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Thousands of acres of crop land in Michigan would produce higher yields if the soil were better drained. This wheel type trencher was used to install tile on the Saginaw Valley Bean and Beet Research Farm.

Tile Drainage for Improved Crop Production

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Excess soil water is a problem in crop production in Michigan. Plants need oxygen as well as water in the root zone. Excess soil water displaces air, thus causing oxygen deficiencies.

Tile drainage helps to remove excess water (gravitational or free) from the root zone of a crop. This is accomplished by installing drains in a subsoil—thus, the terms subsurface or profile drains. Such drains transfer excess water through a tile main to a location where it can be disposed of, and will do no damage or where it can be used or stored for later use.

There are approximately 1.5 million acres of land in Michigan that need draining, according to the Conservation Needs Inventory of the Soil Conservation Service. If tiled, most of this land would be improved for crop production. Much would be drained if producers fully appreciated the benefits of tile drainage.

This bulletin describes the needs, benefits and methods of tile drainage in Michigan from an agronomic (crop production) viewpoint. Engineering specifications have been reported in several publications, including the MSU Extension Bulletin "Recom-

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Figure 1. Edible dry beans grown on nearly level fields respond greatly to tile drainage. Notice the variable sized plants and the small area where the plants suffocated after a rain in this inadequately drained field.

mended Standards for Drainage of Michigan Soils." The legal aspects of drainage, especially as related to property rights and responsibilities, are summarized in MSU Extension publication "Drain Law for Michigan Land Owners."

Objectives of Tile Drainage

The major objectives of tile drainage are to 1) remove excess water from the plant root zone of a soil, 2) serve as an outlet for surface drains, and 3) dispose of water safely so that damage to soil and property does not occur.

All organic soils to be used for efficient crop production need tile drainage. Mineral soils with high water tables frequently respond to drainage, especially flat lands such as the lake plain or till plain areas of the state (Figure 1). Fine textured soils (loams, clay loams and clays with less than 60% clay) respond well. Crop yields produced on two-storied sandy soils that are underlain with fine textured material are usually improved.

Tile may be of value in lower areas of rolling land. Many producers benefit from tile that collect seepage water under grassed waterways, especially those that are relatively wide.

Benefits of Tile Drainage

The benefits of tile drainage are increased yields and quality. The return on investment in drainage is exceptionally high. Increased annual returns ranging from 21 to 46 percent have been reported by Purdue University.

Usually there is a "cumulative effect" from good practices that are possible after drainage. Crop yields often increase more than 50 percent when the producer takes advantage of the improved soil environment after removing gravitational (excess) water not directly available to plants.

Tile drainage increases the volume of soil explored by crop roots. This exposes roots to larger quantities of essential plant food and available water.

Adequately drained soil contains more air, oxygen being the important component. Oxygen diffuses approximately 10,000 times faster through large pore spaces in soil than through water. Satisfactorily drained soil warms faster in the spring because more heat is required to raise the temperature of water than soil material. Soil microorganisms, especially bacteria, respond to warmer temperatures and improved oxygen levels. Their increased numbers and activities improve soil structure. The microorganisms also increase the readily available plant nutrient levels, especially nitrogen and sulfur.

While tile drainage may cause sandy and organic soils to be more susceptible to wind erosion, it reduces erosion from water. Adequately drained soil has a greater capacity to absorb and hold rain water, resulting in less surface runoff and erosion.

Other benefits not directly related to yield are a reduction in time and labor in field operations. With early planted crops such as peas, oats, barley, sugarbeets, and corn, delayed planting usually results in decreased yields (Figure 2). Similarly, harvest delays increase losses and, on occasions, result in damage to grain or forage.

