Subsurface (tile) drainage removes excess water from the soil to create good fieldwork and crop growth conditions on poorly drained soils. When properly designed, installed, and maintained, subsurface drainage systems can perform well for decades (Sands, 2021). However, many design, installation, and management considerations can lead to the under-performance of subsurface drainage systems.

One measure of drainage system performance is that the system should be able to lower the water table from the soil surface to 1-ft depth in less than 48 hours following a heavy rainfall. Additionally, the drainage system should be able to maintain the water table below 2-ft depth over at least 90% of the drained area during at least 90% of the growing season. If the performance of the drainage system falls below these criteria, it is likely to be underperforming and may subsequently reduce profitability.

In this bulletin, three common causes for the under-performance of subsurface drainage systems are described (Section 1). Then, the impacts of these common causes of under-performance are presented (sections 2-4).

1. Causes of under-performance

This section describes design, installation, and maintenance issues as common causes for the under-performance of drainage systems.

1.1. Design issues

Design issues may cause the drainage system to underperform. Most design issues are avoidable by increasing knowledge through education and training opportunities. Drainage system users are also encouraged to use the Drain Spacing Tool to maximize system performance and profit. To learn about the Drain Spacing Tool, see Ghane (2021c).

Common design issues include pipe grade less than the minimum grade requirement (Section 2.2.3), installation in a very poorly permeable deep soil layer (Section 1.1.2), installation in sand layers without an envelope or sand-slot pipes (Section 2.2.3), and installation in high-risk iron ochre areas without special design considerations (Section 2.3).

1.1.1. Under-design issues

Under-design occurs when overestimating the hydraulic conductivity of the soil, underestimating the drainage coefficient, overestimating the depth to restrictive layer, spacing the drains too wide, or sizing the main collector diameter too small. In these situations, the outlet flows at full capacity for too long while lowering the water table slower than is necessary for profitable crop production. The solution to under-design issues can be adding additional lateral drains or upsizing the main.

Even though over-designing of a drainage system does not lead to under-performance, it leads to drain spacing that is too narrow, thereby increasing the drainage system cost, reducing profit, and increasing nitrate loss.
1.1.2. Drain depth issues

If a shallow permeable upper soil layer sits on top of a very poorly permeable restrictive layer, drains should be installed in the more upper layer at a shallower depth while maintaining minimum pipe cover. This is because drains are always more effective when installed in more permeable soils. For more information about shallow drains, see Ghane (2021f). Avoid installing deep drains in muck or peat soils because it may enhance subsidence from the oxidation of organic matter (Vlotman et al., 2020). Avoid too deep (>4 ft) of a drain depth because the drains may draw excessive seepage from nearby areas.

Most commercial tile plows have enough power to install deep drains without difficulty. However, a pull-behind plow is more susceptible to difficulty pulling the plow at deeper drain depths, and it may require a second tractor, especially in heavy soils with stones.

1.1.3. Compromised outlet

Another common design issue is a compromised outlet. The outlet may be off the ditch bottom, but the ditch water level frequently submerges the outlet and reduces outlet flow (Figure 1). In this situation, either clean and deepen the ditch, or raise the outlet to allow normal free flow. Otherwise, a lift station may be necessary.

1.1.4. Lack of breathers

Lack of breathers or vents in the system is another example of a common design issue. Breathers allow air to enter the drain to vent the drain. They are usually installed when going from a relatively flat grade to a steep grade or when the lateral drain is very long (Cooke, 2021). If there is no breather and the water table is above the top of the lateral drains, drain flow may be restricted when going from relatively flat (minimum grade) to a steep grade due to inadequate venting.

Inadequate venting can also cause tile blowouts when steep grades result in high water velocity or when a sudden change of grade from steep to relatively flat (minimum grade) results in high pressure (Cooley & Herron, 2015). Tile blowouts are also caused by outlet clogging, or a broken or cut drain (Cooke, 2021).

1.2. Installation problems

Poor installation may cause the drainage system to underperform. Installation quality should be assured using proper machinery, using suitable methods, following correct specifications and standards, and generally providing good quality control during installation. Installation problems are avoidable by increasing knowledge and gaining experience.

1.2.1. Wet conditions

Avoid installation or any other fieldwork during wet soil surface conditions because it leads to soil compaction, which is one of the causes of impeded infiltration and percolation (Section 3.1).

When the water table is above the drain installation depth, there is more risk of smearing the soil adjacent to the drains, especially in heavy clay soil. When the water table is near the drain installation depth, capillary rise can still create wet conditions for the soil at the drain depth, thereby increasing the risk of smearing. Smearing slows down water entry into the drains, so the system will not work well at first. It may take up to 3 years...
for the drainage system to work efficiently as the ground goes through cycles of drying, wetting, and frost to break up the compaction.

