Drainage Water Management

for the Midwest

Questions and Answers About Drainage Water Management for the Midwest

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Introduction

Subsurface tile drainage is an essential water management practice on many highly productive fields in the Midwest. However, nitrate carried in drainage water can lead to local water quality problems and contribute to hypoxia in the Gulf of Mexico, so strategies are needed to reduce the nitrate loads while maintaining adequate drainage for crop production. Practices that can reduce nitrate loads on tile-drained soils include growing winter forage or cover crops, fine-tuning fertilizer application rates and timing, bioreactors, treatment wetlands, and modifying drainage system design and operation. Drainage water management is one of these practices and is described in this fact sheet. Answers given here apply specifically to Midwest corn and soybean cropping systems, and not to perennial or winter annual crops.

1. What is drainage water management?

Drainage water management is the practice of using a water control structure in a main, submain, or lateral drain to vary the depth of the drainage outlet. The water table must rise above the outlet depth for drainage to occur, as illustrated at right. The outlet depth, as determined by the control structure, is:

- Raised after harvest to limit drainage outflow and reduce the delivery of nitrate to ditches and streams during the off-season. (Figure 1)
- Lowered in early spring and again in the fall so the drain can flow freely before field operations such as planting or harvest. (Figure 2)
- Raised again after planting and spring field operations to create a potential to store water for the crop to use in midsummer. (Figure 3)

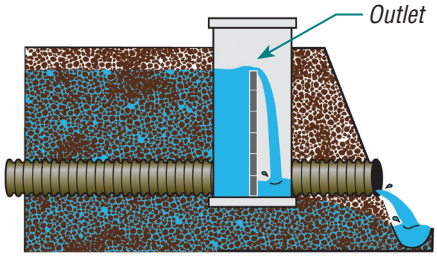

Figure 1. *The outlet is raised after harvest to reduce nitrate delivery.*

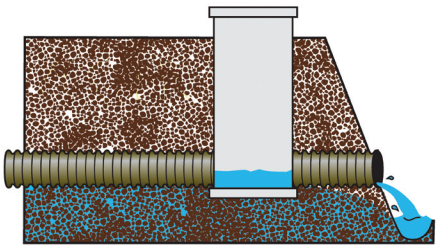

Figure 2. *The outlet is lowered a few weeks before planting and harvest to allow the field to drain more fully.*

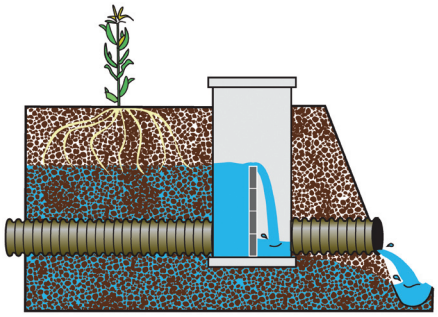

Figure 3. *The outlet is raised after planting to potentially store water for crops.*

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2. Is drainage water management the same as subirrigation?

No. Drainage water management relies on natural rainfall to raise the water table, and the water table will fluctuate below that depth without sufficient rainfall. Subirrigation adds water to the subsurface drainage system to raise the water table close to the outlet depth and to maintain it there. Subirrigation typically requires closer spacing of the tiles than that in a conventional or controlled drainage system. Subirrigation also requires an adequate water supply to meet crop needs throughout the growing season.

3. What fields are most suitable for drainage water management?

The practice is only suitable on fields that need drainage, and is most appropriate where a pattern drainage system (as opposed to a random system) is installed or is feasible. The field should be flat (generally less than 0.5 percent slope) so that one control structure can manage the water table within 1 to 2 feet for as many acres as possible. If drainage laterals are installed on the contour, the practice could be used with greater slopes. The producer must be able to manage the drainage system without affecting adjacent landowners. The practice can be used with any drain spacing; however, narrower drain spacing reduces the risk of yield loss due to excess wetness during the growing season. If a new drainage installation is being planned for a field, drains should be designed for minimum grade (along the contours), so each control structure can control the maximum possible area of the field.

In drainage water management, water control structures are used to vary the depth of the drainage outlet. Flatter fields require fewer structures.

4. How many acres can I manage with one structure?

It depends on field topography and the desired uniformity of water table management. Flatter fields require fewer overall structures and allow each structure to manage a larger area. A field is typically divided into "drainage management zones," each managed by one control structure. The zones are delineated by the desired feet of elevation change within the zone, which corresponds to the desired uniformity of water table management. For example, to maintain control of the water table to within 1 foot of the desired depth, a structure must be placed in a drainage management zone with 1 foot or less of elevation change. One structure can typically control at least 10 or 20 acres, and the larger the area that can be controlled with one structure, the more economical the practice.

