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Tile Drainage in Wisconsin

Inside:

- ✔ Why use a drainage system?
- ✔ Locating tile drains
- ✔ Tips for inspecting
- ✔ Installing/modifying
- ✔ Managing to prevent nutrient loss

Plus:

TILE DRAINAGE QUICK REFERENCE GUIDE

By Matt Ruark, Eric Cooley, John Panuska, Joe Pagel and Aaron Pape

Producers, consultants and agency personnel must understand tile drainage systems and how to properly locate and maintain them to sustain agricultural productivity and protect water quality.

Peggy Compton

INTRODUCTION TO TILE DRAINAGE

Subsurface drainage is used for agricultural, residential and industrial purposes to remove excess water from poorly drained land. An important feature statewide, drainage enhances Wisconsin agricultural systems, especially in years with high precipitation.

Drainage systems improve timeliness of field operations, enhance growing conditions for crop production, increase crop yields on poorly drained soils and reduce yield variability. In addition to agronomic benefits, subsurface drainage can improve the quality of soil by decreasing soil erosion and compaction.

Producers, consultants and agency personnel must understand tile drainage systems and how to properly locate and maintain them to sustain agricultural productivity and protect water quality.

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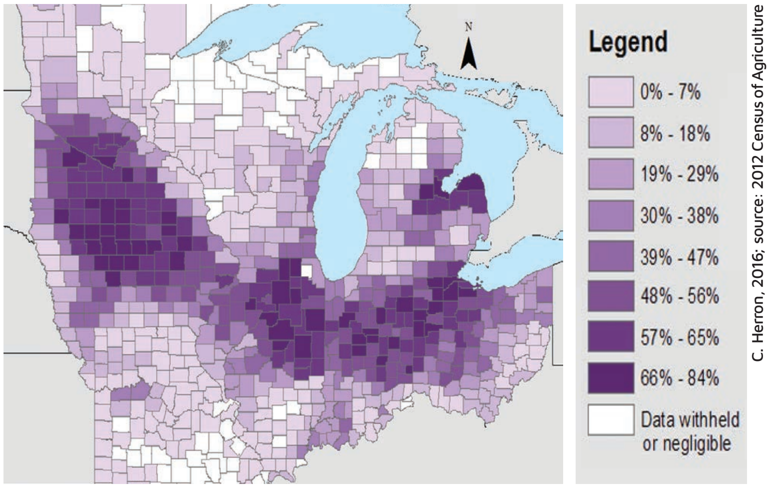


Figure 1. Percent of tile-drained cropland by county in the Midwest, 2012

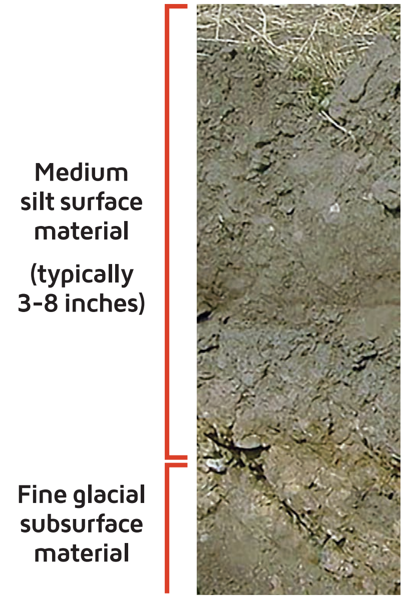


Figure 2. Typical eastern Wisconsin soil profile

Where and why tile drainage systems are used in Wisconsin

Subsurface drainage is not a new management practice. Evidence of these systems dates as far back as ancient Rome. In Wisconsin, drainage systems were originally constructed using short (1-foot) segments of clay or cylindrical concrete "tiles." Tiles were initially installed manually, requiring hand excavation. Modern drain tiles are corrugated, perforated plastic pipes typically installed mechanically using a trencher or a tile plow. These plastic pipes are available in a variety of diameters to accommodate different flow rates. They are typically installed at a depth of 3 to 6 feet below the soil surface and discharge into drainage ditches, streams or wetlands.

The majority of tile-drained land in Wisconsin is located in the eastern and southern portions of the state **(Figure 1)**, although the systems exist statewide.

Tile drainage systems in Wisconsin differ from systems in other eastern Corn Belt states, such as Indiana, Ohio, Illinois and Iowa, which are typically installed in large, flat, poorly-drained areas in a uniform or grid pattern. In Wisconsin's rolling landscape, tile drains are often installed in a random pattern, following depressional areas.

Two primary factors that influence tile system design in Wisconsin are soil type and topography. In eastern Wisconsin, medium-textured silt (loess) soils overlay fine-textured glacial material **(Figure 2)**. In these soils, water drains freely through the upper part of the soil profile (typically 3-8 inches), but the more restrictive subsoil impedes downward water movement. This results in saturation of the upper portion of the soil profile. Tile drainage is needed in these soils to eliminate seasonally high water tables.