Tile Drainage and Crop Yields

While little research has been done in Michigan, it is clear that a great improvement in yield and quality is possible with tile drainage. Farmers' estimates of yield increases from tile drainage varied as reported by the Agricultural Economics Department. Average increases of 49, 50, 59, 62, 66, 77 percent were estimated by farmers for oats, corn, wheat, sugarbeets, alfalfa, and field beans, respectively. These values represent responses on level land in the Saginaw lake plain area. The increased yields were attributed to a combination of practices made possible after improved drainage.

Ohio State University reports an eight-year average increase of 100 percent in corn yields from tile alone with conventional tillage in northern Ohio.* With no-till methods, an 80 percent average increase in yield for four years was obtained on the same Toledo silty clay soil (soil management group 1c). Variation in yields from year to year was greatly reduced by tile drainage in this research. On the undrained soil, yields varied by 48 percent. With only tile drainage, yearly variations were reduced to 21 percent.

The soil was occasionally too wet to be planted to oats but later planted soybeans responded well to tile drainage with yield increases up to 46 bushels per acre reported. The undrained areas did not have harvestable yields.

*Schwab, F. O., *Tile or Surface Drainage for Ohio's Heavy Soils, Ohio Report, March-April 1976.*

Soils Responding to Tile Drainage

The soil survey map is the basis for locating and determining which soils respond. Some county maps are available from the local Soil Conservation District Office, the Cooperative Extension Office, or from the Department of Crop and Soil Sciences at Michigan State University. All farms in Michigan are located within a soil conservation district and all farmers can have the soils on their farm mapped in detail.

The maps outline the location and boundaries of different soils. Each soil is a member of a specific *soil management group* (SMG). This relationship is described in MSU Extension Bulletin E-1262, "Soil Management Units and Land Use Planning."

The SMG serves as the basis for predicting crop yield responses to tile. The opportunities for increasing crop yields from soils within each SMG are reported in Table 1. Because the need for tile drainage is regulated by some factors not closely related to natural soil conditions, care should be used in interpreting the information in Table 1.

The word "slight" in Table 1 means that under normal circumstances a yield response is not usually

TABLE 1. OPPORTUNITIES FOR INCREASING CROP YIELDS WITH TILE DRAINAGE.

		NATURAL DRAINAGE CLASS		
Dominant profile texture	Symbols	Well and moderately well drained a	Somewhat poorly drained b	Poorly and very poorly drained c
Fine clay, over 60% clay	0	Slight	Slight	Slight
Clay, 40–60%	1	Slight	Medium	Great
Clay loam and silty clay loam	1.5	Slight	Medium	Great
Loam and silt loam	2.5	Slight	Medium	Great
Sandy loam	3	Slight	Medium	Great
Loamy sand	4	Slight	Medium	Great
Sand	5	Slight	Medium	Great
Sandy loam 14–40 in. over clay	3/1	Slight	Medium	Great
Sandy loam 20–40 in. over loam to clay loam	3/2	Slight	Medium	Great
Sandy loam 20–40 in. over gravelly sand	3/5	Slight	Slight	Medium
Loamy sand 14–40 in. over clay	4/1	Slight	Medium	Great
Sand to loamy sand 20–40 in. over loam to clay loam	4/2	Slight	Slight	Medium
Sand to loamy sand 40–60 in. over loam to clay	5/2	Slight	Slight	Medium
Muck	M	—	—	Great

Figure 2. Early planted crops respond especially well to tile drainage. This compact soil contains more water than desirable. Tractor and plow wheels are in the furrow, deeply compacting the soil, thus slowing movement of gravitational water to the tile.

expected but that under specific conditions can be obtained. The word "great" means that a great yield response is normally expected such as was described in the Ohio research. Use the information in Table 1 to help evaluate the chance of significantly increasing crop yields with tile drainage.

Tile Drainage Systems

There are four common kinds of tile drainage systems used in Michigan: 1) the gridiron, 2) the herringbone, 3) the natural or random, and 4) the cutoff or interceptor system (Figure 3). The best system to use depends on topography and variability in soil conditions. In many large installations, a combination of two or more systems is effective.

