Introduction to Drainage Water Management

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Goals of Workshop

- Become familiar with drainage terminology
- Understand basic drainage concepts
- Be able to apply the planning and basic design procedures for drainage systems
- Be introduced to Drainage Water Management Techniques

Workshop Topics

- Planning and Management Considerations
- Soils
- Effect of Drainage on Crop Yields
- Economics
- Detailed Design Procedures
- Subsurface Drainage Installation

Planning Considerations

- Needs –
  - Surface Drainage
  - Subsurface Drainage
  - Water Table Management
  - Subsurface Irrigation
- Field topography and soil properties
- Utilities
- Wetland determination

Soils

- Soils formation
- Water movement in soils
- Soil properties
- Drainage class
- Water tables
- Restrictive layers
- Wetlands

Effect of Drainage on Crops

- MU Drainage and Subirrigation Research update.
- This will include yield data for comparison.
- Drainage only and Drainage/Subirrigation systems will be covered.

Economics

- Typical Installation Cost
- Economic Analysis of Systems
- Cost vs. Benefit

Drainage Design Procedures

Notebook Section 5 lists the Design Steps:

- o Planning
- o Topographic Design Survey
- o Soil Properties
- o Drainage Coefficient
- o Drain Spacing
- o Layout Mains and Laterals
- o Main Grades
- o Size Mains

Questions?

NRCS Natural Resources Conservation Service
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Food, Agricultural and Biological Engineering

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Understanding Agricultural Drainage

AEX-320-97

Larry C. Brown
Andrew D. Ward

Agriculture is Ohio's largest industry. Because much of the state is characterized by fertile, flat soils and adequate rainfall, crop production occurs on 45 percent of Ohio's land area. About 55 percent of Ohio's agricultural soils need drainage improvement to minimize soil erosion, excess soil-water conditions in the plant root zone, and unfavorable field conditions for farm equipment in the spring and fall. Ohio's agricultural drainage needs are very similar to those in states such as Arkansas, Florida, Indiana, Illinois and Louisiana. Nationally, drainage improvement is required on more than 20 percent of our cropland (approximately 110 out of 421 million acres). Maintaining existing water management improvements is quite important because proper management of the soil, and soil water, is required to sustain production and profitability on agricultural soils.

In recent years, public concern has increased about the nature of agricultural drainage, and the impact of agricultural drainage improvements on the quality of Ohio's water resources and environment. This publication is designed to help Ohio's citizens understand the purpose and nature of agricultural drainage improvements, particularly those related to the drainage of excess water from cropland in Ohio.

This publication does not address the various legal mechanisms that can be used by Ohioans to make drainage improvements (See *Ohio's Drainage Laws - An Overview*, Extension Bulletin 822). Much of the water terminology used in this publication is defined in *Ground- and Surface-Water Terminology*, Extension Fact Sheet AEX-460. These publications are available through your Ohio county office of Ohio State University Extension.

Agricultural Drainage

Agricultural drainage is the removal of excess water from the soil surface and/or soil profile of cropland, by either gravity or artificial means. The two main reasons for improving the drainage on agricultural land are for soil conservation and enhancing crop production.

Research conducted in Ohio and throughout the Midwest has documented many benefits of agricultural drainage improvement.

In Ohio, most agricultural producers improve the drainage on their land to help create a healthier environment for plant growth and to provide drier field conditions so farm equipment can access the farm field throughout the crop production season. Healthy, productive plants have the potential to produce greater yields and more food. Also, research in Ohio has shown that agricultural drainage improvement can help reduce the year-to-year variability in crop yield, which helps reduce the risks associated with the production of abundant, high quality, affordable food. Improved access of farm equipment to the field provides more time for field activities, can help extend the crop production season, and helps reduce crop damage at harvest.

Types of Improvements

In Ohio, the two primary types of agricultural drainage improvement are surface and subsurface (Figure 1). Many times a landowner installs a combination of these two types.

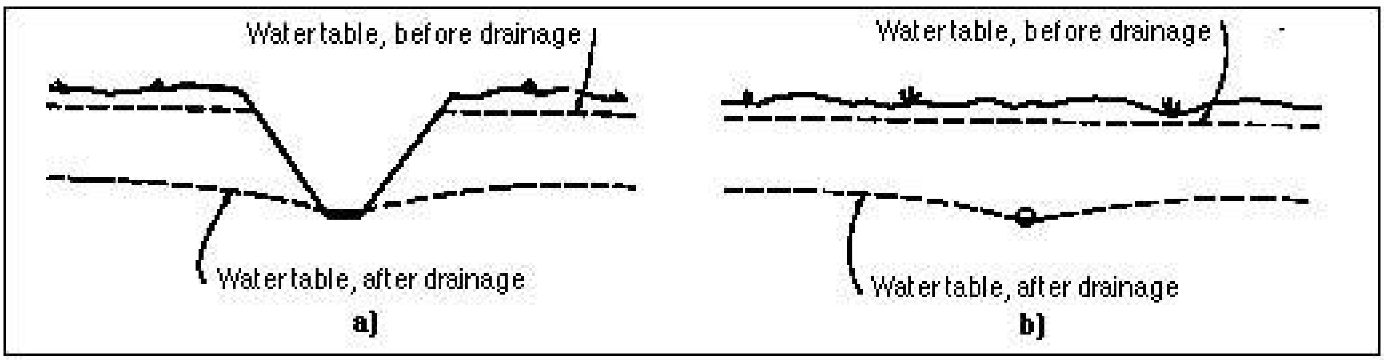

Figure 1. Water table level before and after drainage inprovement: a) surface drainage ditch; b)subsurface drainage pipe. (adapted from USDA-ERS, 1987)

Surface Drainage

Surface drainage improvements are designed for two purposes: to minimize crop damage resulting from water ponding on the soil surface following a rainfall event, and to control runoff without causing erosion. Surface drainage can affect the water table by reducing the volume of water entering the soil profile. This type of improvement includes: land leveling and smoothing; the construction of surface water inlets to subsurface drains; and the construction of shallow ditches and grass waterways, which empty into open ditches and streams.

Land smoothing or leveling is a water management practice designed to remove soil from high spots in a field, and/or fill low spots and depressions where water may pond. Shallow ditches may be constructed to divert excess water to grass waterways and open ditches, which often empty into existing surface water bodies.

Some disadvantages of surface drainage improvements exist. First, these improvements require annual maintenance and must be carefully designed to ensure that erosion is controlled. Second, extensive earthmoving activities are expensive, and land grading might expose less fertile and less productive subsoils. Further, open ditches may interfere with moving farm equipment across a field.

Subsurface Drainage

The objective of subsurface drainage is to drain excess water from the plant root zone of the soil profile by artificially lowering the water table level. Subsurface drainage improvement is designed to control the water table level through a series of drainage pipes (or tubing) that are installed below the soil surface, usually just below the root zone (Figure 2). For Ohio conditions, subsurface drainpipe is typically installed at a depth of 30 to 40 inches, and at a spacing of 20 to 80 feet. The subsurface drainage network generally outlets to an open ditch or stream. Subsurface drainage improvement requires some minor maintenance of the outlets and outlet ditches. For the same amount of treated acreage, subsurface drainage improvements generally are more expensive to construct than surface drainage improvements.

Whether the drainage improvement is surface, subsurface or a combination of both, the main objective is to remove excess water quickly and safely to reduce the potential for crop damage. In a situation where water is ponded on the soil surface immediately following a rainfall event, a general rule of thumb for most agricultural crops grown in Ohio is to lower the water table to 10 to 12 inches below the soil surface within a 24-hour period, and 12 to 18 inches below the soil surface within a 48-hour period. Properly draining excess water from the soil profile where plant roots grow helps aerate the soil and reduces the potential for damage to the roots of growing crops (Figure 2). Further, proper drainage will produce soil conditions more favorable for conducting farming operations. In states that depend heavily on irrigation, subsurface drainage is often used to prevent harmful buildup of salt in the soil.

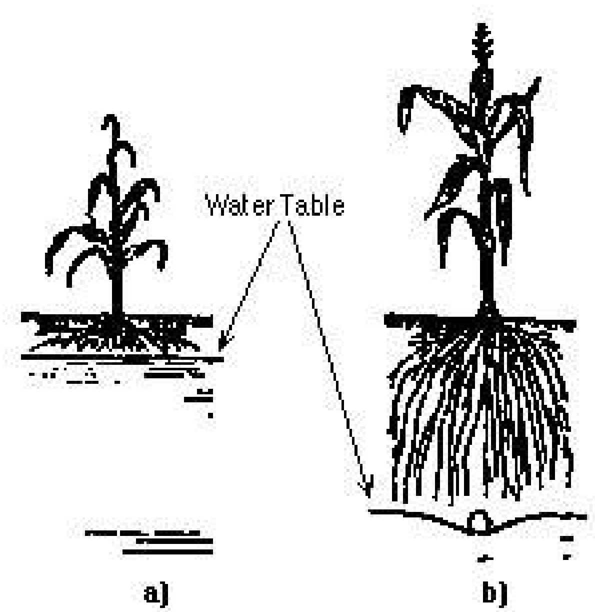

Figure 2. Effect of drainage improvement on crop root development: a) no drainage improvement; b) subsurface drainage improvement (adapted from Irwin, 1989).

Past and Present

Land drainage activities have impacted Ohio's environment and water resources. Early settlers began draining Ohio's swamps in the 1850s, and today approximately 90 percent of Ohio's wetlands have been converted to other uses. This loss is attributed to public health considerations; rural, urban and industrial development; and agriculture. Today, however, an important distinction needs to be made between improving the drainage of wet soils presently in agricultural production and converting our "true" remaining wetlands for other purposes. True wetlands, like bogs, marshes and swamps, have saturated soil conditions over a long enough period of time during the year to maintain water-loving vegetation and wildlife habitat. These areas, once their benefit is determined, should be protected from development.