In the unglaciated Driftless region of southwest Wisconsin, tiles are used to drain springs and sidehill seeps that saturate upland portions of the landscape. Tile drains are also installed to drain closed depressional areas, areas with perched water tables or sand lenses and organic muck soils for improved agricultural production.

Drainage system components

A subsurface drain system is comprised of lateral, sub-main and main line piping. Laterals are the initial collectors of excess water from the soil, with several laterals conveying flow to a main or sub-main. A sub-main carries flow to a main line that typically drains to the outlet **(Figure 3)**.

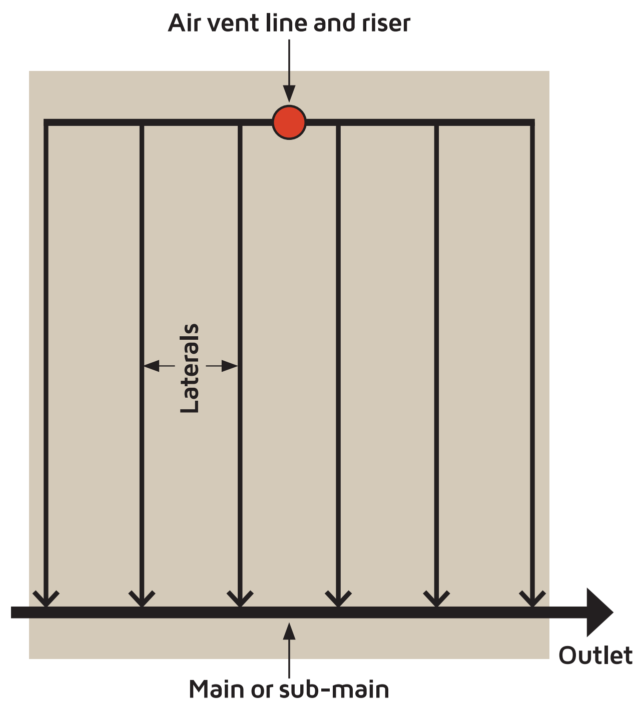


Figure 3. Overhead view of a tile drainage system including vent

LOCATING TILE DRAINAGE SYSTEMS

Knowing the extent of tile drainage can be a challenge, as records of main, lateral and outlet tile locations are often lacking. To properly use and maintain an existing tile drainage system, tile lines and outlets must be located. Although it is often hard to identify old tile systems in agricultural settings, there are a number of techniques and resources that can help.

Information sources

There is a period shortly after spring frost-out when drain locations appear lighter in color than the surrounding soil because drained soils dry more quickly **(Figure 4)**. Satellite and aerial imagery taken during this time can help identify and map tiles. Free satellite maps from Google Earth **(Figure 5)** are a great way to observe color variation, and historical images saved in the program allow users to compare the same location across different years. Advances in drone imagery, ground penetrating radar, geomagnetic surveying and other emerging technologies will also likely result in more effective and efficient methods for locating subsurface drains in the future.

Other potential sources of information are Natural Resources Conservation Service (NRCS) or Land Conservation Department (LCD) offices that may have maps or other materials available from previous interactions with a particular property. Information from these maps should be field-verified.

Figure 4. Visibly drier soil over drain locations

Figure 5. Satellite image revealing drainage systems

Feature identification

Three readily identifiable drainage features can indicate the presence of tile: vents, surface inlets and outlets. Modern tile systems often include vents to increase water removal efficiency and maintain atmospheric pressure within the drain system. Air vents consist of a perforated orange or white pipe protruding a few feet above the ground **(Figure 6)**. Surface water inlets look similar to air vents and are typically installed in low areas lacking a surface outlet. Surface inlets are designed with aboveground openings to allow surface water to directly enter tiles. Tile outlets are where the tile system discharges to drainage ditches, waterways, streams and/or wetlands **(Figure 7)**. Tile outlets should be located and marked in the field for future reference.

Observing soil moisture and crop growth patterns across various periods and conditions can also be useful in identifying existing tile lines. In most instances, crop growth and yield are enhanced in areas where properly functioning tile lines are present. This is true during both wet and dry years.

Landowners who have trouble locating tile drains using standard methods should contact a local drainage professional for assistance. Once tiles are located, accurate maps should be developed and kept in electronic and paper formats. It is important to always record modifications to existing systems and the installation of new tiles.