The gridiron is well adapted to very flat land where tile lines are uniformly spaced and usually enter the main drain at right angles. The herringbone is used in relatively flat fields with the "backbone" or tile main located in the lowest part of the field with lateral drains on both sides. This system is not common in Michigan, and as normally laid out, leaves undrained areas.

The natural or random system is used where the two previously mentioned systems are not suitable. The natural system works well where the field does not need to be completely tiled. It is sufficiently flexible in design that drains are located where they are most needed such as wet waterways and small acreage depressions in rolling fields. The natural system tile line also serves as a convenient outlet for a surface drainage system with the use of surface or drop inlets in ponded areas.

The cutoff or interceptor system is sometimes used with the natural system where there are springs or seep areas. Such drains should be graded off from the contour and located to intercept seepage water that moves on top of a tight soil layer. It is important to use the system that meets the need.

Movement of Water Into Tile Drains

Gravity moves excess soil water downward in the soil. In clay or concrete tile, water enters the system in the open joint area between the individual tile sections. Tile are spaced 1/8 to 1/4 inch apart, depending upon soil texture. Corrugated plastic tubing contain holes or slits for water entry and average about 24 per foot or 1.5 square inches of opening per foot of drain.

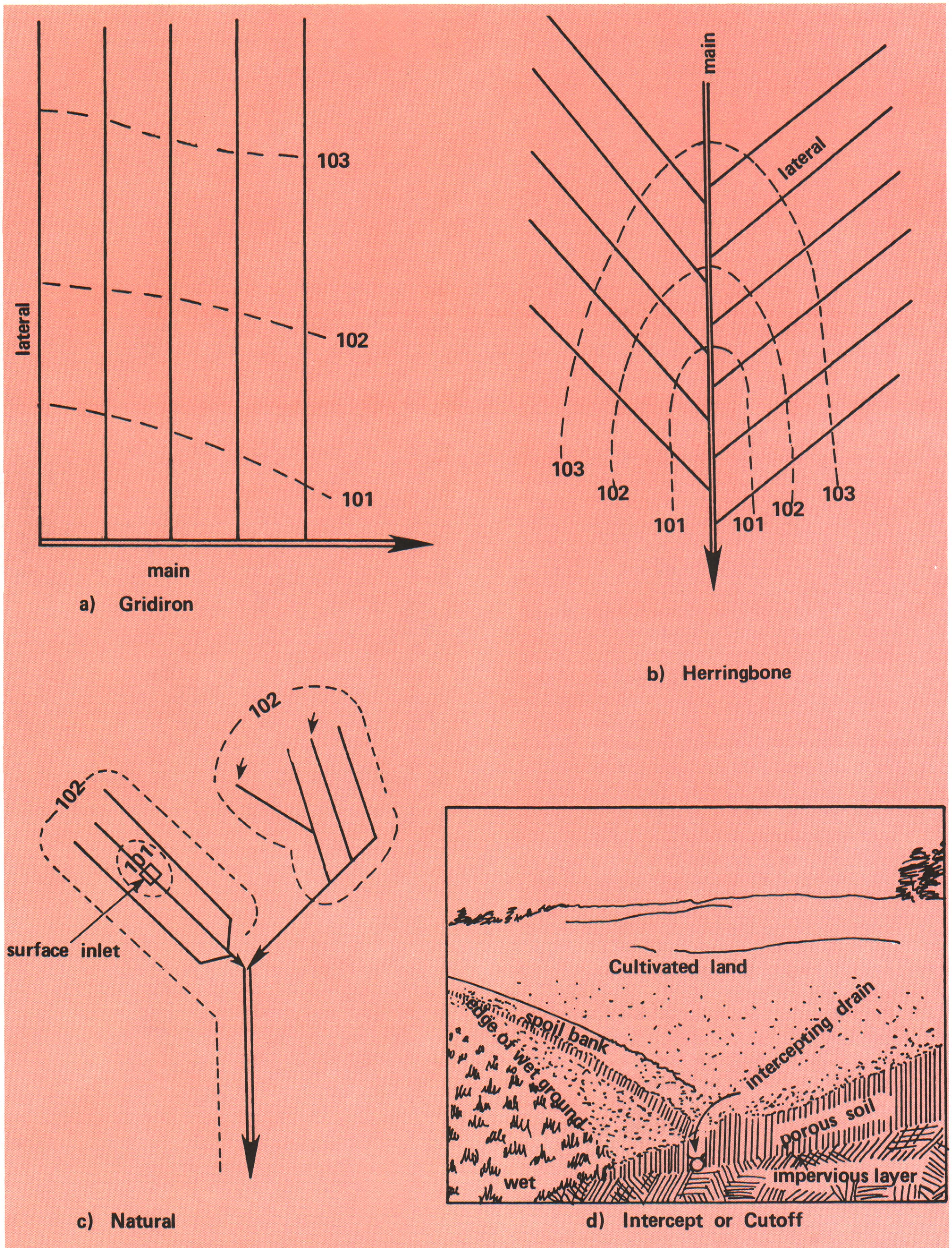

FIGURE 3. COMMON LAYOUT OF THE TILE DRAINAGE SYSTEMS

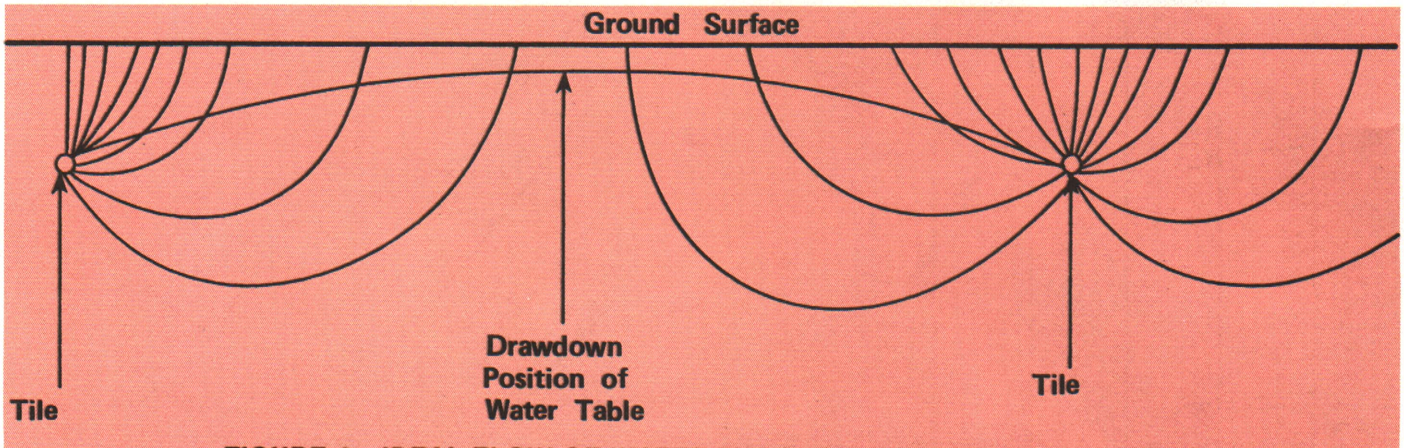

FIGURE 4. IDEAL FLOW OF WATER THROUGH A UNIFORM SOIL AND WATER TABLE DRAWDOWN POSITION BETWEEN TWO TILE LATERALS.

Figure 4 shows how water moves in a uniform soil to the system. The flow lines are drawn so that the quantity of water moving along any line is similar. Thus, more water is removed from the soil near the tile than from some distance away. After draining for a day or two, the amount of free water in soil directly over the drains is less than the amount half way between the tile lines.

