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Planning a Subsurface Drainage System

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Introduction

Drainage is an important and profitable practice for conservation farming. Through drainage, it is possible to improve crop production and to use more intensive farming practices on level land.

Subsurface drainage is used where the soil is permeable enough to allow for economical spacing of the drains and productive enough to justify the investment. The need for subsurface drainage systems is related to the water table elevation in the spring, the permeability of the soil and underlying subsoil materials, and the crop requirements. Often at a site, subsurface drainage is complemented by other practices such as surface drainage and erosion control. To maximize the benefits of drainage, there must be a complete system of management: proper fertilization, improved crop varieties, higher plant populations, earlier planting, weed and insect control, and improved harvesting methods. One weak link in the system reduces the possibility of making a profit.

The major objective of a subsurface drainage system is to remove excess water from the plant root zone of a soil affected by a high water table. Subsurface drains lower the water table so that the whole field can be cultivated, planted, and harvested when conditions are right (1). Subsurface drains improve plant growth by enabling aeration of the root zone.

Planning an effective subsurface drainage system requires a number of considerations. The following is a brief discussion of the factors that need to be considered by planners, designers, landowners, contractors, and others in planning an effective drainage system.

Legal Concerns

Draining water from one parcel of land to or through another has historically created many conflicts with adjoining landowners. Each state has common and statutory provisions that regulate drainage; these provisions vary between states. It is important for the designer, the contractor, and the landowner to be thoroughly familiar with the drainage law provisions in their state; they must know what their rights and responsibilities are concerning both receiving and removing water from the land.

The Food Security Act of 1985 has mandated that any new or improved drainage project must be evaluated for "wetland" restrictions. It is important that the local Soil and Water Conservation District be contacted for an interpretation of potential wetlands before beginning any drainage project. Failure by the landowner to comply with "wetland" provisions can result in loss of all USDA program benefits.

Site Conditions

Drainage Outlet

The starting point in planning a subsurface drainage system is the location of the outlet. When an open channel is used as an outlet, it must be large enough to remove the drainage runoff from the watershed quickly enough to prevent crop damage. The open channel outlet must also be deep enough so that when drain lines are laid at the specified depth, there is at least one foot of clearance between the flow line of the tile outlet and the usual low flow of the outlet during the growing season.

When an existing subsurface drainage main is used as the outlet, it should be in good condition, free of failures, and working properly. The main should have sufficient available capacity, based on the area served, to handle the proposed tile drainage system. The depth should be sufficient to permit the new tile system to be laid at the depth specified for good subsurface drainage.

Before connections are made into existing outlets, it is important to seek and receive written permission to make such connection from proper individuals and/or authorities, seek and receive written permission from adjacent landowners if there is a need to extend a drain across their land to an outlet, and consider a cost-sharing arrangement with adjoining landowners where there is mutual benefit.

Where an open channel or drainage main outlet is not available, drainage pumping plants can be used to pump the drain discharge water to a shallow outlet ditch.

Topography

In planning a subsurface drainage system, determine the topography of the site to be drained, keeping in mind that many installation machines cannot exceed 5 to 5½ feet without removal of overburden and there should be a minimum of 2 feet of cover over the drain for most soils. The amount of surveying needed to obtain topographic information depends on the lay of the land. Where the slope of the land is obvious, only a limited amount of data is needed to locate the drains. A detailed topographic survey is necessary, however, for flat and slightly undulating land, because it is not as obvious where drains ought to be located. The topographic survey needs to include elevations of the outlet as well as high and low areas in the field. It is best to obtain enough topographic information so the entire system can be planned before installing any part of the system. Planning the job without first gathering enough data may result in a piecemeal system that may eventually be very costly (2).

Soils

A drainage system cannot be adequately designed without a good understanding of the soil profile and the drainage characteristics of the soil. Ideal soils for subsurface drainage are those that are medium-textured and well-structured with approximately half the total volume made up of a continuous network of large and small pores. Gravitational water is removed quickly from the large pores by a subsurface drain; the fine pores will hold and store water for plant use.