Figure 6. Air vent

Figure 7. Tile outlet

Use the following tips to help identify existing tiles:

1. **Water will pond in fields during or just after snowmelt.** As these localized ponds begin to disappear, drier soil conditions will appear over tile compared to the surrounding soils. This condition may last from a few hours to a few days.
2. **From April-June, drier soil conditions will appear over tiles** compared to the rest of the field immediately after significant precipitation (usually over a half-inch of rain). This will last only 2-3 hours after precipitation (Figure 4).
3. **If June conditions are wet and cool,** knee-high corn will often be a deeper green over tile lines due to an improved moisture environment and nutrient availability.
4. **Watch the dew on east-facing alfalfa at sunrise.** Plants in tile line locations will reflect more sunlight due to greater leaf density.
5. **During drier conditions, deep-rooted crops such as alfalfa will be taller over tile lines** than in the rest of the field. This is due to extended moisture availability closer to tiles.
6. **When soybeans first start blossoming, the plants over tile lines will flower up to a week earlier** than others due to accelerated plant growth and maturity.
7. **In fields with foxtail, the weed will be absent over tiles** since foxtail favors conditions with compacted soils and excess moisture.
8. **Yield increases in localized areas of corn and soybeans** during both wet and dry years can help identify tile locations. Review GPS yield monitoring data for clues.

Figure 8. Rodent guard

ANNUAL SYSTEM INSPECTIONS

Once tile drainage systems are identified, inspect them annually during peak flow times — typically during spring melt and after heavy rainfall. Regular maintenance of tile drains is an important management practice to ensure agricultural productivity on tile-drained land.

Annual maintenance recommendations

INSPECT OUTLETS AND LOOK FOR DEBRIS AND ANIMAL BURROWS

Ensure that rodent guards are in place and working properly **(Figure 8)**. Rodent guards prevent rodent nests and debris from plugging tile outlets and can be cleaned by sliding a hand inside the pipe under the guard and removing any trapped material. Tile outlets should also be inspected for excessive erosion and broken or crushed pipe. If there is a change in field moisture conditions, such as when traditionally well-drained areas exhibit prolonged periods of wetness, inspect the tile line for a possible mid-field blockage and to verify that an adequate outlet exists.

CHECK FIELD FOR TILE BLOWOUTS AND REPAIR PROMPTLY TO AVOID SOIL LOSS

Blowouts, also known as tile sinkholes, can range in diameter from a few inches to several feet and are sometimes hard to find. Pathways created by these features can result in large amounts of sediment, debris, manure, fertilizer or chemicals entering tiles.

Blowouts result from excessively high flow velocity or pressure inside the tile, causing cracks or bursts. Blowouts are common at tile junctions,

Annual peak-flow inspection checklist:

- ✔ Make sure **rodent guards** at outlet pipes are installed, working and clear of obstructions.
- ✔ Look for **blowouts**. If spotted, repair immediately.
- ✔ Check drainage ditches for **excessive vegetation growth, erosion and sediment accumulation**. Remove debris.
- ✔ Inspect tiles for **iron ochre**.
- ✔ Maintain **good records** of vent and outlet locations, conditions and performance.

Figure 9. Water gushing from blowout

Figure 10. Water entering blowout

fittings and weak spots and will often create a blowout when the surrounding material is drawn into the tile and transported downstream **(Figures 9 and 10)**.

During high flow periods, water rises and falls within the developing void. During low and no flow periods, the void is empty **(Figure 11)**. Repair blowouts promptly with the help of knowledgeable individuals. Improper repairs and quick fixes can result in ongoing problems with blockages. Always contact Diggers Hotline, 1-800-242-8511, prior to any excavation.

A blowout can also occur when a tile outlet is blocked. Blockages create back pressure within the tile, and the surrounding soil becomes saturated. When the pressure within the drain drops, the saturated soil next to the pipe will get sucked into the tile, resulting in a blowout. Blowouts can also result from large (>10x) changes in tile line grade (e.g. going from 0.1-1.0% or greater pipe slope) or when the flow velocity exceeds approximately four feet per second.

REGULARLY INSPECT DRAINAGE DITCHES FOR EXCESSIVE VEGETATION GROWTH, EROSION AND SEDIMENT ACCUMULATION AND CONDUCT MAINTENANCE AS NEEDED

Regular maintenance typically includes removal of trees, brush and other debris from the drainage ditch. The most essential requirement for any drain system is an unobstructed and properly installed outlet.

CHECK FOR IRON OCHRE GROWTH

Iron ochre is a red, yellow or tan gelatinous material that adheres to drain wall openings or forms around the outside of the buried portion of the drain tile, obstructing flow. Ochre is a filamentous bacterial slime composed of organic masses and iron oxides. Iron ochre formation is most common in sand and organic muck soils (Ford and Harmon, 1993). Alternately wet and dry soils, such as those under irrigation, are also susceptible to ochre formation.