Figure 5 illustrates the combined effect of evaporation from the soil's surface and the rate of water movement into the tile on water loss. To do this, the rate of oxygen movement into the soil under actual field conditions in Saginaw County on a Sims sandy clay loam soil (SMG 1.5c) was evaluated. This was measured with an artificial root (platinum microelectrode) as illustrated in Figure 5, which also depicts an undrained and a tile-drained soil. Notice the short distance between the soil air and the microelectrodes or the root in the drained soil. The total supply of oxygen is greater and the distance that the oxygen needs to move to get to the root is shorter in the drained soil.

The information in Figure 6 is from the same research project. Again, oxygen movement through the soil is used as an index of water movement into tile drains. The four-inch spring rain on dry soil rapidly filled the soil pores with water which displaced the air. An oxygen deficiency developed and existed for only one day followed by five days with an adequate oxygen supply. As the water moved into tile and as some evaporated, a relatively light rain of only one inch occurred and an oxygen deficiency rapidly developed which lasted for two days. Thus, if the soil is relatively wet when a light rain occurs, an oxygen deficiency, caused by excess water, can quickly reoccur.

Figure 7 shows a case study of oxygen levels as related to tile drainage. On April 19 the soil in the en-

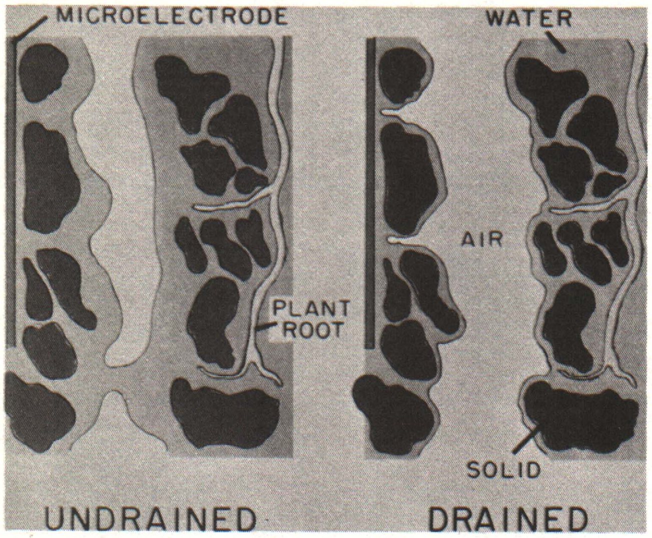

Figure 5. Diagram of air space in drained and undrained soil. The microelectrode is an artificial root used to measure oxygen diffusion rates. Notice that the distance the oxygen has to move to the roots is much shorter in the drained soil than in the undrained.

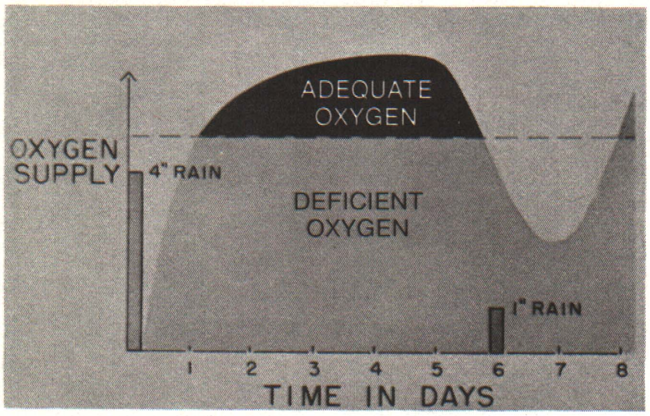

Figure 6. Oxygen availability of a tile drained Sims sandy clay loam as affected by spring rains.