Wetlands provide many benefits for the environment, including wildlife habitat and enhanced water quality. An important water quality function of wetlands is the trapping and filtering of sediment, nutrients and other pollutants that enter runoff from agricultural, construction and other rural and urban sources. Interestingly, subsurface drainage improvements, in a more limited capacity, provide some of these same water quality benefits while providing a necessary element for sustained agricultural production on a majority of Ohio's productive agricultural soils.

Present agricultural trends are toward more intensive use of Ohio's existing cropland, with much of the emphasis on management. Maintaining existing agricultural drainage improvements and improving the drainage on wet agricultural soils presently in agricultural production helps minimize the need for landowners to convert additional land to agricultural production. In many cases, restoration of previously converted wetlands would be impossible because of large-scale channel improvements, urbanization and Lake Erie shoreline modification. The focus should be placed on protecting existing true wetlands and establishing new wetland areas, while maintaining our highly productive agricultural areas.

Note: The use of surface and subsurface drainage improvements is not limited to agricultural lands. Many residential homes use subsurface drainage systems, similar to those used in agriculture, to prevent water damage to foundations and basements. Golf courses make extensive use of both surface and subsurface drains. Houses, streets and buildings in urban areas depend heavily on surface and subsurface drainage systems for protection. These generally are a combination of plastic or metal gutters, and concrete pipes or channels.

Summary

Throughout Ohio and the Midwest, the removal of excess water from wet agricultural soils is essential for providing a healthy environment for crop growth, and subsequently, helps provide affordable, high-quality food. Agricultural drainage improvement is necessary to sustain agricultural production. This publication was developed to help the reader better understand the purpose and nature of agricultural water management improvements, particularly those relating to the drainage of excess water from cropland in Ohio. Publications and technical references used to support the material in this publication are included in the "Bibliography" section, along with other publications that may be of interest to the reader.

For more information, contact the lead author of this publication or your Ohio county office of Ohio State University Extension.

Factors Contributing to Excess Water Problems in Soils

In Ohio, factors that contribute to excess soil water problems include: fine soil texture; massive soil structure; low soil permeability; topography; soil compaction; restrictive geologic layer; and excess precipitation.

Soil Texture: The sand, silt and clay composition of the solid mineral particles in a soil is called soil texture. For a loam soil texture, for instance, the mineral content might consist of 40 percent clay, 30 percent silt and 30 percent sand. Soil texture can have a dramatic effect on how well the soil holds water, and how easily water can move through the soil. Fine-textured soils have a large percentage of clay and silt particles. These soils generally hold water well, but drain poorly. Coarse-textured soils have a large percentage of sand or gravel particles. These soils drain well, but have poor water-holding ability.

Soil Structure: The physical arrangement of the solid mineral particles of a soil is the soil structure. A granular structure helps promote the movement of water through a soil, but a structure that is massive (lacking any distinct arrangement of soil particles) usually decreases the movement of water.

Permeability: In general terms, the relative ease with which water can move through a block of soil is soil permeability. A soil's permeability can be affected by its texture, structure, human activities, and other factors.

Topography: The shape and slope of the land surface can cause wet soil conditions, especially around depressions where water tends to accumulate. Without an outlet, the water may drain away very slowly.

Geologic Formation: The geological formation underlying a soil can impact the drainage of water from that soil. For instance, a soil could have texture and structure properties that are beneficial to the movement of water. However, if the geologic formation underlying this soil consisted of dense clay or solid rock, it could restrict the downward movement of water, causing the soil above the formation to remain saturated during certain times of the year.

Compaction: Human activities may help create excess soil water problems. For example, operating equipment on a wet soil can compact the soil and destroy its structure. A soil layer that is compacted will generally have no structure, and most of the voids in this layer will have been eliminated. Voids are open spaces between soil particles that can be filled with air, water, or a combination of both. Soil water will tend to accumulate above the compacted layer because movement of water through the compacted layer is severely restricted. If the compacted layer is located at the soil surface, very little water will enter the soil and much of the water will runoff, potentially creating a flooding and/or erosion hazard.

Precipitation: Ohio's average annual precipitation is 38 inches, based on a 50-year period of precipitation records. Even though the distribution of precipitation across the state varies (see Figure 3), the state receives an abundant supply of precipitation in an average year. In an average month, most areas of the state receive 2 to 4 inches of precipitation. This amount is adequate to sustain high crop yields. However, excessive rainfall, and/or winters with heavy snowfall, often produce excess soil water conditions. Furthermore, thunderstorms will frequently result in runoff because the rainfall rate is greater than the rate at which water can enter (infiltrate) into the soil.

Note: The physical properties of a particular soil can vary throughout the soil profile, and from place to place in the same field. All across Ohio, soils have different physical characteristics, and the geological formations underlying soils vary as well. Therefore, each soil will have particular drainage characteristics. Soil scientists and engineers have classified many of Ohio's soils based on their drainage characteristics. For general information about the nature of soils and their properties, refer to a soil science textbook. For specific information regarding the drainage ability of a particular soil in your area, contact the USDA Natural Resources Conservation Service (NRCS) office in your county.

Figure 3. Generalized map of average annual precipitation in Ohio for the period 1931-1980 (adapted from Harstine, 1991).

Bibliography

Brady, N.C. 1990. The Nature and Properties of Soils. (10th Ed.). MacMillan Publishing Co., Inc. NY.

Brown, L.C., and L.P. Black. 1994. Ground- and Surface-Water Terminology. Fact Sheet AEX 460. Ohio State University Extension.

Brown, L.C. 1994. Ohio's Hydrologic Cycle. Fact Sheet AEX 461. Ohio State University Extension.

Brown, L.C. and J.W. Johnson. 1996. Nitrogen and the Hydrologic Cycle. Fact Sheet AEX 463. Ohio State University Extension.

Brown, L.C., and J.L. Stearns. 1991. Ohio's Drainage Laws - An Overview. Bulletin No. 822. Ohio State University Extension.

Fausey, N.R., L.C. Brown, H.W. Belcher and R.S. Kanwar. 1995. Drainage and water quality in Great Lakes and cornbelt states. ASCE J. Irr. and Drain. Engr. 121 (4): 283-288.

Fausey, N.R., E.J. Doering, and M.L. Palmer. 1987. Purposes and Benefits of Drainage. Pp 48-51 In: Farm Drainage in the United States. History, Status, and Prospects. USDA-Economic Research Service. Misc. Pub. No. 1455.

Fogiel, A., and H.W. Belcher. 1991. Research Literature

Review of Water Table Management Impacts on Water Quality. Agricultural Engineering Department, Michigan State University. East Lansing, MI 48823.

Frost, L.H., and W.A. Nichols. 1985. Ohio Water Firsts. Published by Water Resources Foundation of Ohio, Inc. Volume I.

Harstine, L.J. 1991. Hydrologic Atlas for Ohio: Average Annual Precipitation, Temperature, Streamflow, and Water Loss for the 50-Year Period 1931-1980. Water Inventory Report No. 28. ODNR Division of Water.

Irwin, R.W. 1989. Handbook of Drainage Principles. Publication 73. Ministry of Agriculture and Food, Ontario.

Nolte, B.H., and N.R. Fausey. 1986. Soil Compaction and Drainage. AEX 301. Ohio State University Extension.

Schwab, G.O., N.R. Fausey, E.D. Desmond and J.R. Holman. 1985. Tile and Surface Drainage of Clay Soils. Res. Bull. 1166, OARDC, The Ohio State University, Wooster, OH.

Schwab, G.O., D.D. Fangmeier, W.J. Elliot and R.K. Frevert. 1993. Soil and Water Conservation Engineering. (4th Ed.) Wiley and Sons, NY.

Skaggs, R.W., M.A. Breve and J.W. Gilliam. 1994. Hydrologic and water quality impacts of agricultural drainage. Crit. Rev. in Envir. Sci. and Technol. 24 (1): 1-32.

Sporleder, T.L., L.J. Hushak and D. Pai. 1990. OHFOOD: An Ohio Food Industries Input-Output Model. The Farm Income Enhancement Program. (1985 Data). Department of Agricultural Economics & Rural Sociology, The Ohio State University.

USDA-ERS. 1987. Farm Drainage in the United States. History, Status, and Prospects. USDA-Economic Research Service. Misc. Pub. No. 1455.

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Principles of Drainage

Stewart W. Melvin

Subsurface drainage is a practice that has been shown to improve crop yields in many naturally wet soils. Drainage is the artificial control of the water table elevation in soils in order to provide a better root zone environment for crop production.

The objectives of drainage in the Midwest are (1) to provide a proper balance between soil, water, salt, and air in the root zone to provide optimum growth; (2) to increase the yield or quality of a crop or to improve the soil environment to allow production of a higher-valued crop; and (3) to provide better conditions for planting and harvesting the crop.

Drainage systems are installed throughout the Midwest mostly by independent contractors working directly with farm owners and operators. The objective of this paper is to review some of the basic principles of drainage for technicians working in the drainage industry.

Soil Characteristics and Composition

Soil is composed of solid particles and void spaces. The void spaces can be filled with water, air, or both, which is the most common condition. Figure 1 shows a soil column and a solid mass and a void space partially filled with both air and water. Figure 2 represents the volumetric relationship of a moist silt loam soil. Solid particles including both mineral and organic fractions account for approximately 50 percent of the volume in a silt loam soil while voids account for the remaining 50 percent of the volume. Under moist conditions about one half of the void space is filled with water. Figure 3 illustrates the condition of a granular soil structure. Water is commonly stored for plants as a thin film on soil particles and aggregrates.

Soil texture refers to the size of the individual soil grains. As the texture of a soil becomes finer (heavier), void space remains nearly constant but void size decreases. Resistance to flow of water in a saturated state is greatly increased, which results in slower flow rates through fine-textured soils. In such soils, the effect of soil structure or the arrangement of individual particles into larger particles plays an important role. In well-structured clay soils, drainage may work satisfactorily. In poorly structured clay, drainage systems may fail as a result of low hydraulic conductivity. In poorly-structured clay soils, the effect of micropores such as worm holes or cracks can play an important role in drainability.