5. How much management is required?

The level of management required depends on whether the water control structures will be used to raise the system outlet during the fallow season, the growing season, or both. During the fallow season, the only management required is to raise the outlet after harvest and field operations in the fall, and to lower it about two weeks before the start of field operations in the spring. During the growing season, management may involve temporarily lowering the outlet height to increase the drainage during periods of heavy rain or sustained wet periods. Automated devices are available to aid in management.

6. How do I manage the outlet?

Current recommendations are to place the control structure outlet within 6 inches of the field surface for maximum water quality benefits in the winter months. (Some surface ponding might occur in depressional areas of the field.) Researchers have yet to determine the optimum outlet height during the growing season, but they suggest an outlet depth of 2 or more feet below the field surface. The goal is to provide enough drainage for good aeration and root development but to capture some of the water that would otherwise drain out under conventional systems. It is important to understand that the drainage outlet setting does not ensure that a water table will be present at the desired depth; sufficient rainfall must occur for the water table to rise to the depth of the outlet setting. Caution should be exercised during the growing season, because maintaining water table depths shallower than 2 feet may increase the risk of crop excess water stress during pro-

Management includes raising the outlet after harvest and planting, and lowering the outlet before field operations in the spring and fall.

longed wet periods in spring/summer. Particular attention should be paid to the management of soybean fields, since soybeans are less tolerant of wet roots.

7. Do I need a pump for drainage water management?

Not unless you need a pump for your existing drainage system, such as drainage systems that outlet into pumped sumps where gravity flow outlets are difficult or impossible to establish.

8. When is it possible to retrofit an existing system?

Most drainage systems can be retrofitted with control structures, but sometimes the benefits will not be significant because of the slope and layout of the pipes. The best candidates for retrofitting are pattern drainage systems where the grade of the laterals is 0.2 percent or less.

9. Will I need more drain tile (narrower spacing)?

No. This practice is not like subirrigation, which is only economical with narrower spacing. Drainage water management is more likely to increase yield on fields with pattern drainage, rather than those with random drainage. Narrower drain spacing may reduce the risk of yield loss during times of heavy rainfall, because water is removed faster.

10. What yield impact can I expect?

With proper management of the structures and timely rainfall, the potential exists to improve crop yields beyond the typical crop response to drainage. However, field research on the agronomic benefits of the practice is very limited and inconclusive. Field studies in North Carolina have found average yield increases of about 5 percent, with greater response in some years. For Midwest conditions, computer modeling studies show limited long-term crop yield benefits (up to 5 percent) with controlled drainage, because yield benefits will not accrue in years where rainfall is not sufficient or not at the right time to raise the water table above the tile depth. Potential crop yield increases will be greater in regions where drains typically

With proper management of the structure and timely rainfall, drainage water management may improve crop yields in some years.

flow for long periods after planting, because more water is available to be stored in the root zone. In all regions, increases in crop yields will be much greater in some years than in others. There may be a risk of excessive moisture in some years, but the risk can be minimized with proper management.

11. How much less nitrate flows into ditches and streams?

Studies have found reductions in annual nitrate load in drain flow ranging from about 15 percent to 75 percent, depending on location, climate, soil type, and cropping

Drainage water management reduces the nitrate that flows to ditches and streams from tile drains compared to unmanaged drainage (shown above).

practice. Nitrate load is reduced by about the same percentage as drain flow is reduced, since most studies have found that drainage water management does not change the nitrate concentration in the drain flow. In regions where much of the drainage takes place during the winter (such as Illinois, Indiana, and Ohio), the reduction is likely to be greater than where most of the drainage takes place in April or later, such as in parts of Iowa and Minnesota.

12 Can I use less nitrogen fertilizer?

No. Reducing the annual drain flow does not imply that all of that unreleased water with its soluble nitrate is still in the field. Most of this water and nitrate leave the field by some other route. That flow path is longer and slower, giving more opportunity for denitrification or assimilation of the nitrate into organic nitrogen forms, and any nitrate that remains in the root zone will be lost when water is released before planting.

13. Where does the rest of the nitrate go?

Nitrate reductions from drainage management systems result from three factors: (1) reduced volume of drainage water exported from the system, (2) denitrification within the soil profile, and (3) deep seepage. The decrease in drainage water has been measured in several locations and is a major factor in reducing nitrate flow to ditches and streams. Some of the water that is not drained becomes surface runoff instead, but nitrate concentrations are considerably lower in the surface runoff. Denitrification converts some of the nitrate to harmless nitrogen gas (N_2) as well as a small amount of nitrous oxide (N_2O), a potent greenhouse gas, but the extent of denitrification is not known. The amount of deep seepage has not been quantified, nor has the extent to which the nitrate will be denitrified as it travels through these pathways.