Soils with high clay content, particularly if poorly structured, restrict movement of water and require close drain-line spacing. Sandy soils allow wide drain-line spacing but may have lower productivity because they lack fine pores for water storage.

Permeability is an important soil characteristic for evaluating the drainability of a soil. Soil permeability, or hydraulic conductivity, is a measurement of how well water or air moves through the soil. The rate of downward flow has traditionally been termed "permeability" and is expressed in inches per hour. There is a wide range of soil permeabilities. Such values can be obtained from local soil surveys and state drainage guides. The most common rates will vary from 0.2 to 0.6 inches per hour for slowly permeable soils to 0.6 to 2 inches per hour for moderately permeable soils.

Another very important soil consideration is the depth to an impermeable barrier. Often soils that need subsurface drainage have a dense compacted clay or silt layer that enables the build up of a water table. If that layer is above, or near, subsurface drain depth, water movement into the drains is restricted and the drain lines must be spaced closer together for effective drainage.

Soil types and their characteristics are generally published in county soil survey reports prepared jointly by the Soil Conservation Service and the Cooperative Extension Service. Drainage recommendations have evolved over a period of many years, and from these recommendations drainage

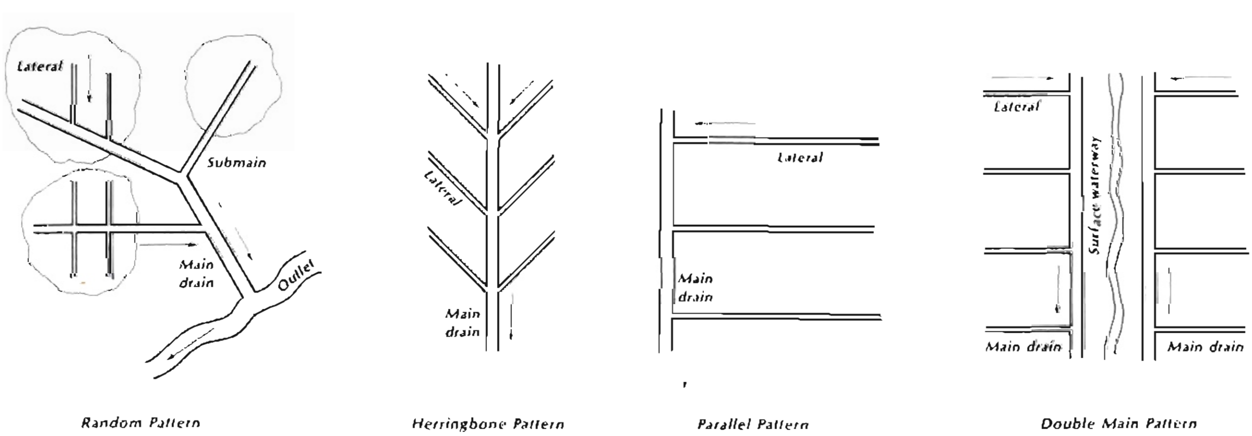

Figure 1. Basic patterns for subsurface drainage systems (the arrows indicate the direction of water flow).

method of payment, and any other factors. An understanding between all parties about how the job will be performed before it is started is much better than a misunderstanding after the job is completed (8).

Since proper installation is very important, it is essential to select a qualified contractor. The first step is to obtain names of drainage contractors in the area. In most states, there is a Land Improvement Contractors Association which maintains a directory listing member contractors. Other sources are your local Cooperative Extension Service personnel and the district conservationist with the Soil Conservation Service. In making your selection, establish criteria that you think is important for a contractor to possess: honesty, integrity, timeliness in doing the work, technical knowledge of the practice, cost, etc. Interview several contractors that you feel have the potential to meet this criteria; request a list of clients as a reference. Select the contractor that will do quality work at a reasonable price, not the one with the cheapest rates.