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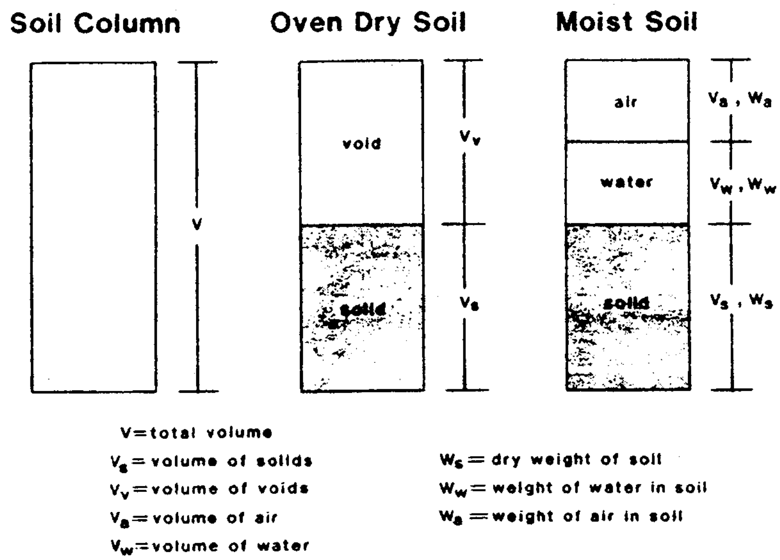


Figure 1. Volumetric relationships of soil.

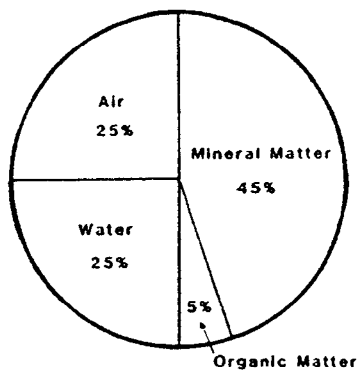


Figure 2. Composition of a moist silt loam soil at field capacity.

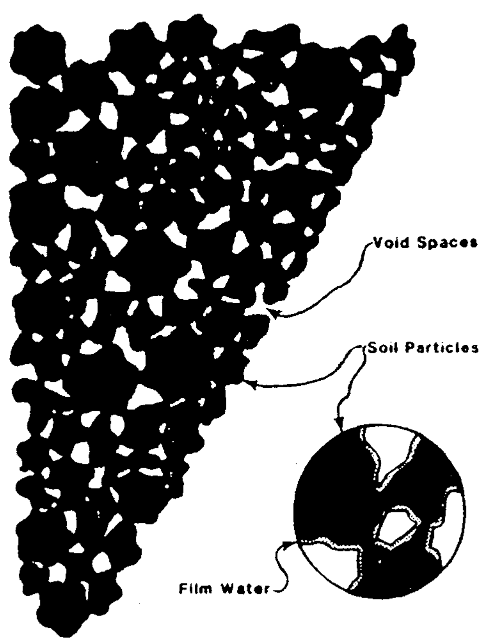


Figure 3. Characteristic structure of granular soil.

Soil Water

Soil water is held less tightly as the film thickness increases around and between soil particles. Film thickness and pore size affect drainability and the moisture-holding characteristics of soils. In Figure 4, a corn plant is shown growing in a silt loam soil with a water table well below the root zone. This could represent a common moisture situation during summer. The corn plant has extracted some water for growth from the surface layers. At the surface, however, the plant has used up all the available water. This moisture content is referred to as the WILTING POINT. All water held in the soil below this level is held too tightly for the plant to remove.

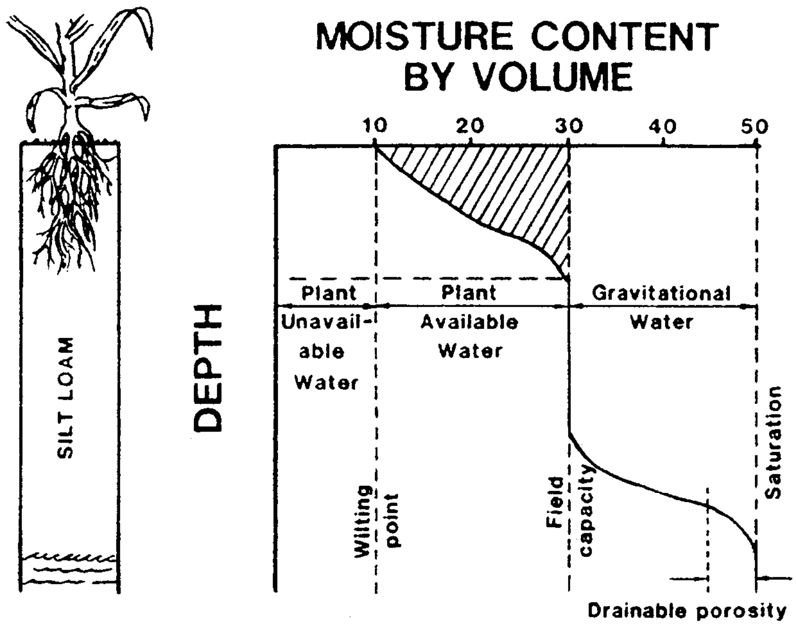


Figure 4. Moisture relationships in soils.

As we move further down in the root zone, the soil is wetter since the plant has not yet extracted it for growth. Near the base of the root zone, the soil is moist and is said to be at FIELD CAPACITY. This is the maximum water the soil can hold against the force of gravity. Water held in the soil between field capacity and the wilting point is called PLANT AVAILABLE WATER. Near the water table, soil moisture increases to saturation. Water held in soils between saturation and field capacity is called GRAVITATIONAL WATER. This is the water that is removed with a subsurface drainage system. DRAINABLE POROSITY is a term that is used to determine the amount of water rapidly removed from the soil when the water table drops.

Water Movement in Soils

Water is continuously moving in soils as a result of many processes. Figure 5 illustrates the basic processes of precipitation, evaporation, transpiration by plants, infiltration, deep percolation, and groundwater table fluctuation due to groundwater movement. Scientists and engineers studying water movement in soils have found that water flow can be described as flowing from a high energy state to a low energy state in much the same way as electricity flows from a high voltage to a low voltage. The energy state is referred to as SOIL WATER POTENTIAL. Water energy is primarily due to pressure and elevation. The sum of the pressure and elevation terms in saturated flow is commonly referred to as HYDRAULIC HEAD. Hydraulic head of water in a soil is the sum of the elevation of the point in the soil above a reference elevation plus the pressure head at that point.

For saturated flow conditions (all pores filled with water), the flow can be described with Darcy's Equation:

$$V = K \frac{\Delta H}{L};$$

where: V = Velocity of flow of water through soil;

K = Hydraulic conductivity or permeability;

H = Hydraulic head loss across soil sample; and

L = Length of the soil sample.

See Figure 6 for an illustration of this experiment.

In several drainage situations it is found that water apparently moves "uphill" against the force of gravity. This phenomenon is real since, in such cases, water is moving from a position of high potential to one of low potential. Figure 7 illustrates such a case. Even though water moves up through the sample, there is a higher total head at the lower end of the sample than the upper end. Therefore, water moves "uphill" through the sample.

Hydraulic conductivity, K, is an important property of soils with respect to drainage. The higher the value of K the more rapid the movement of water given the same driving force through the soil. Conductivity values for natural soils are difficult to measure but ranges of values are estimated in soil survey reports of local soils. Table 1 lists some common soil textures, permeability class and estimated hydraulic conductivity values as well as some commonly used ranges of depth and spacing of drains. Note the increase in K values moving from clays to loams to sands.

Table 1. Typical Drainage Recommendations for Various Soil Types

Soil	Permeability class	Hydraulic conductivity (K), feet per day	Spacing, feet	Depth, inches
Clay	Very slow	<0.1	30 to 50	36 to 42
Clay loam	Slow	0.1 to 0.4	40 to 70	36 to 42
Loam	Moderately slow	0.4 to 1.6	60 to 100	42 to 48
Fine sandy loam	Moderate	1.6 to 5.0	100 to 120	48 to 56
Sandy loam	Moderately rapid	5.0 to 10.0	100 to 200	48 to 60
Peat & muck	Rapid	10.0 to 20.0	100 t0 300	48 to 60

Let's examine the background of the recommendations for depth and spacing for subsurface drains.

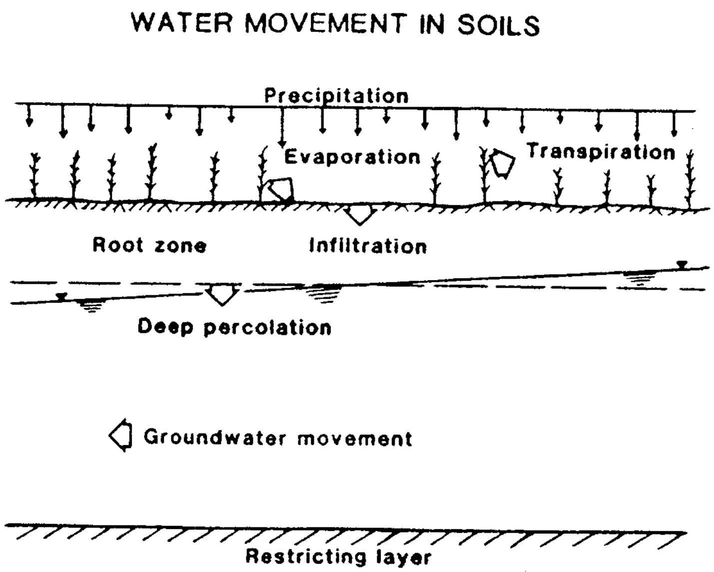


Figure 5. Water movement in soils.