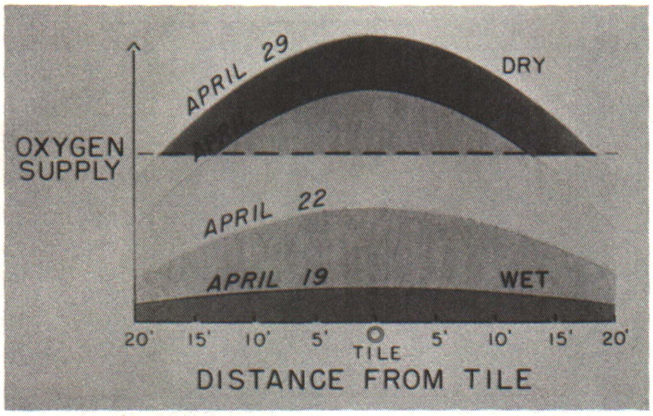

Figure 7. Oxygen availability in surface soil of a tiled drained Sims sandy clay loan as related to time and distance from tile.

tire field was wet and oxygen deficient and water was rapidly moving to the tile. Three days later, on April 22, the soil was still too wet to support plant growth or farm equipment. The surface of the entire field continued to appear wet.

By April 27, the area over the tile and approximately 15 feet on each side of the tile appeared to be dry. Measurements of oxygen diffusion rates showed that there was ample oxygen in the soil over the tile but not half way between the tile lines. This was still the case two days later, April 29, but the width of the band of wet soil (oxygen deficient) between the tile lines had been greatly reduced. It was now a very narrow band halfway between the tile lines. These data illustrate how tile dry the soil and why it may be possible to start field operations ten days to two weeks earlier in the spring on tiled land.

Tile Drainage Vs. A Complete Drainage System

This bulletin considers only tile drainage which is but one part of a *complete drainage system*. Sometimes, only tile are needed, other times only surface drainage. Usually, the two systems working together produce the best results.

This is illustrated with Ohio data for 8 years on conventional tillage plots. The combination of tile plus surface drainage increased corn yields an average of 6 bushels per acre per year over the tile-only system. Average yields with the complete drainage system were increased 56 bu/acre/year over yields produced on the undrained soil.

On the no-tillage plots, average yields on the complete drainage area were 19 bushels per acre higher than on the tile only plots. The complete drainage areas yielded 47 bushels per acre more than the undrained areas.

The explanation for the extra yield from the total drainage system is related to the fact that water removed with surface drains does not need to move down through the soil. Therefore, the soil dries more rapidly and field operations are more likely to be timely.

For information on surface drainage, refer to MSU Extension Bulletin E-1295, "Surface Drainage for Improved Crop Production."

Installation Considerations

For tile drain systems to function properly, they must be correctly designed and installed.

Kinds of Tile

There are several kinds of field drain tile. The best are 1) strong enough to support both static (soil weight) and impact (farm equipment) loads, 2) resistant to weathering 3) resistant to water absorption, 4) resistant to damage by freezing, thawing and soil chemicals, 5) uniform in shape, size and thickness of the wall, and 6) free from defects such as ragged ends or cracks.

Clay and concrete tile are standard lengths (12 inches) in the smaller sizes while pipe or tube made of steel or plastic are variable lengths. Good concrete tile are known to be very resistant to freezing and thawing but may be short lived if the proper ASTM* "grade" is not selected for exposure in acid or alkali soils.

Corrugated plastic tubing is used with increasing frequency in Michigan because of lower handling and installation costs. Other advantages include better alignment in unstable soils and the ease of handling in soft soil. Corrugated plastic tubing (4-inch) weighs approximately 1/25th that of clay tile of the same size and averages from 72 to 85 pounds per 250 feet of 4-inch tubing (Figure 8).

Disadvantages of corrugated plastic tubing: 1) reduced strength at high temperature, 2) reduced flexibility at low temperature, 3) reduced strength by stretching which may occur during installation, and 4) tendency to float in shallow depths of water. Under such circumstances it is necessary to hold the tubing in place and cover immediately.