Ongoing maintenance is the only economical option for controlling iron ochre formation. If iron ochre has formed on plastic drain tiles, high and low pressure water jet cleaning is the most cost-effective management option. Higher pressure (>400 psi) can be used with larger drain tile perforations or when drains are enveloped in gravel. Lower pressure (<400 psi) should be used in sandy soils, when drain tile perforations are small or when a synthetic sock is used to envelop the tile (Ford and Harmon, 1993).

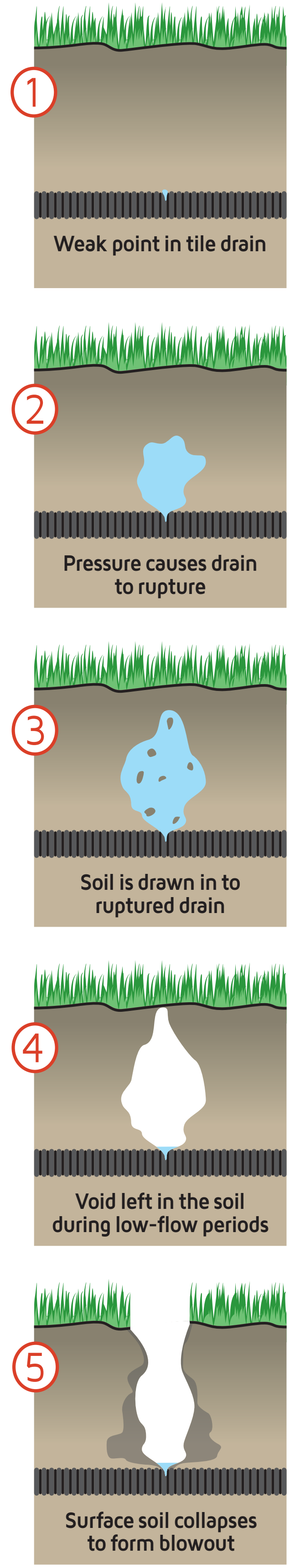


Figure 11. Tile system blowout formation

DEVELOPING AN INSTALLATION OR MODIFICATION PLAN

Develop a detailed installation plan that addresses specific drainage needs and follows NRCS standard practices (NRCS Code 606) when designing, modifying or installing a tile drainage system (NRCS, 2014). A detailed drainage plan requires assistance from a knowledgeable individual, such as an engineer or experienced tile installer, and should consider crop and soil types as well as site topography.

Drainage system best practices

ADEQUATELY SIZE MAIN LINES

When enlarging lines or adding new laterals to existing drainage systems, be certain main lines are adequately sized to accommodate additional flow, thus avoiding back pressure and blowouts. Keep tiled waterways and buffers clear of trees. Tile lines located within 80 feet of trees may have flow obstructed by tree roots entering the line.

LOCATE OUTLETS APPROPRIATELY

Locate tile outlets approximately one foot above the normal ditch water level to allow water to fall freely into the ditch, preventing erosion of the streambank. Drain tiles typically discharge into open ditch systems that eventually flow into a larger body of water such as a stream or river.

INSTALL AIR VENTS

Air vents maintain atmospheric pressure throughout the system and allow for maximum flow and relief from back pressure conditions. Vents should be open at the ground level to expose the system to the atmosphere **(Figure 6, page 5)** and should protrude about one foot above the surface to minimize clogging. They are commonly placed in low traffic areas (e.g. along fence rows). For existing systems, the property owner should ensure vents are located, mapped, inspected and cleared of obstructions. For systems that do not have vents, which is typical of older systems, the property owner should use a flashlight to inspect tile flow rates and water levels through a surface inlet if available.

DETERMINE IF DITCHES ARE PART OF A PUBLIC SYSTEM

Prior to conducting maintenance of larger drainage ditches, determine if the ditch in question is part of a public drainage system or drainage district (Wis. Stat. §88). If this is the case, any maintenance must be approved and may be paid for by the drainage district board. For assistance in determining if a ditch is part of a drainage district, contact the State Drainage Engineer at the WI Department of Agriculture, Trade and Consumer Protection (DATCP).

Due to the potential for tile systems to drain protected wetlands, several regulatory agencies have jurisdiction over drainage projects including tile and ditch maintenance. Agencies to contact prior to construction include the county planning and zoning department, the local WI Department of Natural Resources (WDNR) office and the local USDA-Natural Resources Conservation Service (NRCS) field office. Violation of wetland conservation laws can result in enforcement action. In the case of NRCS, violations can result in ineligibility for USDA programs.