Summary

A subsurface drainage system is used in soils that are permeable enough to provide an economical installation. If the spacing is too narrow, the costs will be excessive. If the spacing is too wide, crop yields will be reduced. The soil must also be productive enough to justify the investment. Moreover, since a subsurface drainage system functions only as well as the construction of the outlet, it is important to make sure that a suitable outlet is available. Consider topography: keep in mind that installation equipment has depth limitations and that a minimum amount of soil cover is required over the drains. Other factors which must also be considered include soil type, layout, selection of drainage materials, and determination of drain size. To be assured that the system will function according to intent, there is need for careful and systematic planning. For the final plan to be completely functional and accepted, the wishes and desires of the landowner must be incorporated. It is also important that a qualified land improvement contractor be retained to install the drainage system; the contractor should provide the landowner with a complete set of "as built" plans. A drainage system that has been properly planned and installed will function as intended for many years.

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guides have been developed in many states. In addition to making drainage recommendations, these guides also serve as a handy reference for drainage design. In addition to drainage guides, the American Society of Agricultural Engineers and the Soil Conservation Service have design standards that should be followed. To plan a system that will meet the land user objectives, the designer will use recommendations in drainage guides, soil survey information, topographic surveys, field evaluations, and cost of system.

System Patterns

Because subsurface drainage is used primarily to remove excess water from the soil over a general area and to lower the water table, the drains are often placed in a pattern determined by the characteristics of the area. Four commonly used subsurface drainage system patterns are illustrated in Figure 1. The system designer will select the pattern that best fits the topography of the land and makes the most efficient use of the investment in the subsurface drainage system.

Random. The random pattern is suitable for undulating or rolling land containing isolated wet areas such as potholes in glacial till soil areas. The main drain is usually placed in the swales rather than in the deep cuts through ridges.

Parallel. The parallel pattern consists of parallel lateral drains located perpendicular to the main drain. The laterals in the pattern are spaced at any interval consistent with site conditions This pattern is used on flat, regularly shaped fields and on uniform soil.

Herringbone. The herringbone pattern consists of parallel laterals that enter the main at an angle, usually from both sides. The main is located on the major slope of the land, and the laterals are angled upstream on a grade. The herringbone pattern can provide the needed drainage for the less permeable soils found in narrow depressions.

Double main. The double main pattern is a modification of the parallel and herringbone patterns. It is applicable where a depression, frequently a watercourse, divides the field in which drains are to be installed. This pattern is sometimes chosen where the depressional area is wet because of seepage coming from higher ground. Placing a main on each side of the depression allows the main to intercept the seepage water and to provide an outlet for the laterals.

Economic Factors

Most wet soils can be drained satisfactorily; but for some soils, the installation cost may be so great that the benefits derived do not justify the expense. The long-range economic benefits must exceed the cost of the system. To make this analysis, the cost of the drainage system and the potential crop yields must be estimated over time. With appropriate interest tables it is possible to determine if the investment has economic feasibility. Consult with a farm management specialist if you have difficulty in evaluating benefits of drainage. Also suitable outlets may not be available at a reasonable cost. Many states have drainage guides which provide depth and spacing recommendations. These recommendations are based on local experience, and in some cases, on computer models, such as DRAINMOD (3). It is possible with DRAINMOD to make economic evaluations.

Materials

Material specifications establish quality standards for drain conduits. The specifications benefit both the drainage contractor and the landowner. The specifications enable manufacturers to maintain uniformity in their products, thus giving buyers some assurance that the products will be strong and durable and perform adequately in drainage systems. The materials used for subsurface drainage in the Midwest include clay (4), concrete (5), and corrugated plastic tubing (6,7). The local Soil Conservation Service office can provide specifications for the material you prefer to use. Any of these materials will provide adequate drainage for many years if properly installed and properly maintained. Special conditions, such as acidic soils or excessive depths, may require extra strength or a special quality of material.

