drainage control on a small portion of the land surface and may result in high fluid head pressures in tile systems and tile blowouts. Many of Wisconsin's tile-drained landscapes have 2–6% slopes. New technologies allow for infield drainage control for lands with higher slopes (figure 5). This type of system has two benefits: It is installed underground so as not to interfere with field operations (including deep tillage), and it can be "stair-stepped" to control drainage on higher sloped land up to 2% (figure 5). The level in each of the structures is controlled by the downstream water control structure located either at a field boundary or tile outlet.

Constructed wetland treatment of tile drainage flow has been shown to be more effective for nitrogen (N) than phosphorus (P) removal, but there are many limitations with this practice *(Miller et al., 2002).* Constructed wetlands can take large amounts of land out of production for effective treatment sizing. Reported P removal and N concentration reductions vary due to a number of factors, including system design, retention time and local climatic and physical conditions. Temperature effects on microbial activity may have large influence on N removal capacity, especially in the cold temperature extremes of the northern regions, such as Wisconsin *(Jin et al., 2002).* The P removal potential of constructed wetlands is limited and highly dependent on the nature of materials used for construction. In fact, during constructed wetland establishment, increases of ammonium N, dissolved reactive P and total P have been seen in wetland effluent *(Tanner et al., 2005).*

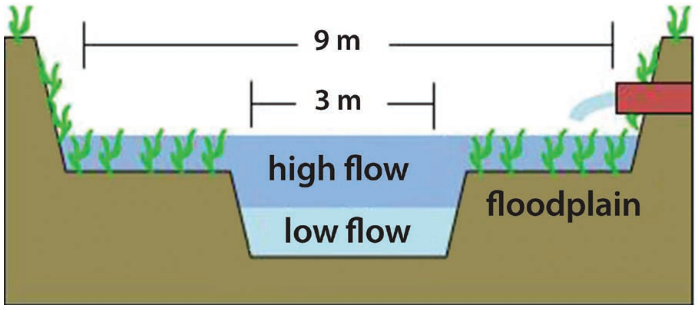
For tile systems that outlet to drainage ditches, a two-stage drainage ditch can reduce the scouring of ditch banks and increase the removal of sediment, nitrogen and phosphorus from tile drainage water. The two-stage design, as seen in figure 6, spreads flow over a larger area that decreases water velocity, allowing for sediment to settle out, and increases residence time for biological N removal. During low ditch flow periods, if the drainage ditch is constructed properly, tile water will spill onto vegetated benches, allowing for increased removal of sediment and nutrients.

Figure 6: Traditional and two-stage drainage ditches.

Conventional Ditch



Two-Stage Ditch



Images courtesy of Sarah Roley

Emerging technologies in drainage water management will likely provide increased options for reducing sediment and nutrient transport from tile drainage systems. Some of these technologies include blind and alternative surface inlets, bioreactors and saturated buffers.

Contact your local Natural Resources Conservation Service (NRCS) or Land Conservation Department (LCD) to obtain additional information on management practices to reduce nutrient loss from tile drainage systems and local regulations on manure application requirements and setbacks.

While there are current and emerging technologies to remove nutrients from tile drainage systems, many are limited in effectiveness, are unsuitable for the landscape, or are cost-prohibitive. Overall, the best method to minimize tile drainage release of nutrients to fresh water systems is to utilize management practices that prevent nutrients from reaching tile.

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Fact sheet NO. 3

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For more information on managing tile-drained lands, visit the Cooperative Extension Tile Drainage Resources website:

http://fyi.uwex.edu/drainage

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