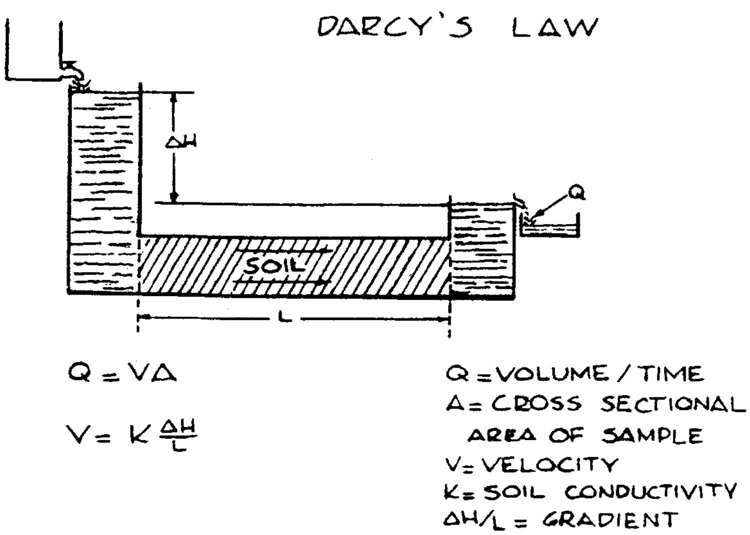


Figure 6. Experiment for hydraulic conductivity measurement.

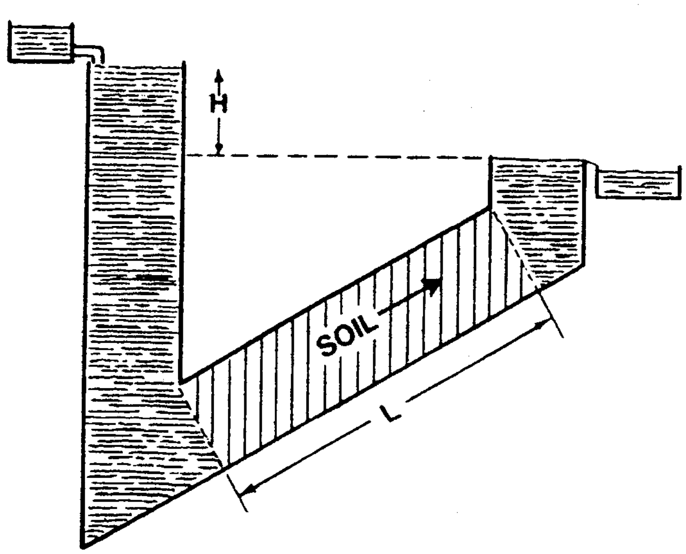


Figure 7. Water movement as a result of potential difference.

Theoretical Flow of Water Into Tile Lines

For the special case when water is thinly ponded over a tile line, the flow net is shown in Figure 8 (flowlines and equal potential lines). In this case water can redistribute on the surface prior to infiltration. Therefore, 50 percent (flowline left 25 to right 25) of the water flows into the line in approximately 10 percent of the spacing. Also consider the path along the 95 percent flow line. Water moves nearly vertically downward, then almost horizontally toward the drain and then nearly vertically upward into the drain. This phenomenon is again the result of the flow being caused by head difference and also the problem of flow convergence near the tile line. In this case, approximately 50 percent of the water enters the lower half of the drain.

Drainage Spacing Formulas

For the non-ponded, steady-state case such as that illustrated in Figure 9, a water table builds up between the drains and can be described with the equation:

$$S^2 = \frac{4KH}{R}(H + 2d)$$

where: S = Spacing;

K = Hydraulic conductivity;

H = Hydraulic head measured from the elevation of the, drain to water table elevation at midpoint;

D = Depth to an impermeable layer below drain; and

R = Rainfall rate, or drainage removal rate, i.e. drainage coefficient.

The steady-state equation uses the term R as a constant infiltration rate or as a drainage coefficient. The DRAINAGE COEFFICIENT is defined as the depth of water to be removed from the drainage area in 24 hours. Typical recommended values for subsurface drainage range from 3/8- to 1/2-inch per 24 hours in most midwestern conditions.

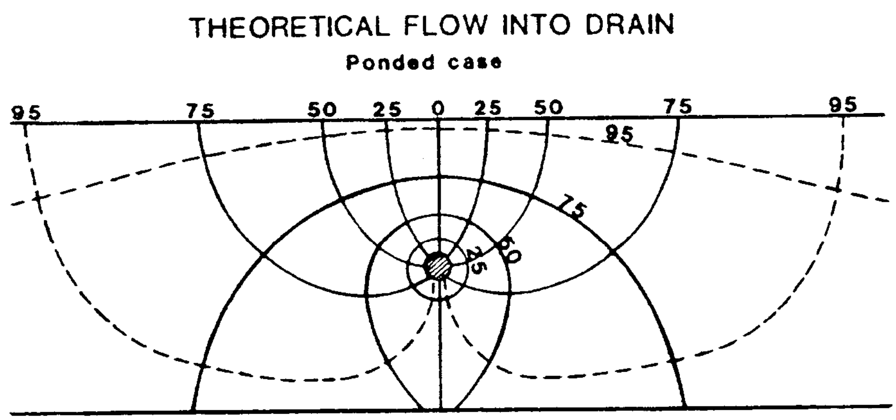


Figure 8. Theoretical flow into a drain.

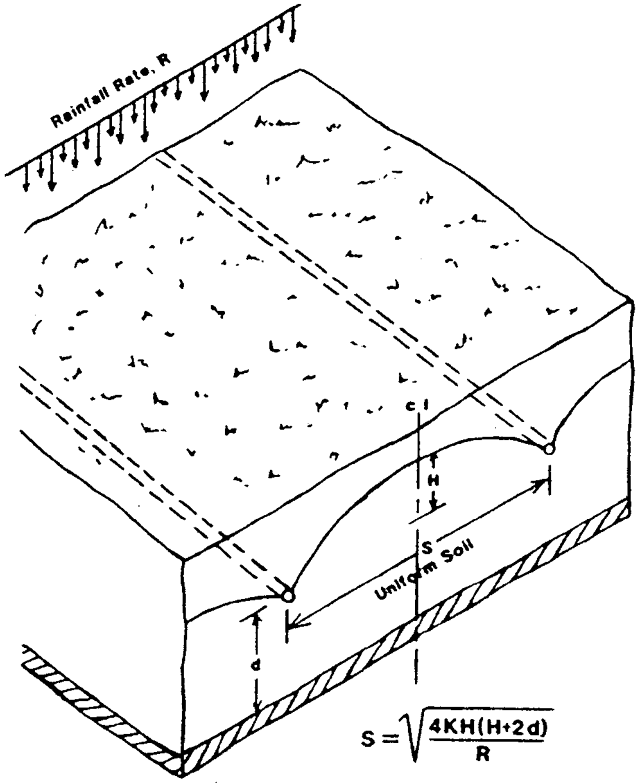


Figure 9. Steady-state drainage condition.

Many drains in the humid area of the country are based on the use of the steady-state equation if adequate soil information is available. When it is not, trial and error through experience has been the basis for most depth and spacing recommendations.

In the Midwest, intermittent wetting and drying cycles cause the water table to fluctuate almost constantly. Engineers have tried to explain the position of the water table with time through mathematical formulas. Figure 10 illustrates a water table at two different times between two tile lines. The spacing formula used to describe the falling head case is:

$$S^2 = \frac{9Ktde}{F[\ln m_o\ (2de + m) - \ln m\ (2de + m_o)]}$$

where: S = Drain spacing;

K = Soil hydraulic conductivity;

de = Effective depth -- d corrected for convergence;

m_o = Height of water table between drains at midpoint at time 0;

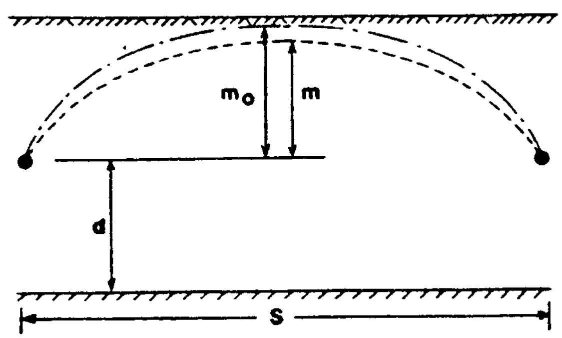
m = Height of water table between drains at time t;

t = Time of water table to drop from m_o to m; and

f = Drainable porosity of the soil.

Figure 11 indicates the effect of depth and spacing of drains on the position of the water table. If the water table is at the surface following a heavy rainfall or snowmelt event, then the water table at the midpoint between the drains should drop from 6 to 12 inches after 24 hours for a good drainage system. It should be below the surface 18 to 24 inches at 48 hours. Spacing drains at too shallow a depth or too wide apart will result in an unsatisfactory water table drawdown rate.

FALLING WATER TABLE



$$S = \sqrt{\frac{9Ktd_e}{f\left[\ln m_o(2d_e+m) - \ln m(2d_e+m_o)\right]}}$$

Figure 10. Falling water table drainage condition.

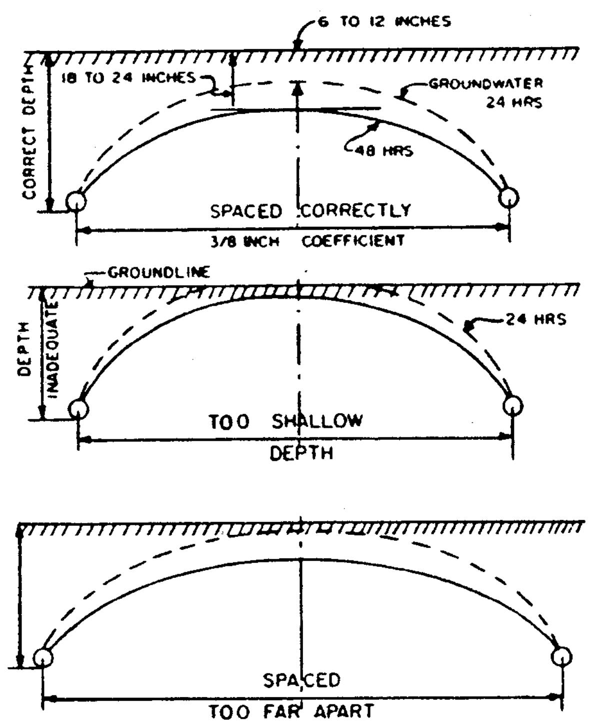


Figure 11. Depth and spacing relationships.