14. How does drainage water management affect soil quality?

This question has not been studied under field conditions, so the answer is based on knowledge from related studies. A small increase in soil organic matter content is likely with drainage water management, and this would be a positive effect on soil quality. Drainage water management will cause prolonged wetness during the non-growing season, and this may promote the breakdown of aggregates. But normal drying of the soil is likely during the growing season, and this process contributes to aggregate formation and stability. Field operations carried out when the soil is wet add to soil compaction, but proper drainage water management would allow drainage for a sufficient amount of time before field operations so that soil wetness would be comparable to that in fields with conventional drainage.

15. Will earthworms be affected?

Maybe. Worms in general do not like soil that is too wet, but scientists are not sure how wet is "too wet" for earthworms. The effect of drainage water management is likely to vary for different species of worms. Some evidence suggests that nightcrawlers may be most sensitive to excessive wetness, although more studies are needed. Worm populations are also highly variable. Some fields or portions of fields have high populations, and other areas have low populations. To understand whether the higher water table has affected worms at specific sites, researchers must count

Earthworms may be impacted by drainage water management, but more research is needed.

worms before drainage water management is initiated and then again several years later. These studies are just beginning.

16. Will the practice cause blowouts?

Not with most commercially available control structures installed on shallow gravity flow drainage systems. Excessive pressure heads within a drainage pipe cause blowouts. Most commercial control structures do not close tile outlets, but simply raise the elevation or height of the outlet. Water is free to flow over the top of the control structure, keeping pressure heads within the field drainage system only marginally greater than that at the top of the control structure. Some control structure designs use pressure-sensitive valves that, again, will not allow excessive buildup of pressure heads within the drainpipe. However, if the drains are closed using valves, excessive pressure heads are possible and these need to be monitored carefully. Finally, if the downstream drainage mains are not sized correctly, the large discharge volumes that can result from lowering the water table in the spring, especially if several fields are lowered at once, could cause blowouts below the farmer's field.

17. Will drainage water management cause tile plugging?

Probably not. Raising the water table can cause water to move more slowly or stagnate in the tile drains, allowing any sediment to settle out. However, the high flow rates that result from setting the control structures to lower the water table in the spring will probably flush any accumulated sediment from the tile system, especially systems that are installed on a self-cleaning grade.

18. Will tile freeze?

Soils rarely freeze as deep as the tile, and they are less likely to do so when the water table has been raised with the control structure. Freezing of the control structure itself could be an issue, as cold air can settle in the structure housing. A frozen control structure could make it impossible to lower the outlet depth in the spring to lower the water table. However, there have been no reports of control structures being frozen in the spring at the recommended time for lowering the water table.

19. Will my neighbors be affected?

Maybe. Site selection certainly needs to include consideration of potential impacts on neighbors. Upstream neighbors on the same drainage main could be affected,

Freezing is unlikely to be a concern, as soils rarely freeze as deep as the tile.

so managing the outlet of a shared main is not a good idea unless the upstream field is at least 2 to 4 feet higher in elevation than the outlet being managed. There are no anticipated impacts on downstream neighbors on the same drain system, unless mains are not sized correctly (see answer to Q16). Other potential problems include raising the water table near home septic fields. Septic leach fields need several feet of unsaturated soil below them for adequate treatment.

20. Will surface runoff, erosion, and the loss of other chemicals be increased?

Maybe. Wetter soils are likely to have more runoff and erosion. Since some contaminants such as phosphorus and pesticides are lost through surface runoff and erosion, this is an important consideration. If there is a pathway for runoff to leave the field, drainage water management may increase runoff and associated contaminants during the time that the water level is raised. However, most pesticides are applied just before planting, when the water controlled over the winter would have already been released. Also, land that is most suitable for drainage water management is very flat, and is therefore less likely to be susceptible to water erosion. A wetter soil profile due to drainage water management could potentially reduce wind erosion on selected soils and landscapes.

21. Will manure application be affected?

Possibly. Spring application of manure is generally not compatible with drainage water management, while summer and fall application can be. When the water table is near the soil surface, as it would be in spring with drainage water management, manure cannot be applied because of trafficability and soil compaction problems. Lowering the outlet even earlier in the spring to allow for spring application would negate much of the nitrate reduction benefit of drainage water management. When the soil is dry, however, such as in summer or early fall, raising the subsurface drain outlets can prevent the entry into surface water

of liquid manure that has leaked directly into drainage pipes through macropores caused by roots, earthworms, or cracks. In fact, raising subsurface drain outlets before liquid manure application is a recommended practice in some states (e.g., Michigan and Ohio). In most years in the fall, there is an adequate time window for manure application between when the outlets are raised and sufficient rainfall occurs to raise the water table to near the surface. Because of an increased potential for surface runoff after the water table has risen, manure should be injected or incorporated into the soil.