The ideal installation condition is when the ground is driest and the water table is as deep as possible, usually during summer. Typically, there is limited control over this because the condition may be less than ideal when the drainage contractor is available to work during normal installation windows (before and after planting). To reduce the risk of under-performance due to installation under wet conditions, one option is growing crops with an early harvest (wheat, barley, oats, rye, and corn silage) during the year planned for installation to provide ideal installation conditions after harvest. Another option is installing through a standing crop when the ground is driest.

1.2.2. Examples of installation problems

Examples of avoidable installation problems include installing perforated drains through trees or shrubs (Section 2.1.1), improper connections causing root clogging (Section 2.1.1) and sediment clogging of the drain (Section 2.2.1), off-grade dips or humps in the drain causing root clogging (Section 2.1.1), improper installation speed, improper use of pull-behind or mounted plows, mishandling of pipes, and lack of outlet protection.

Improper installation speed can cause off-grade outcomes. Flatter grades require slower installation speed than steeper grades.

An inexperienced operator using a pull-behind plow may cause poor installation because it is harder to maintain a consistent grade. These machines can cause installation challenges when encountering dead furrows, fence lines, ridges, swales, and rocks (Wright & Sands, 2001). Thus, experience is essential with pull-behind plows.

Two examples of pipe mishandling are exposing the pipe (with or without sock) to the sun for too long and over-stretching the pipe when not using a power feeder. Exposing black-colored sand-slot pipes to the sun for too long may cause the narrow perforation widths to stretch during installation and become wider perforations, which allow fine sand or silt to enter the pipe, causing sediment-clogged drains (Section 2.2).

When installing laterals downslope to save time, if water enters the lateral drains during installation, it may mean connecting to the main under water, leading to a poor connection.

In some situations, air-locking can occur when there is a severe negative grade in a section of the drain and the water table is above the top of the drains. In this case, air generally cannot exit the pipe and it restricts drain flow.

1.3. Inadequate maintenance

Generally, drainage systems need maintenance to keep them in good working condition. When proper maintenance is lacking, the system will not work as designed. For example, drain outlets should be regularly maintained to prevent clogging of the outlet. The field should be checked for blowouts and wet spots. Inadequate maintenance can result in drain clogging and under-performance of the drainage system (Section 2).

2. Drain clogging due to design, installation, and maintenance issues

Drain clogging occurs due to design, installation, and maintenance issues, causing slower water removal from the field than needed. Use a camera to inspect the inside of the drain to identify what is blocking the drain. Drains can clog by roots, sediment, and iron ochre.

2.1. Root clogging

2.1.1. Root clogging occurrence

Roots of annual crops do not pose a risk of drain clogging when drains are installed properly between 2.5- and 4-ft depth. Some smaller younger roots enter the drains, but they die after plant harvest and slowly decay, and their remains wash away.

When poor installation of drains results in an off-grade dip or hump in the drain, water will stand in the drain, thereby promoting increased root growth in and around the drain. Also, improper connections can increase the chance of root clogging. For example, when tap-tees are not correctly inserted, they can lead to an obstruction that can catch the younger roots flowing with water in the drain. Then, the roots can accumulate and clog the drain, or significantly reduce the flow (Figure 2). Use fittings that have minimal parts sticking into the pipe.
Why Do Subsurface Drainage Systems Underperform?

If radish cover crops grow too much, they may cause drain clogging with their long roots. Avoid planting radish cover crops too early to prevent their roots from getting too long. Early planting such as with prevented planting, may lead to radish roots reaching and clogging the drains. Radishes planted late August or early September should not pose a risk of drain clogging for drainage systems in good condition.

Perennial crops may cause root clogging depending on the type of vegetation. For example, when drains need to go through trees or shrubs, use a nonperforated drain to prevent root entrance.

2.1.2. Root clogging mitigation methods

For addressing root clogging, flushing the younger weaker crop roots with a high-pressure jet nozzle (also known as jetting) helps remove some of the crop roots. With stronger roots or tree roots, jetting may need to be combined with rodding to break up the roots. Consider that, generally, rodding takes more time than jetting and is useful to remove clogging closer to the outlet. If these solutions do not work, new drains may need to be installed. Contact a local sewer, plumbing, or septic tank cleaning company for jetting (Figure 3).