THE OHIO STATE UNIVERSITY

FactSheet Extension

Ohio State University Fact Sheet

Food, Agricultural and Biological Engineering

590 Woody Hayes Dr., Columbus, Ohio 43210

Agricultural Water Table Management Systems

AEX 321-97

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The management of Ohio's agricultural drainage waters has important consequences for agricultural productivity and profitability, and for environmental quality. Water table management is a package of management practices and strategies that can be used by agricultural producers and land managers to manage drainage waters. The purpose of this publication is to provide the reader with a general understanding of how agricultural drainage waters can be managed to help balance production and environmental goals. This publication was designed to help persons who have a good understanding of agricultural drainage extend beyond their current knowledge of drainage water management. For background information, the reader is referred to a basic primer on agricultural drainage, *Understanding Agricultural Drainage* (AEX 320), which is available through your Ohio county office of Ohio State University Extension.

What is Water Table Management?

In simple terms, water table management is the management, control, and/or regulation of soil-water conditions in the profile of agricultural soils. Essentially, excess and deficit soil-water conditions in the soil profile can be managed to provide better plant growth conditions for the production of food. Through the implementation of proper management practices and strategies, there also can be an environmental benefit. Soil-water conditions can be managed through the use of water management structures and strategies designed specifically for the given site conditions.

Water Table Management Practices

Water table management consists of three basic practices. These are conventional subsurface drainage, controlled drainage, and subirrigation. Each of these are illustrated in Figure 1 and discussed in more detail below.

Subsurface Drainage

Cropland that is susceptible to seasonal or intermittent high water table conditions usually requires subsurface drainage improvement, which serves to lower the water table to a level equal to the drain depth (see Figure 1a.). Subsurface drainage is common throughout the flat and gently rolling areas of the Midwest, as well as in other parts of the country. Subsurface drainage improves trafficability, enhances field conditions for more timely planting and harvesting operations, and helps decrease crop damage that can result from saturated soil and standing water.

Two of the longest duration studies on the effect of drainage on crop yield were conducted in Ohio. Both studies document crop yield increases with subsurface drainage on poorly drained soils compared to no subsurface drainage on these soils.

Controlled Drainage

The addition of properly designed and constructed water control structures to a subsurface drainage system allows the drainage outlet to be artificially set at any level between the ground surface and the drain depth (see Figure 1b.). Raising the outlet after planting helps keep water available for plant use longer than does "free," uncontrolled subsurface drainage. This practice also can be used to recharge the water table between growing seasons. Most existing subsurface drainage systems can be retrofitted for controlled drainage. Controlled drainage systems require a moderate level of management so that excess soil-water conditions following heavy rainfall can be avoided.

Based upon research conducted in North Carolina, controlled drainage may provide some reduction in nitrate losses from subsurface drained cropland, and helps to increase corn and soybean yields. Although controlled drainage has long been used in Ohio's organic soils to control subsidence and iron ochre problems, the effect of this practice on crop yields and water quality in Ohio has not been fully evaluated.

Subirrigation

With subirrigation, one system provides the drainage and irrigation requirements for the crop. Water is supplied through the subsurface drainage system using control structures to regulate the water table level in the field. Irrigation water is applied below the ground surface, thus raising and maintaining a water table at an appropriate depth in the crop root zone (see Figure 1c.). The pumping system and water control structure can be managed to create a constant water table depth or a fluctuating water table. Some existing subsurface drainage systems may be retrofitted for subirrigation. Subirrigation systems require a high level of management to avoid excess soil wetness following rainfall.

Benefits of Subirrigation

As stated above, one properly designed and managed system can be used to completely meet all the water table management requirements at a site. The drainage and irrigation components of a subirrigation system are one and the same. Installing a subirrigation system usually costs less than installing a subsurface drainage system and a surface irrigation system together on the same field.

For certain soils, subirrigation is very efficient. If the system is properly designed for the site and soil conditions, loss of water through deep seepage is negligible, and runoff of irrigation water rarely occurs. The water is always applied where the crop needs it most. Most importantly, crops respond well to subirrigation when other production management factors are not limiting. In over ten years of study in Ohio, soybean yields have been consistently over 75 bushels per acre under subirrigation and a high yield management system.

Requirements for Subirrigation

A number of factors should be considered before installing a subirrigation system. Several of the more important ones are discussed below.

Soil

In general, agricultural soils that respond well to subsurface drainage improvement tend to respond well to subirrigation. Subirrigation is usually effective in soils that have a soil layer of low permeability located below the subsurface drains. This layer helps reduce deep seepage losses. The permeability of the restrictive layer should be less than one-tenth that of the soil in the crop root zone.

Both vertical and horizontal hydraulic conductivities should be measured in the field before designing the system. High values of horizontal hydraulic conductivity creates the potential for lateral seepage. This allows for a wider drain spacing, which can reduce installation costs. However, losses from the edge of the field may be excessive under these conditions, especially if the adjoining field is drained.

Water Supply

Available water from a reliable source is a very critical factor for all types of irrigation. Water is needed most during the driest parts of the growing season. Streams are often unreliable, because flow rates decrease when water demand is highest. Wells, ponds, and reservoirs are used frequently for irrigation water supply. Net irrigation water requirements in the Midwest depend on crop, location, and weather. Irrigation to meet the evapotranspiration demand for a typical Ohio growing season may require as much as 5 gallons per acre per minute per day.

Drainage

The ability to drain rapidly when rainfall occurs during subirrigation periods is critical. In addition, drainage system improvements may be necessary to adequately distribute the irrigation water throughout the field. For most soils, the subsurface drain spacing is usually closer than that required for conventional subsurface drainage alone. In general, the subirrigation system will be a more intense subsurface drainage system. Surface drainage improvements, such as land grading or field ditches, may be used to help safely and efficiently avoid ponded surface water after a rain.

Topography

Subirrigation is best suited for flat or gently sloping lands (less than 1% slope) because uniform depth to the water table is much easier to maintain. A field with considerable surface undulation could result in excessive variation of the depth to the water table within the field. For this case, the field may need to be divided into zones within which the land slope variation is limited. For this type of situation, proper water table management may require a separate water control structure for each zone within the field. This will increase the cost of installation of the system, but should increase the irrigation efficiency.

Materials

The materials needed for the subirrigation system will include all the same types of materials used for a typical subsurface drainage system. In addition, the subirrigation system will require water control structures, a properly designed pumping system, and perhaps simple, water table level monitoring wells (piezometers) at several locations within each field. Water control structures are needed, at least in the main line, to maintain a uniform water table depth. Provisions for adjusting the weir setting (water level) within the water control structure must be included and should be easy to adjust and operate.

Converting from Drainage to Subirrigation

Subsurface drain spacings for subirrigation usually are 30% closer than those for drainage only. Retrofitting an existing subsurface drainage system for subirrigation may be possible in some cases by installing additional drains between existing lateral drains, water control structures and a pumping system. Extra mains are often required when laterals run upslope.

Management

Management is a very important aspect for water table management to be successful, and time requirements by the manager may be high. Until the operator or manager has gained much hands-on experience and is well acquainted with how the system works, daily monitoring of the water table both over and between the drains may be necessary. Automated water level controllers reduce time inputs, but are more costly. Raising the water table four feet in a sandy loam soil with drains 60 feet apart could take 3 to 5 days. Times would be longer for silt loam and clay soils.

Design

Information usually needed for a properly designed subirrigation system includes soil properties, topography, water supply, power supply, existing drainage specifications, crops to be grown, time available for system operation and management, and other information. The designer will determine the layout of the system, the depth and spacing of the drains, the pumping plant capacity, and the size and location of water control structures. The slope, hydraulic gradeline, and the size of drains must be determined for both subsurface drainage and subirrigation. An important final part of the design process is the economic analysis.

Potential Problems when using Subirrigation

The system operator or manager should be well aware of several potential problem that may occur with subirrigation. Sudden heavy rains during the irrigation mode may flood the crop root zone, especially if the weir setting in the water control structure is high (and thus a high water table in the field). When there is a high water table, there will be less water storage available in the soil. This problem may be solved by careful on-site management. The operator or manager should review weather patterns, and if possible allow time for the soil to partially drain before a rain occurs. This will help create some storage capacity in the soil for the expected rain.

Another major problem may be creating and maintaining a level water table throughout the field. This is especially true in soils with low lateral hydraulic conductivity, such as clays. Problems also exist in soils that lack an adequate restrictive layer below the drain depth. Careful site evaluation is very important before proceeding with design and construction.

Summary

There are a variety of water table management practices and strategies that can be used by agricultural producers and land managers to manage agricultural drainage waters in Ohio. Proper management of Ohio's agricultural drainage waters has important consequences for agricultural productivity and profitability, and for environmental quality. The purpose of this publication is to provide the reader who is knowledgeable about agricultural drainage with a better understanding of how drainage waters can be managed to help balance production and environmental goals.

Over all the factors that are important to be evaluated before deciding to install a subirigation system, the two most important are the soil and the water supply. If the soil is not capable of responding to subirrigation, or if there is not a reliable and sufficient water supply available, then the potential for success with subirrigation is greatly reduced. Other options should be evaluated.

Current Water Table Management Research in Ohio

Numerous research and Extension personnel in the College of Food, Agricultural and Environmental Sciences at Ohio State University are actively involved in various aspects of water table management research and demonstration throughout the State. Much of this work is conducted cooperatively with a number of local, state, and federal agencies, agricultural, environmental, and industrial organizations, and other university personnel. A few of the more interesting plot and field studies and their location by county are listed below.