KEEP GOOD RECORDS

Good recordkeeping is an essential part of any drainage maintenance program. The location of tile lines, vents, surface inlets and outlets is critical for troubleshooting and design modifications. Modern GPS technology is an indispensable tool for mapping tile lines. Conduct tile system mapping when new tiles are installed and whenever information becomes available for existing systems (e.g. during routine maintenance). Tile location records should be stored in a safe, readily-accessible location.

Planning checklist:

- ✔ **Be in touch with local agencies** about drainage district and wetland status.
- ✔ **Adequately size** main lines.
- ✔ Keep tiled waterways and buffers **clear of trees**.
- ✔ Install **air vents**.
- ✔ Make sure tile outlets are **one foot above normal ditch water level**.
- ✔ Keep **good records**.

MANAGING TILE-DRAINED LANDSCAPES TO RETAIN NUTRIENTS

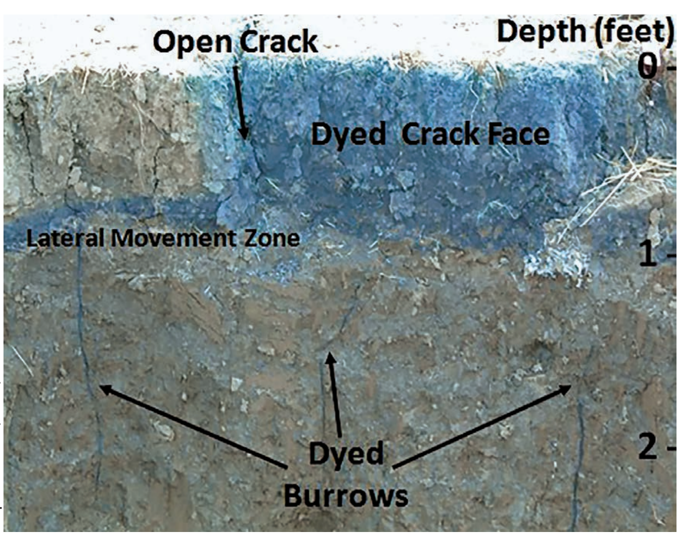
Tile drainage of agricultural land has the ability to improve yields and reduce surface runoff and erosion losses. However, with a reduction in surface runoff, more water infiltrates into the soil and percolates through the soil profile. This water can also transport essential plant nutrients, specifically nitrogen and phosphorus, out of the root zone. Once nutrients reach the tile drain, they are directly transported to surface waters.

Tile-drained agricultural land must be well managed to reduce the loss of nutrients to surface waters. Careful nutrient management practices minimize the risk of nutrient loss and 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.

Preferential flow paths

Preferential flow paths are direct conduits from the soil surface to deeper depths in the soil profile and are key factors in nutrient loss from tile systems. Paths are formed by earthworm burrows, decayed root channels, shrinkage cracks and the structural porosity of the soil. As water moves 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 **(Figure 12)**, the dye traveled through the soil using a combination of different preferential flow paths. In this case, most of the dye entered the soil through shrinkage cracks in the soil surface, then moved laterally along the plow layer, finally moving deeper in the soil profile through earthworm burrows. Water and nutrient transport through the soil matrix is much slower than through macropores like earthworm burrows. Figure 12 clearly illustrates that unknown subsurface soil conditions are a main cause of nutrient leaching.



Shipitalo et al. (2004)

Figure 12. Preferential flow paths revealed by dye

PREFERENTIAL FLOW PATHS IN LONG-TERM NO-TILL SYSTEMS AND AREAS WITH HIGH-CLAY SOILS

The development of preferential flow paths in soil varies significantly with soil type and management. Long-term no-till typically results in increased macropores within soil due to a lack of preferential flow path disruption. Soils with higher clay content often develop large shrinkage cracks as soil dries. These cracks can go deep into the soil profile and rapidly transport nutrients and organic material. For example, plant debris has been observed in well-developed shrinkage cracks down to 17 feet in Fond du Lac County (F. Madison, personal communication, 2006).

Long-term no-till typically results in increased macropores within soil due to a lack of preferential flow path disruption.

Earthworm activity results in considerable macropore development in soil and tends to be greater in no-till fields than in fields that are annually tilled. 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 the area is less frequently saturated. Earthworm populations over tile lines can be double those between tile lines (Shipitalo et al., 2004). This is important because earthworm burrows within two feet of a tile drain cause direct drainage from the burrow to the tile outlet (Smetler, 2005).

Manure application considerations

Additional precautions are needed when applying manure on tile-drained land, especially land likely to have preferential flow paths. 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.

APPLICATION METHODS

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.