Size of Tile

The best size of tile depends upon the size and characteristics of the area to be drained and the requirements of the crops to be grown. Remember, water flows more slowly through corrugated plastic tubing than through the same diameter smooth concrete and clay. On the average, small diameter cor-

**ASTM—American Society for Testing and Materials*

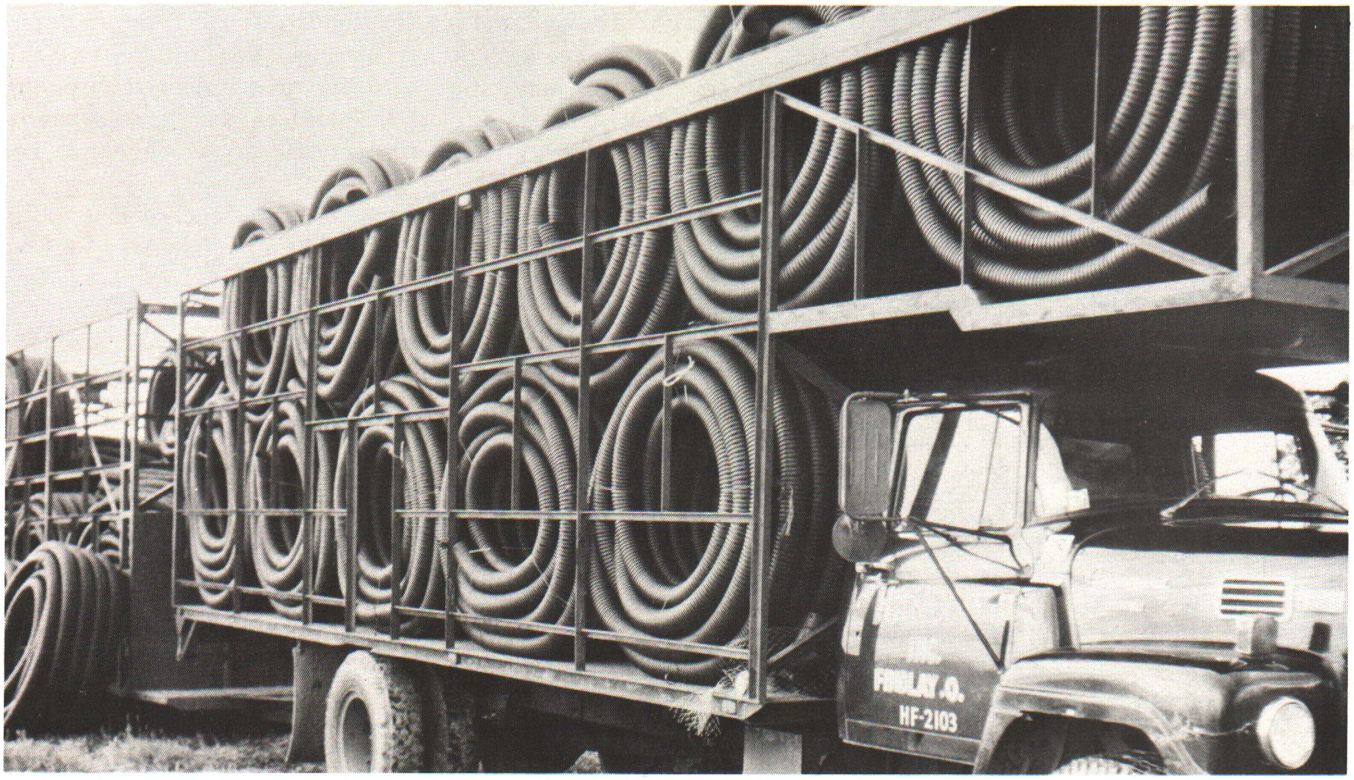

Figure 8. Corrugated plastic tubing is a popular material because of its light weight and lower handling and installation costs.

rugated pipe, when full, carries about 75 percent as much water as well aligned concrete or clay tile.