2.1.3. Root clogging preventive measures

A good installation reduces the chance of root clogging (Section 2.1.1). Also, controlled drainage reduces the risk of root clogging. If the field is suitable for this controlled drainage, it can reduce the risk of root clogging by keeping the area around the drains saturated during some of the growing season.

The area in the vicinity of the outlet pipe should be kept clear from brush growth because brush roots can follow the wall of the outlet pipe in the upstream direction. Then, they can enter the drain through the first connection and clog the drain. A good practice is to mark the area in the vicinity of the outlet pipe so that the site can be easily found and the brush removed.

2.2. Sediment clogging

2.2.1. Sediment clogging occurrence

Drains may become partially or fully clogged by sediment if proper drain materials are not used. When fine sand or silt particles enter the drain, they can remain near the drain entry point, build up over time, and cause clogging of the drain. At typical drain grades of 0.1% to 0.2%, sand will not be carried with water to the outlet. When clay particles enter the drain, they wash away and do not cause a problem. Sediment clogging of the drains can be a problem in soil with low clay and organic matter such as loamy sand, sandy loam, loam, and silt loam (Stuyt et al., 2005). Soil with high clay provides cohesion (sticking of particles together) to keep the soil in place and prevent it from entering the drain.

Improper connections can cause drain clogging. Avoid connecting laterals to the bottom half of the main to reduce the chance of sediment clogging the drain. When poor installation
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results in an off-grade dip or hump, or improper connection (Section 2.1.1), it creates an obstruction where fine sediment can accumulate and clog the drain (Figure 4).

2.2.2. Sediment clogging mitigation method

The entry of sediment into the drain typically occurs up to one to two years after installation because the soil around the drain has not had the chance to stabilize. In the early period after installation, fine sediment is carried by water to the outlet, causing turbid water. If severe sediment issues exist beyond two years, occasionally clean the drains with a high-pressure jet nozzle to flush the sediment. If sediment is not flushed, it can harden and make the jetting more difficult. If this solution does not work, new drains may be needed.

2.2.3. Sediment clogging preventive measures

A good installation will reduce the chance of sedimentation (Section 2.2.1). Two materials can be used to prevent sediment from entering the drains: a knitted-sock envelope or sand-slot drains (narrow-slot, knife-cut, and fine-slot). Knitted-sock envelopes have two key properties that make them suitable as an envelope material: increasing water flow into the drains and keeping sediment out of the drains. To determine if drain sedimentation is a problem for your drain pipes, see Ghane (2021b). Eventually, some sediment may enter the drain, so it is important to meet the minimum grade requirement to maintain minimum water velocity for carrying the sediment to the outlet.

2.3. Iron ochre clogging

Iron ochre occurs when soluble iron enters the drain. Then, bacteria oxidize soluble iron to insoluble iron and create ochre. Iron ochre can cause clogging of drain perforations, valleys of corrugations, and inside of the drain. This results in under-performance or failure of the drainage system.

For information about iron ochre potential, identification, and mitigation, see Ghane (2021d).

3. Impeded infiltration and percolation due to soil and installation problems

Impeded infiltration and percolation occur due to soil management and installation problems, causing slower water removal from the field than needed. Thus, the performance of the drainage system is reduced. Also, this problem could lead to increased surface runoff. One sign of this problem is when surface ponding lasts for extended periods with little to no drainage discharge, indicating that water cannot reach the drains.

In impeded infiltration, water cannot infiltrate the soil surface fast enough because of surface sealing, and ponding usually occurs on the surface. In the case of impeded percolation, water in the soil cannot move downward to the drains and causes a perched water table due to a plow-pan or compacted layer below the surface. In both cases, soil auguring and consultation with a soil scientist can identify this problem.

3.1. Impeded infiltration and percolation caused by compaction

The most common cause of impeded infiltration and percolation is field operations (planting, spraying, harvesting, and drain installation) during wet soil surface conditions that lead to soil compaction. Tillage can also create a compacted layer just below the tillage depth that limits percolation.

Figure 4- Photos of a 6-inch main installed in 2013 and was 2/3 filled with sand in 2020. The use of regular-perforated drains in sandy loam soil was the cause of drain sedimentation (photo credit: William Word).
The following are some guidelines to address the compaction issue:

- If a plow-pan or compacted layer is the problem, break it up with subsoiling or moling. Mole drains result in soil cracks, leading to increased infiltration. For more information about mole drains, see Ghane (2021e). Caution is advised when subsoiling or moling under wet surface conditions as these can worsen the compaction issue.

- Improve soil health with reduced tillage, cover crops, manure or compost, and diverse rotations, thereby improving infiltration and percolation.