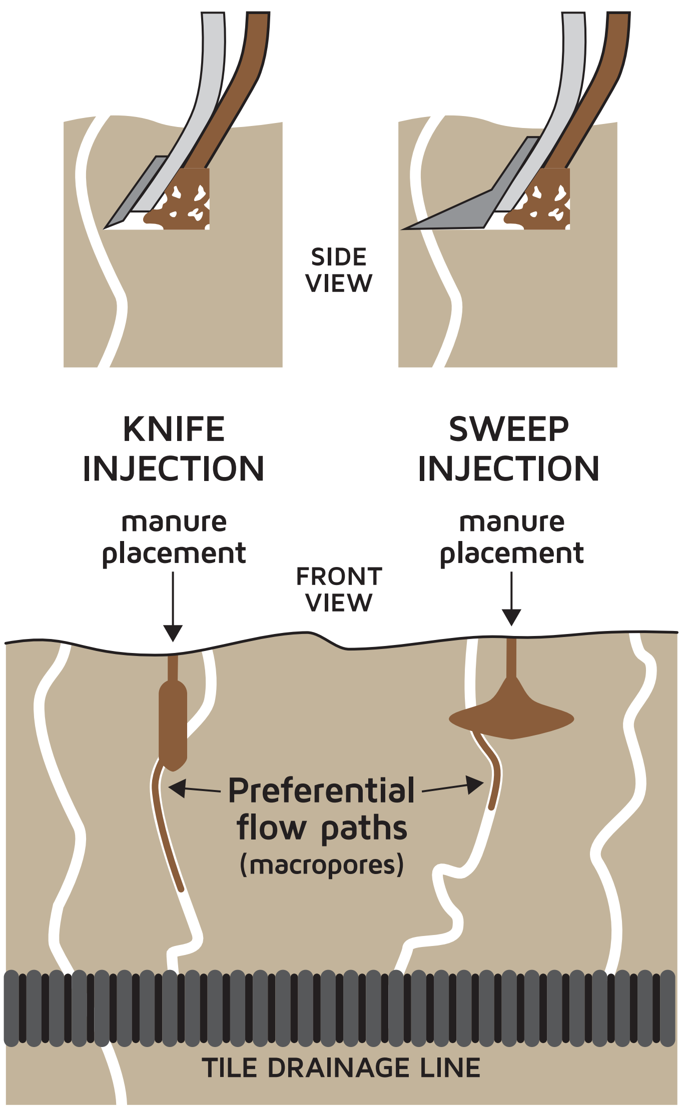


Figure 13. Nutrient leaching aided by macropores

Knife injection can be problematic if sufficient tillage is not performed before application. As the knife passes through the soil, it leaves a column of manure behind the knife **(Figure 13)**. 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. Tillage, and the resulting breakup of macropores, decreases the likelihood that the applied manure will leach.

Horizontal sweep injection can also be problematic if sweeps are too tightly spaced or if the implement is pulled through the soil too rapidly. This results in lifting the soil above the sweep, filling the void with manure. The weight of the soil may force manure into preferential flow paths and eventually into tile drains (Figure 13).

Increasing the spacing 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 gallons/acre in the area above the sweep (Figure 13). 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 higher than the example used. Emerging technologies for manure injection may disrupt preferential flow pathways and reduce the potential for nutrient leaching, but caution should be used in all application scenarios.

MANURE CONSISTENCY AND APPLICATION RATE

The consistency and rate of liquid manure applications also factor into the potential for manure transport to 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 high probability of moving via preferential flow and has been observed in fields (F. Gibbs, personal communication, 2005). Additionally, the higher 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 7,000 gallons of liquid manure per acre has the same amount of water applied to the soil as a quarter-inch rainfall.

SOIL CONDITIONS PRIOR TO LIQUID MANURE APPLICATIONS

Both high and low soil moisture can greatly increase the potential to transmit manure to tile drains. When soils are near saturation, additional water added via 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.

Alternatively, high-clay soils with shrink-swell capacity will have an elevated potential to transmit manure when soil moisture is low. As previously mentioned, cracks in these soils can extend deep into the soil during droughty periods. 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 no-till land during low soil moisture conditions, decrease the initial application rate to add moisture to the soil and facilitate closing of the cracks.

WEATHER

Weather forecasts should always be considered prior to manure applications, and applications should be avoided when rainfall is predicted – this is especially true when soil moisture levels are elevated. Research in Ohio identified manure applications to high-moisture-content soils and heavy rainfalls after manure application as the most common factors contributing to manure entry into tile drains (Hoorman and Shipitalo, 2006). Manure transmission to tile drains can occur days to weeks after application.

Engineering strategies to enhance tile benefits and reduce nutrient loss

There are a number of emerging techniques and technologies to consider that help retain water and nutrients in the soil profile – all of which employ one or more of these principles: reduced tile flow, biological activity or physical filtration.