- Subirrigation of corn and soybean - Northwest Branch Station of the Ohio Agricultural Research and Development Center (OARDC), Wood County
- Subirrigation of corn and soybean - Wooster Branch Station of OARDC, Wayne County
- Subsurface drainage, tillage, and rotation for corn and soybean - Northwest Branch Station of OARDC, Wood County
- Subirrigation and seasonal wetland for corn and soybean production and nitrate remediation - Piketon Research and Extension Center (PREC), Pike County
- Subirrigation, constructed wetand, and water supply reservoir for corn and soybean production - Demonstration farms in Defiance County (Defiance Agricultural Research Association), Fulton County (Shininger farm), and Van Wert County (Farm Focus)
- Subsurface drainage and micro-irrigation for blueberry - PREC, Pike County
- Controlled drainage for corn and soybean - Demonstration farms in Union County
- Controlled drainage for corn and soybean - PREC, Pike County
- Subsurface drainage, controlled drainage, and micro-irrigation for pepper and melon - PREC, Pike County

Where to get Information

For more information about water table management in general, or the projects listed above, please contact any of the authors of this publication. Dr. Brown can be reached through the internet address Brown.59@osu.edu .

Bibliography

Agricultural Drainage and Subirrigation Systems: Designing Systems for Production and Environmental Balance. 1993. L.C. Brown (compiler). 1993 Overholt Drainage School Reference Notebook. Department of Food, Agric., and Biol. Engineering. Ohio State University.

Controlled Drainage Management Guidelines for Improving Drainage Water Quality. 1991. R.O. Evans, J.W. Gilliam and R.W. Skaggs. Pub. AG-433. North Carolina State University Agricultural Extension Service. 16 pp.

Drainage and Water Table Control. 1992. Proc. 6th Int'l Drainage Symp. ASAE Pub. 13-92. 501 pp.

Drainage and Water Quality in Great Lakes and CornBelt States. 1995. N.R. Fausey, L.C. Brown, H.W. Belcher and R.S. Kanwar. ASCE J. Irr. and Dra. 121(4):283-288.

Economics of Controlled Drainage and Subirrigation Systems. 1988. R.O. Evans, R.W. Skaggs and R.E. Sneed. Pub. AG-397. North Carolina State University Agricultural Extension Service. 18 pp.

Farm Drainage in the United States: History, Status and Prospects. 1987. USDA-ERS. Misc. Pub. No. 1455. Washington, D.C.

Guidelines for Operating Subirrigation Systems for Water Quality Benefit (Corn, Soybeans and Sugar Beets). 1991. H.W. Belcher. AEIS No. 584. Michigan State University Cooperative Extension Service. 2 pp.

Learning to Manage Controlled Drainage. 1991. Agri-Book/Drainage Contractor 17(2):6.

Operating Controlled Drainage and Subirrigation Systems. 1985. R.O. Evans and R.W. Skaggs. Pub. AG-356. North Carolina State University Agricultural Extension Service. 11 pp.

Operation of Controlled Drainage Systems to Improve Drainage Water Quality. 1995. ASAE Engineering Practice: ASAE EP X507 (draft engineering practice standard).

Overhead Irrigation vs. Subirrigation. 1991. H.W. Belcher. AEIS No. 580. Michigan State University Cooperative Extension Service. 3 pp.

Practice Aspects of Controlled Drainage. 1949. R.E. Morris. Agric. Engr. 30(6):280-283.

SI-DESIGN. Computer Model to Assist with Subirrigation System Design. Version 2.0, September, 1992. Reference Manual. Michigan State University Cooperative Extension Service. 44 pp.

Soil and Water Conservation Engineering. 1993. G.O. Schwab, D.D. Fangmeier, W.J. Elliot and R.K. Frevert. John Wiley and Sons. 507 pp.

Subirrigation. 1984. B.H. Nolte, M.L. Palmer and G.O. Schwab. AEX 309. Ohio State University Extension. 2 pp.

Subirrigation and Controlled Drainage. 1995. H.W. Belcher and F.M. D'Itri (Eds.). Lewis Publishers. 482 pp.

Subirrigation: Irrigation and Drainage Through the Same Underground Pipe. 1991. H.W. Belcher. AEIS No. 579. Michigan State University Cooperative Extension Service. 4 pp.

Subirrigation in the Midwest. 1987. B.H. Nolte, R.Z. Wheaton, C.J.W. Drablos and T. Loudon. L-365. Ohio State University Extension.

Understanding Agricultural Drainage. 1996. L.C. Brown and A.D. Ward. AEX 320. Ohio State University Extension. 4 pp.

Water Supplies for Subirrigation. 1987. R.O. Evans, R.E. Sneed and R.W. Skaggs. Pub. AG-389. North Carolina State University Agricultural Extension Service. 13 pp.

Water Table Management Effects on Water Quality and Productivity. 1993. Tidewater Research Station, Plymouth, NC. North Carolina State University.

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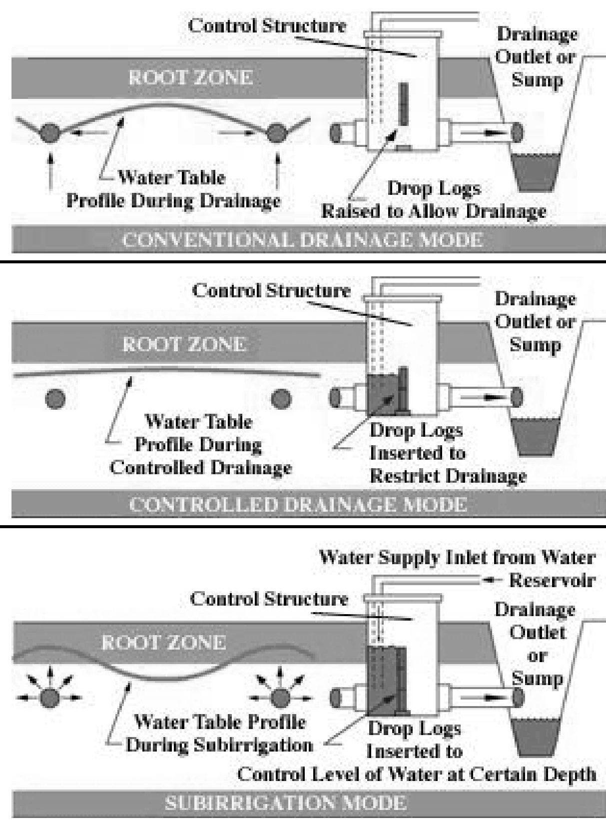

Figure 1. Three water table management practices: a) conventional subsurface drainage, b) controlled drainage, and c) subirrigation.

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TDD No. 800-589-8292 (Ohio only) or 614-292-1868

Agricultural Drainage Water Management Systems for Improving Water Quality and Increasing Crop Production

Introduction

Drainage water management can improve water quality and increase crop production. The purpose of an agricultural drainage water management system (ADMS) is to allow for the adjustment of the water table, minimize drainage during times of the year when drainage requirements are reduced, and provide for adequate drainage when needed most. Management of drainage water can provide environmental benefits by reducing the quantity of nutrient enriched drainage water leaving fields, and can provide production benefits by extending the period of time when soil water is available to plants. Water management structures are installed in strategic locations on a field drainage system that provide points of management for the operator. This fact sheet identifies published materials describing agricultural drainage and provides some key considerations for planning and designing a surface, subsurface, or combination surface and subsurface ADMS.

Publications

Agricultural drainage guides are published by both the Cooperative State Research, Education, and Extension Service (CSREES) and by Natural Resources Conservation Service (NRCS). Guides published at the national level provide information for the design, operation, and maintenance of various types of drainage systems. State and local guides provide specific information that address local conditions such as unique soils, local agronomic practices, as well as important legal information regarding regulations, easements, necessary permits, and discharge regulations.

Local CSREES offices and NRCS offices should be contacted concerning the availability of local and state drainage guides. Sources and contents of national publications that deal with drainage design and management are listed below.

The National Handbook of Conservation Practices (NHCP) Practice Standard 544, Drainage Water Management, contains information on why and where the practice is applied, and sets forth the minimum technical criteria that must be met during the application of that practice in order to achieve intended purposes. National conservation practice standards are adapted locally to include State and local criteria. The conservation practice standard developed for the county or parish in which you are working should be used to plan, design or install a conservation practice. This standard can be found in Section IV of the Electronic Field Office Technical Guide (eFOTG) at <http://www.nrcs.usda.gov/technical/efotg/>. If this standard is not available in the eFOTG, you should contact the NRCS State Office <http://www.nrcs.usda.gov/about/organization/regions.html#state>, or a local USDA Service Center <http://offices.usda.gov/>. Additional information, such as construction specifications and job sheets, may also be available from the eFOTG web site or the local NRCS office.

National Engineering Handbook, Part 650, Engineering Field Handbook, Chapter 14, Water Management (Drainage) provides comprehensive guidance for the planning and implementation of surface and subsurface drainage systems for agricultural land. Chapter 14 may be found at <ftp://ftp.wcc.nrcs.usda.gov/water_mgt/EFH&NEH_Drainage_Chapters/EFH14.pdf>.

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. It is similar to Part 650 Chapter 14, but with a greater emphasis on water table control. Chapter 10 may be found at <ftp://ftp.wcc.nrcs.usda.gov/water_mgt/EFH&NEH_Drainage_Chapters/neh624_10.pdf>.

Where to Apply the Practice

Agricultural drainage is accomplished by a system of surface ditches, subsurface conduits, or by a combination of surface and subsurface components. Drainage systems collect and convey water from fields. Drainage water management can be applied on drained fields where outflows from the drains can be controlled. Some older systems and many newer systems can be adapted to allow for the management of drainage water. Management of drainage water is most effective on systems with pattern drainage, but some systems with random drains can also achieve benefits. If the existing drainage system needs extensive repair or is otherwise not functioning properly it may be necessary to install a new drainage system. When replacing an older drainage system with a new system, make the older system inoperable or incorporate its operation into the new system to avoid undesirable interactions between the two systems. Even where drainage water management is not a goal for new systems, consider planning for future conversion to a managed system.