- If the impeded infiltration is in a depressional area, a blind inlet can be installed to increase infiltration. For more information about blind inlets, see Ghane (2021a).

- Surface drainage can be used to prevent surface ponding. For more information about surface drainage, see Ghane (2018).

Another reason for impeded infiltration is soil dispersion on the soil surface, which causes soil structure degradation, sealing of the soil surface, reduced infiltration, and increased surface runoff. Soil dispersion can be caused by mineral imbalance and raindrop impact.

**3.2. Impeded infiltration caused by soil dispersion**

3.2.1. Mineral imbalance causes soil dispersion on the soil surface and around the drains

Generally, soils are more susceptible to dispersion when the mineral concentration of the soil solution is low (Vlotman et al., 2020). One method of increasing the soil mineral concentration is to add calcium to enhance the soil’s physical properties and improve infiltration. Soil dispersion can also occur when the ratio of soil calcium to magnesium is too low, that is low calcium and high magnesium (Qadir et al., 2018). Soil dispersion can also occur if the soil has high sodium and low calcium (sodic soil). The high sodium causes clay particles to disperse and seal the soil surface, thereby reducing infiltration. In Michigan, most soils are rich with calcium, so the risk of impeded infiltration due to excess magnesium or sodium is generally low. Nevertheless, soil test and consult a soil scientist to identify soil dispersion.

In parts of the Red River Valley in the Upper Midwest U.S.A., sodic or saline-sodic soil may cause under-performance of the drainage system due to soil dispersion on the soil surface. Before installing subsurface drains in those soils, evaluate the suitability for subsurface drainage as described in the Extension bulletin by Cihacek et al. (2012).

3.2.2. Raindrop impact causes soil dispersion

The impact force of raindrops on bare soil can break soil aggregates, disperse soil particles, and reduce infiltration (Figure 5). To reduce soil dispersion, protect the soil from raindrops with cover crops, crop residue, or mulch. The cover absorbs the raindrop impact force and reduces soil dispersion.

![Figure 5- Top: A soil surface with a failed germination. Bottom: A close-up of the same soil surface showing soil dispersion and crusting caused by mineral imbalance and raindrop impact (photo credit: Zouheir Massri).](image-url)
4. Water-quality decline due to under-performance

When design, installation, or maintenance issues cause under-performance, the system does not remove water as designed and surface runoff increases. As a result, more soil-attached phosphorus moves with surface runoff. A properly functioning drainage system reduces issues from surface runoff, but it increases transport of nitrate and phosphorus through subsurface drainage discharge. The excess phosphorus in downstream water bodies causes adverse economic, social, and environmental impacts. Also, excess waterlogging conditions resulting from drain clogging or impeded infiltration harms the soil structure and reduces crop yield. The poor soil structure decreases infiltration, causing an increase in surface runoff and nutrient loss.

Generally, improving soil health enhances the performance of drainage systems, but nitrogen and phosphorus losses to surface water are still an issue. Therefore, use conservation drainage practices to reduce nutrient loss while maintaining crop productivity. See Christianson et al. (2016) for more information about conservation drainage practices.

<table>
<thead>
<tr>
<th>Glossary</th>
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<tbody>
<tr>
<td>Drainage coefficient</td>
<td>The depth of water that the drainage system is designed to remove from the soil in 24 hours (units of inches per day).</td>
</tr>
<tr>
<td>Hydraulic conductivity</td>
<td>A measure of the soil's ability to transmit water in units of inches per hour.</td>
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<tr>
<td>Restrictive layer</td>
<td>A soil layer that considerably impedes water movement. This can be dense clay-pan layers, cemented layers, or bedrock.</td>
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5. Conclusions and recommendations

If there is a drainage system failure, it usually occurs during the first two years after installation. Subsequently, the system should function properly if adequately maintained. Most under-performance problems can be avoided with proper design, installation, and maintenance. However, unforeseen situations can lead to under-performance. Increasing knowledge about design and installation is key to avoiding most under-performance issues. Drainage system users are encouraged to attend educational drainage workshops as a means of increasing knowledge.

The under-performance of a drainage system can lead to yield decline due to slower water removal and lead to poor water quality due to increased surface runoff. The solution for an under-performance issue depends on local conditions. If the under-performance issue is severe, consult a drainage contractor and soil scientist to identify the problem, and address it early to avoid adverse crop and environmental outcomes. Generally, improving soil health improves the performance of drainage systems, but nutrient loss is still an issue. Therefore, use conservation drainage practices to reduce nutrient loss while maintaining crop productivity.

Expert Reviewed

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References


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