Interested landowners should contact a local NRCS or LCD office for additional information on management practices to reduce nutrient loss from tile drainage systems and local regulations on manure application requirements and setbacks. For a comprehensive list of current treatment strategies, read the University of Illinois Extension publication titled Ten Ways to Reduce Nitrogen Loads from Drained Cropland in the Midwest: draindrop.cropsci.illinois.edu/wp-content/uploads/2016/09/Ten-Ways-to-Reduce-Nitrate-Loads_IL-Extension-_2016.pdf.

NOTE: 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 nutrient loss from tile-drained land is to use management practices that prevent nutrients from reaching tile.

Figure 14. Macropores

WATER LEVEL CONTROL STRUCTURES

These structures keep water table elevation at a desired level throughout the year, maintaining the water level higher in the soil profile after crops are removed to minimize nitrogen loss to surface water. This practice, while effective at reducing fall nutrient losses, is limited to lands with slopes less than 2%, such as those found in central and southern Wisconsin.

CONSTRUCTED WETLANDS AND BIOREACTORS

These options use biological activity to capture nutrients in tile water before they reach the stream. The effectiveness of both is highly dependent on the retention time of water in the systems, as well as climatic conditions. It is important to keep in mind that biological activity is severely reduced in cold temperatures, which reduces the nutrient removal capacity of these treatment systems (Jin et al., 2002). While they can be effective, constructed wetlands and bioreactors can be expensive to construct and also take some land out of production.

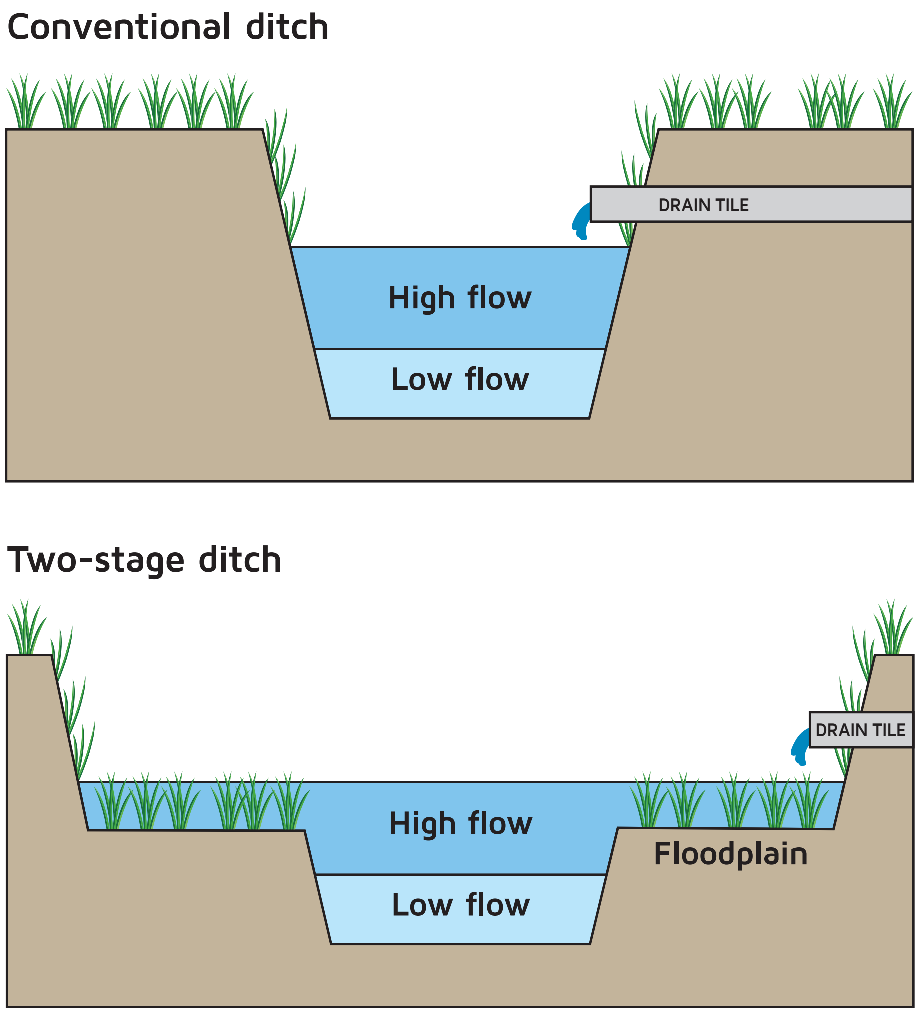


Figure 15. Beneficial floodplain created with a two-stage ditch

TWO-STAGE DITCH

A two-stage drainage ditch **(Figure 15)** can reduce the scouring of ditch banks and increase the removal of sediment, nitrogen and phosphorous from tile drainage water. A two-stage ditch has a narrow, deep channel that moves water during low flow periods, along with wide, vegetated benches that accommodate high flows. These benches slow water and remove sediment, and the vegetation takes up nutrients. This practice does require that a narrow strip of land on both sides of the ditch be taken out of production to accommodate the wider channel.