The topography should be relatively uniform, and flat to gently sloping within a management unit or zone. Non-uniform water table depths can lead to non-uniform crop growth that complicates management decisions. Slopes of 1% or less are recommended. Water management structures should be placed every 1' to 1.5' change in elevation along the drainage ditch or conduit. As the slope increases, more water management structures are required and economic factors and erosion concerns begin to detract from the benefits of the ADMS. A way to minimize the number of water management structures is to install the drains along the contour. Structures should be located on main lines that serve a number of laterals in order to minimize the total number of structures required.

Some agricultural drainage systems are part of a network involving multiple landowners. In such situations, managing a drain on one field can have an adverse impact on operations of adjoining properties. Even without interconnected drainage systems, the impacts of ADMS should be evaluated with respect to adjoining fields.

Water Management Structures

Retro-fitting an existing subsurface drainage system involves the installation of water management structures. The management mechanism on the structures may be flash boards, gates, valves, risers, and pipes. Flash board risers allow flexibility in manual management of the drainage water. Flashboard type risers can be full-round pipe risers or half-round pipe risers. The full-round risers are used when the control structure is located within the field, while half-round risers are used at the outlet. Gates or valves can be used to temporally stop the flow through the drain, or may be used in such a way that there is a low water table when the gate is opened, and a raised water table when the gate is closed. Gate or valve structures are sometimes automated.

The riser should be large enough to maintain the cross-sectional area of flow from the drain and the length of the flashboard should compensate for the transition from pipe flow to weir flow. It has been a common practice to make the length of the weir a minimum of 1.3 times the diameter of the drain in rectangular risers and 1.7 times the diameter of the drain in circular risers. It is important to size the riser large enough for the easy removal and placement of flash boards. Flashboards made of wood can swell when wet and become difficult to remove. It may be more convenient to remove these boards with a chainsaw and replace them with new flashboards.

Water management structures that are not automated must be easily accessible and clearly visible for safety purposes so they are not damaged during field operations. The drainage conduit should be non-perforated within 20 feet of a control structure. Small amounts of seepage at the control structure are usually not a problem. Providing the materials are resistant to damage from ultraviolet light, plastic risers are acceptable except where there is danger of fire, or where they may be damaged by freezing of water surrounding the riser.

Impacts of Drainage Water Management

Drainage water management can have a significant impact on the transport of nitrogen, phosphorous and sediment to surface waters and on crop production. Lowering the water table increases the amount of water passing through the soil. Nitrates and soluble phosphorous move with the drainage water and are transported to the drainage outlets. A lower water table also reduces the frequency and magnitude of surface runoff, and thereby reduces the erosion potential, sediment transport, and the transport of sediment-adsorbed phosphorus. The aerobic conditions created in drained soils decrease the occurrence of denitrification.

Raising the water table decreases the amount of water passing through the soil, and proportionally decreases the transport of nitrates and soluble phosphorous from the field. Raising the water table during the non-growing season can result in a 30% reduction in the discharge of nitrates, but reductions of 50% or greater have often been accomplished. Raising the water table can also increase the amount of surface runoff, leading to increased erosion, sediment transport and transport of sediment-adsorbed phosphorous. Erosion and sediment transport can be controlled with residue management, buffers, grassed waterways, and other conservation practices. Anaerobic conditions created in saturated soils increases the occurrence of denitrification, further reducing nitrate-nitrogen in the drainage water

Lowering the water table improves field trafficability and timeliness of crop management operations such as field preparation, planting, and harvesting, and can extend the growing season by allowing earlier access to the field. With a low water table, ponding is less likely to occur or to be sustained when it does occur. A lower water table results in aerobic soil conditions and an increased depth of the root zone. Partially raising the water table after crops are established can conserve soil moisture and may enable a crop to be more productive in the years where there is an extended dry period during the growing season.

A Basic Recommended Strategy

A drainage system infrastructure that enables the operator to manage the water table provides an opportunity to take advantage of the benefits of both high and low water tables. Deciding when to raise or lower a water table can be a difficult decision, particularly when rainfall is uncertain. As with many other practices, more intensive and careful management creates a potential for achieving greater advantages from the system.

In absence of a detailed analysis, there are some basic strategies that can be employed to greatly improve the functionality and benefits of the system. A high water table in the winter months will decrease the transport of nitrates and soluble phosphorus to surface waters. The water table should be lowered in the spring early enough for the field to be accessible for seedbed preparation, planting, and other field operations. Lowering the water table two weeks before field operations in the spring is generally sufficient.

After planting, the water table can be raised to conserve soil moisture for use by the crop during extended dry periods. Once the crop is established, evapotranspiration will often be sufficient to remove excess water from the root zone. It may be necessary to lower the water table during extended wet periods. Careful attention to drainage water management for water conservation may increase yields, particularly in dry years.

In addition to drainage water management, soil, crop, and nutrient management should be a part of a plan to improve water quality in agricultural areas. Nutrient management practices should follow state and local recommendations and NRCS practice standards. Nutrient management applied in conjunction with drainage management can help maximize the effectiveness of both practices.

Field Scale Monitoring

Monitoring of water table elevations can be accomplished by observing water depths in the water management structures, but in many instances it is better to monitor the water table by establishing monitoring wells in the field. A monitoring well can consist of a perforated PVC pipe that extends below the water table with a measuring rod attached to a float. Other methods for reading water depths include a chalked tape or a string and bobber. Monitoring wells can be located near the edge of the field, where they are easier to monitor and where they are protected from agricultural equipment, but for more representative readings, they should be located farther within the field. Monitoring wells placed between drain lines are more representative of the entire field than those placed directly over a drain line. When they are located in the field they need to be clearly marked and protected from damage by farming operations and livestock. The top of the riser and the measuring rod should be higher than the anticipated crop height during the monitoring periods. In colder climates the monitoring wells may not function over the winter months due to freezing. It may not be necessary to maintain the monitoring wells once the relationship between the water table elevation in the field and the depth of water in the control structure is understood.

USDA NRCS
United States Department of Agriculture
Natural Resources Conservation Service
Conservation Beyond Boundaries

Drainage Water Management

October 2011

Trempealeau Bluffs in the Upper Mississippi River Basin.

Overview

The drained farmlands in the Upper Mississippi River Basin have been identified as a contributor to nutrient loading of receiving waters, that often leads to adverse environmental and economic consequences.

The Natural Resources Conservation Service (NRCS) will focus resources to assist in voluntary conservation efforts to reduce nitrates leaving drained farmlands in Illinois, Indiana, Iowa, Minnesota, Missouri, and Ohio.

The NRCS will work in close collaboration with partners to develop and implement an action plan that will provide incentives to producers that voluntarily apply nutrient and water management practices to reduce nitrate loading.

A June 2010 draft report, "Assessment of the Effects of Conservation Practices on Cultivated Cropland in the Upper Mississippi River Basin," showed that between 2003 and 2006 conservation practices reduced total nitrogen losses from cropland in the basin by 18 percent, sediment losses from fields by 69 percent, and nitrogen losses in surface waters by 46 percent. The study was conducted by NRCS as part of its Conservation Effects Assessment Project to estimate conservation benefits at national and regional levels.

However, the report also revealed that nitrogen losses in subsurface water were reduced by just 5 percent, identifying the need for comprehensive conservation planning throughout the basin and the expansion of agricultural drainage water management to increase benefits to the environment.

As part of the action plan, NRCS will examine how drainage water management is being used in the basin, identify barriers to adoption, and document lessons learned by drainage water management users. From this information, a team will make recommendations to increase the adoption of drainage water management.

A group comprised of 17 technical specialists from NRCS will then focus on broader conservation priorities in both the Upper Mississippi River and Great Lakes basin states of Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, South Dakota, and Wisconsin. With input from many agricultural and conservation partners, NRCS will address two near-term major priorities: developing an action plan and holding a national summit.

Priorities

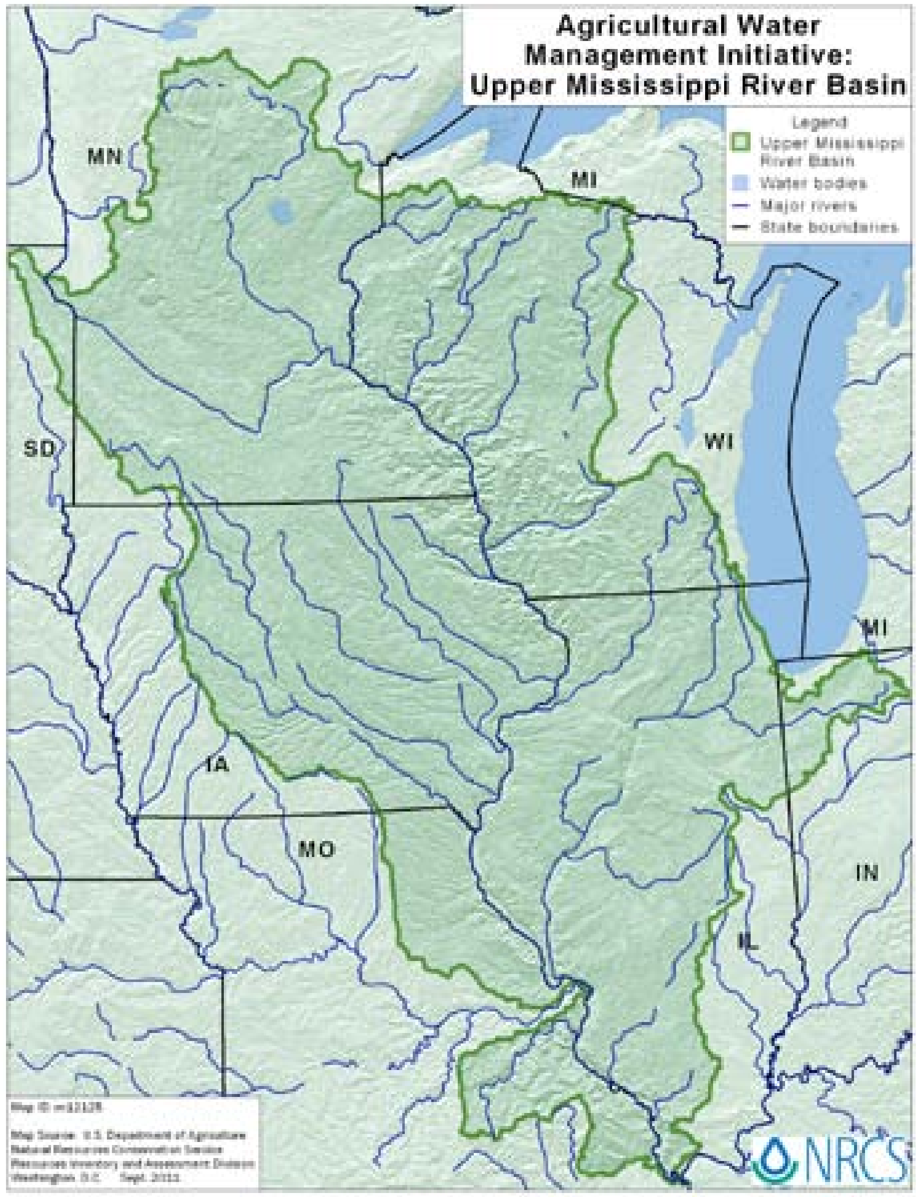
- Encourage producers to manage water in existing tile and surface drainage systems for environmental benefits
- Evaluate recommenda-tions for feasibility and priority
- Develop and implement the NRCS action plan with partner input and involvement
- Stimulate innovation and creativity
- Evaluate progress, performance and outcomes
- Practice "adaptive management"
- Encourage producers to adopt voluntary, incentive based conservation practices.