Installation Techniques

Proper installation of drainage materials is critical for proper drainage system performance and longevity. Some installation techniques vary according to the type of drainage materials used. However, all drainage systems require proper installation procedures to be followed faithfully. Important installation considerations are listed as follows:

Installation Requirements	Comments
1. Uniform Gradient	The grade should be great enough to prevent silting, but flat enough to prevent flow from exceeding the allowable velocity and subjecting the drain to excessive pressure.
2. Depth	The minimum depth of cover over the drain and the maximum trench depth are influenced by such limiting factors as the type of bedding, the nature of the trench bottom, the width of the trench, the amount of live load. The desirable depth of laterals is between 2 to 4 feet.
3. Bedding	A specially shaped groove is required in the trench bottom for tubing where a gravel envelope is not specified. The groove provides side and bottom support to the lower part of the tubing and further provides a means of controlling alignment during installation.

4. **Blinding** — Blinding is the placement of bedding material consisting of loose, mellow soil on the sides and over the top of the drain to a depth of 6 inches. The bedding material will permit water to reach the drain easily, help maintain proper alignment of the tubing, and provide some protection to the drain during the backfilling operation.

5. **Backfilling** — Place the remaining excavated material into the trench and mound it over the trench to allow for settling. The backfill material is placed in the trench in a manner that displacement of the drain will not occur.

6. **Connections** — The weakest point in a drainage system is where a connection is made into a line. Use manufactured fittings at all joints, at all changes in direction where the radius of the centerline is less than three times the diameter of the drain, at changes in diameter, and at the end of the line.

7. **Envelopes and Filters** — Envelope material is installed around the drain to ensure proper bedding support and to improve the flow of ground water into the drain. A filter is used to restrict fine particles of silt and sand from entering the drain. Gravel envelopes are not normally designed as filters, but because they consist of well-graded material, they do act as partial filters. Prefabricated nonbiodegradable filter materials such as fiberglass, spun bonded nylon, and plastic filter cloth may be used instead of a sand and gravel type filter.

Special Considerations

Utilizing Existing Systems

Drainage systems have been installed in the north central states since the beginning of the early to mid 1800's. Drainage is, therefore, not a new practice, and today there are many existing systems. Many of these systems are adequate, while others are obsolete and broken down and require complete replacement. It is important for the drainage planner to take an inventory of what presently exists. If the existing system is not properly functioning, a totally new system may need to be considered. On the other hand, if the old system is properly functioning, perhaps it can be incorporated into the new system.

The planner should think in terms of a total system. The temptation may be to use random lines to manage existing wet spots and then discover at a later time that other areas of the field remain wet. A plan should be developed for the entire field even though the total system may not be initially installed. This enables the landowner to expand the system as needed (8).

Public Utilities

In planning a drainage system, it is important that any utility (especially pipelines) near the drainage system be properly located. Many public utilities are well-marked, but some are not. Whenever possible, avoid constructing drain lines across buried cables, pipelines, and other facilities. Determine the exact location and depth of the utility by consulting the utility owner. You will likely be required to obtain a special permit and meet certain other requirements to install drain lines across a county, state, or federal highway. When working around a buried pipeline, the landowner and contractor may be liable for the cost of interrupted service and repair if damage occurs to the buried utility and the contractor has not properly notified the owner of plans to work near the utility.

Maintenance Plans

Although subsurface drainage systems do not require extensive maintenance, the maintenance that is required is extremely important. Therefore, the development of a maintenance plan is essential. If the subsurface drains are working and the field has adequate surface drainage, water will stand in the field for only a short time after a heavy rain. If water stands for a day or two, the drain may be partly or completely blocked. Regular inspection of the drainage system is essential. Prompt repair of any failure will keep the system in good working order and prevent permanent damage to it.

A written maintenance plan may or may not be necessary, depending on the complexity of the required maintenance. The essential point is a complete understanding of needed maintenance. When a written plan is required, it may be a separate document. Each plan must be tailored to the specific job to which it applies. It is important to cover all items needed to ensure that the practice will be maintained for the expected life (4).

Review Installation Plans

The landowner needs to be a part of the overall planning process. The drainage system will be a part of the operation and the owner needs to be familiar with what it will do and also what it will not do. The landowner can also supply some valuable information about the property which should be of assistance during the designing process. It is good practice to have face-to-face meetings between the owner-farmer and the designer to discuss the preliminary design, installation procedures, cost-benefit ratio,