SATURATED BUFFER

A saturated buffer removes nutrients through biological activity and plant uptake. Instead of tile emptying straight to a ditch, a diverter box directs water to a perforated pipe that runs parallel to the ditch. The water diffuses slowly through the bank where bacteria and plants can remove nutrients before the water reaches the ditch. Early research shows promising nutrient removal results, but the concerns of reduced biological activity during cold weather still apply.

Saturated buffers require well-defined ditch banks to operate properly, which means they pair well with two-stage ditches.

SURFACE INLET MODIFICATIONS

Advancements in surface inlet design can improve sediment and nutrient filtration before water reaches tile lines. One example, a rock inlet, operates much like a French drain and eliminates any aboveground obstructions. The inlet is covered with soil, allowing the field to be farmed even when tile is present. Other new surface inlet designs simply retrofit existing surface inlets and are designed to slow water flow and allow sediment to drop out before water enters the inlet.

TILE DRAINAGE QUICK REFERENCE GUIDE

There are a variety of management practices customizable to fit individual cropping systems and various tile-drained landscapes. This section highlights key management practices for anyone with tile-drained land, as well as additional steps for those spreading manure. These practices will lead to proper nutrient management on tile-drained land and minimize the potential to transmit manure to tile drains.

GENERAL TILE DRAINAGE GUIDANCE

- **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 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).

- **Take special care when applying manure, fertilizer and pesticides in fields with surface tile inlets**

  Surface inlets are commonly used in fields with closed depressions without a surface outlet. Extra precautions need to be taken in proximity to 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. Further information can be found in *Tile Drainage in Wisconsin: Managing Tile-Drained Landscapes to Prevent Nutrient Loss* (Cooley et al., 2013).

Extra precautions need to be taken in proximity to surface tile inlets because they are a direct conduit to tile drainage systems.

- **Use established best management practices for fertilizer and manure management**

  Fertilizer and manure best practices apply to tiled land too, including 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 lower than 50°F. If applications are necessary when soil temperatures are above 50°F, use nitrification inhibitors. Research in Indiana has 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).

- **Use conservation practices that reduce erosion and conserve nitrogen**

  Practices can include the use of cover crops, conservation tillage and grassed waterways. Practices that reduce soil loss also reduce sediment-attached nutrient movement on the soil surface and will help reduce the potential of loss to tile drains.

BEFORE LIQUID MANURE APPLICATION GUIDANCE

- **Assess soil conditions**

  Both high and low soil moisture content 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 pre-till before application or reduce the initial application rate to slowly add moisture to the soil to facilitate closing of the cracks.

- **Review weather forecasts**

  Avoid applications when rainfall is predicted. 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 because soil moisture levels are typically elevated.

- **Have an emergency plan in place**

  If manure enters tile drains, take immediate steps to stop the flow and prevent discharge to freshwater systems. This can be performed by blocking or diverting the tile outlet, intersecting the tile system or digging a pit directly downstream of the spill site to collect manure. Contact the WDNR Spills Hotline at 1-800-943-0003 to report the spill and get assistance with subsequent remedial actions.

Soil moisture levels are increased by liquid manure applications, and subsequent rainfall can result in tile flow and release of manure to tile drains.

- **Use tillage to break up preferential flow paths prior to or concurrent with application**

  Pre-tillage before surface and injected liquid manure applications or application methods that concurrently disrupt preferential flow paths below the manure injection depth should be used 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.

DURING AND AFTER LIQUID MANURE APPLICATION GUIDANCE

- **Monitor tile outlets**

  Tiles should be monitored before, during and after liquid manure applications for potential discharge of manure. 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**

  If water level control structures are installed in tile systems, insert stoplogs 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 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).

- **Take precautions when surface-applying liquid manure to no-till or perennial crops**

  Preferential flow paths are more developed in no-till systems and in areas with prolonged perennial crop growth. Additionally, manure can be transported along growing or decayed roots of deep-tap-root crops like alfalfa. In these scenarios, split applications or reduced rates should be considered for liquid manure applications. The best method to control nutrient loss from tile-drained agricultural land is to prevent nutrients from reaching tile.

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Tile Drainage

in Wisconsin

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For over a decade, UW Discovery Farms has worked with Wisconsin farmers to identify the water quality impacts of different farming systems around the state. The program, which is part of UW–Madison Extension, is under the direction of a farmer-led steering committee and takes a real-world approach to finding the most economical solutions to agriculture's environmental challenges. If you are interested in learning more about UW Discovery Farms, visit Go.wisc.edu/DiscoveryFarms.

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