Expected Outcome

The outcome anticipated from this effort is an increase in the adoption of drainage water management and its associated conservation practices to achieve diverse environmental benefits in the Upper Mississippi River Basin.

More Information

For more information and updates about the Drainage Water Management Initiative in the Upper Mississippi River Basin and other NRCS conservation efforts, please visit the NRCS Web site, www.nrcs.usda.gov, or contact your local NRCS office.



The Concept Defined...

For years, talk of the Gulf's "Dead Zone" pinned a large portion of ecological blame on ag production in the Midwest.

For decades though, thousands of conservation farms with sloping and steep ground diligently used conservation practices and techniques to reduce soil erosion, minimize nutrient loads, and improve water quality.

Here now is a way for producers with essentially flat ground (.5 or 1% and flatter) to join the fight against excess Nitrate runoff and use this new water quality solution on the farm.

It's called Drainage Water Management, or "DWM" for short—and it's an NRCS approved conservation engineering practice that eligible landowners can receive technical & financial assistance to install through the Environmental Quality Incentives Program (EQIP).

DWM works in Illinois. It improves water quality and it may increase crop production as well.

Sound like an option for your operation? Call your local NRCS office or visit www.il.nrcs.usda.gov to learn more.

USDA NRCS
United States Department of Agriculture
Natural Resources Conservation Service

Helping People Help The Land.
USDA is an equal opportunity employer and provider.

Illinois
September 2011

Water & Drainage...

Ag producers know how water works—there's either too much of it or not enough. They need a way to control water; to fine-tune water delivery on THEIR terms.

Drainage Water Management holds water in root zones when crops need it and drains it when there's too much. Simple.

It might be time to consider adding Drainage Water Management to your operation. Talk to NRCS today. See how well DWM techniques could work for you!

DWM Benefits...

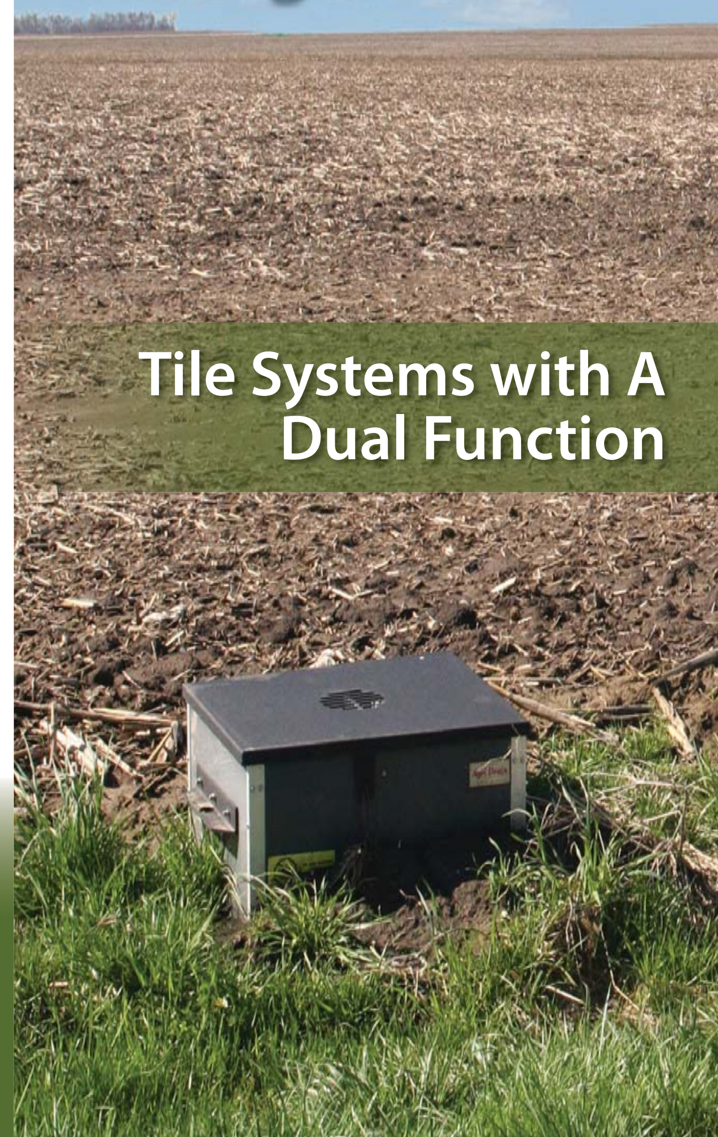
- Reduce loading of nutrient pathogens and/or pesticides into the drainage system and off the farm
- Improve plant/crop productivity & profitability
- Reduce oxidation of soil organic matter
- Provide seasonal wildlife habitat
- Prevent leaking of manure into tile drains during land application by raising riser boards.

Make drainage tiles work BOTH ways: take excess water off or hold it back for later.

USDA NRCS
United States Department of Agriculture
Natural Resources Conservation Service

Drainage Water Management

Tile Systems with A Dual Function



Looking Back....

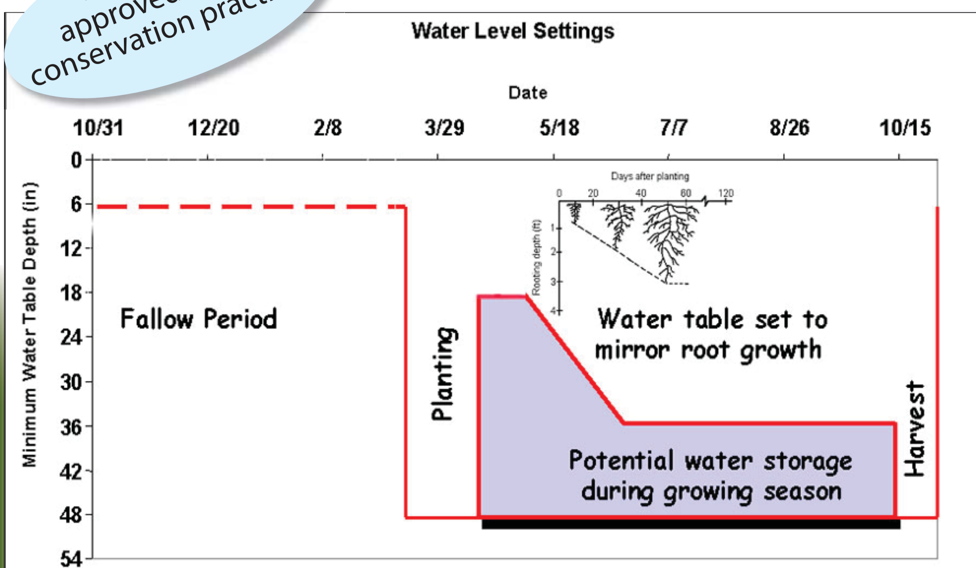
Historically, subsurface tile drainage made profitable crop production possible here on Illinois' flat landscape. One unwanted byproduct of this process is excess nutrients—nitrates and phosphorous—that ultimately enter creeks and streams through tile drain water and negatively impact the environment.

The Big Question...

How can we better use existing tile lines in a way that makes them part of the ***solution*** and not part of the ***problem***?

According to the Natural Resources Conservation Service (NRCS) and University researchers, agricultural producers can use concepts like Drainage Water Management, or DWM.

DWM is an approved NRCS conservation practice.



What is DWM?

DWM manages the timing and amount of water discharged from agricultural drainage systems. The process is based on the premise that identical drainage intensity is not required at all times during the year.

Water quality benefits are possible by minimizing unnecessary tile drainage and reducing nitrate amounts that leave farm fields. DWM systems can also retain water needed for late season crop production.

DWM systems work best on very flat ground—a fact that eliminates farms with steep or sloped ground. Even so, DWM still offers valuable options to many Illinois landowners.

These are the producers NRCS conservation specialists can assist by developing Drainage Water Management Plans.

Have local Illinois Contractors install DWM structures on your ground.

How Does It Work?

To make it possible for operators to truly manage water table levels, they simply retrofit an existing tile system with a **water control structure**. Each structure controls an elevation-defined area, based on lay of the land and the tile system layout already in place. Structures are small, reasonably priced, and operating instructions are fairly simple:

1. Before tillage, remove riser boards to drop water table levels about 10 days prior to planting fieldwork/operations.
2. During the growing season, stack riser boards to raise water table high enough to provide capillary water to crop root zone.
3. Before harvest, remove boards to lower water table 10 days before Fall fieldwork.
4. After harvest, raise water table up even further--near ground surface—to hold nutrients in the field/soil over winter.