22. How much does drainage water management cost?

Costs include purchase of the water control structure, installation of the structure, and management time. Structure costs range from $500 to $2,000, depending on height, size of tile, structure design, manufacturer, and whether it is automated. Some contractors and farmers fabricate their own structures. Installation costs may be about $200 for a basic structure in a new drainage system installation, but may increase depending on the size of the structure, level of automation of the structure, and for retrofit situations. Assuming grades are flat enough for one structure to control 20 acres, initial costs would be in the range of $20 to $110 per acre. A producer should also consider the cost of the time spent on management of the structure.

23. What is the life of a water control structure?

The practice of drainage water management is still fairly new, so there is not a large body of experience on which to base estimates of structure life. Materials used in control structures may include plastics, metal, rubber (gaskets), and electronic components (for automated structures), each with varying durability and longevity of use. One manufacturer's structures have been used for water management in wetlands and are still working well after 20 or 25 years.

24. What crop varieties work best?

No research has considered this question. The best varieties may vary by location. High-yield varieties with good early vigor and disease resistance should perform well in a managed drainage system.

25. How is the application of other conservation practices affected?

Drainage water management should be one of a suite of practices in an overall conservation plan. Drainage water may need to be managed differently, depending on other practices in a plan. For example, drainage water management may not work well with cover crops unless the water is not raised as high in the winter and is let out earlier in the spring. No-till soils tend to be colder and wetter, and water may need to be released earlier to allow for longer warm-up. Drainage water management can work well in conjunction with riparian buffers to remove nitrate not otherwise treated by the buffer.

The cost of drainage water management includes installation, as well as purchase and management of the structure.

26. Who will help pay for the practice?

The USDA National Resource Conservation Service (NRCS) has approved conservation practice standards that support drainage water management in some states. The standards are 554, "Drainage Water Management," and 587, "Structure for Water Control." Farm Bill programs, including the Environmental Quality Incentives Program (EQIP) and the Conservation Security Program (CSP), may provide some of the cost of structure installation and/or a management incentive for a number of years in some states. The Conservation Reserve Program (CRP) and Conservation Reserve Enhancement Program (CREP) may provide funding for the installation of structures in riparian buffers in some states. For more information, talk with your local District Conservationist.

27. Where can I get more information?

The Agricultural Drainage Management Systems Task Force is a national effort to improve drainage practices to reduce adverse impacts while enhancing crop production and conserving water. <extension.osu.edu/~usdasdru/ADMS/ADMSindex.htm>

More information about USDA cost-share programs is at www.nrcs.usda.gov/programs/.

The following Extension publications, NRCS standards and handbook chapters, and books provide information on what is known about drainage water management.

- NRCS Conservation Practice Standard 554, "Drainage Water Management," and 587, "Structure for Water Control." State and local standards are in Section IV of the Electronic Field Office Technical Guide (eFOTG) at www.nrcs.usda.gov/technical/efotg/.
- "Operating Controlled Drainage and Subirrigation Systems" by R. Evans and R.W. Skaggs. North Carolina Cooperative Extension Service, Publication Number AG 356, 1996. <www.bae.ncsu.edu/programs/extension/evans/ag356.html>
- "Agricultural Water Management for Coastal Plain Soils" by R. Evans, J.W. Gilliam, and R.W. Skaggs. North Carolina Cooperative Extension Service, Publication Number AG 443, 1996. <www.bae.ncsu.edu/programs/extension/evans/ag443.html>
- American Society of Agricultural and Biological Engineers Standard ASAE EP479 "Design, Installation and Operation of Water Table Management Systems for Subirrigation/Controlled Drainage in Humid Regions" March 1990.
- Agricultural Drainage, by R.W. Skaggs and J. van Schilfgaarde (eds), ASA, CSSA, SSSA: Madison, Wis., 1999. Chapters 20, 21, and 22 consider controlled drainage.
- USDA NRCS National Engineering Handbook Part 624, Chapter 10, "Water Table Control," is a guide for the evaluation of potential sites and the design, installation, and management of water table control in humid areas. <ftp.wcc.nrcs.usda.gov/water_mgt/EFH&NEH_Drainage_Chapters/neh624_10.pdf>
- Subirrigation and Controlled Drainage. Edited by H.W. Belcher and Frank M. D'Itri. 1995. Lewis Publishers, an imprint of CRC Press Inc., Boca Raton, Fla. 482 pages.

Drainage water management can work well in conjunction with riparian buffers to remove nitrate not treated by the buffer.

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