Unless you have had some experience with tile drains and are knowledgeable about soil variability, it is best to have a drainage engineer determine the size of tile to use, especially when large areas are to be drained. The amateur may use tile mains that are much too small and will be disappointed in the rate of water removal. On the other hand, unnecessary expense is added to the total cost by using larger than necessary tile mains.

Depth of Tile

The depth to place tile applies only to laterals and has little relationship to mains and submains which are regulated primarily by elevation of the outlet and the topography of the drained area.

Variable soil conditions make it difficult to recommend depth for location of tiles.

Shallow drains are likely to be less effective than deep drains in soils that do not have tight subsoils. In general, tile should be located at a depth of more than two feet and are commonly placed at depths of 3 or 4 feet. Again, a drainage engineer can interpret soil conditions. Many farmers have been successful by arbitrarily placing graded tile lines at an average three-foot depth.

Spacing of Tile

A close relationship exists between tile spacing, depth of tile, and soil permeability. Where soil materials are uniform, the deeper the drains, the wider the spacing should be and vice versa. Closer spacings are used more in the fine-textured soils than in the coarser.

A spacing of three to four rods (one rod = 16.5 feet) is adequate for most field crops. Recently, two to three rod spacings have been used in fine textured soils. In some instances, fields have been retiled by locating new lines half way between the old. These closer spacings provide a more intensified drainage system and are beneficial where high value crops are grown.

Retiling between old lines is more evidence that many flat, naturally poor drained soils are being mechanically compacted during tillage and harvest. Spacings of two or three rods provide for a higher degree of drainage but should not be used as a substitute for other good soil management practices.

Grades of Tile Lines

A drainage engineer knows what is best for a specific situation. In general, a grade should be no less than 0.2 percent. Sediment accumulation occurs in some soils when free-running material is not excluded by filters, when grades are flatter than 0.1 percent.

Uniformity of grade is of major importance. Grades up to two or even three percent are not major problems provided the capacity of all points near the outlet is greater or at least equal to that of the tile some distance back of the outlet.

On occasion, relief pipes may be needed for periods of high water flow. Relief pipes are vertical risers which extend from the drain line to the surface of the soil. They prevent excessive pressure from building up which can cause a "blowout," particularly at the base of a slope where the grade flattens. Blowouts occur where there is sufficient pressure to force the water to surface.

Outlets

A tile system is no better than its outlet. Soil erosion and rodent entry are major problems at outlets. Use metal pipe with a flap gate or rodent guard. Where flood water may get above the level of the outlet, use a flood gate. A trained engineer knows what is necessary at the outlet and can assist with both design and installation.

A satisfactory outlet is not easily available in some areas. Sometimes, it is possible to use a pump to elevate the water to another ditch lying at a higher elevation. A drainage engineer can help plan and design the pumping plant and any needed dikes as an integral part of the drainage system.

Installation

Because of increased labor costs, tile are no longer installed by hand. Trenchers, either wheel or endless chain type, have been used. They make it possible to examine the trench as installations proceeds and to locate problem areas.

Envelope filters around the tile line filter material out of the water before it enters the tile. "Blinding" refers to the use of top soil, high in organic matter, that is backfilled onto and around the tile. Corncobs, screened cinders or other porous material have occasionally been used. The organic materials such as corncobs, sawdust or straw are generally less durable and therefore less satisfactory than mineral materials.

Recently, fabric filter wrappings on plastic tubing have become available. They seem to be effective, but there has been little or no research on how long they remain functional. Some soil scientists are concerned that the fabric filters might plug, making the tile ineffective.

The newest concept in plastic tubing installation is the mole plow which feeds the tubing into the soil to a predetermined grade (Figure 9). Using a laser beam for grade control, this method has resulted in more rapid and inexpensive installation.

Some agronomists and engineers, understanding how variable some soils are, are concerned that tile might unknowingly be located in "water sand." These non-cohesive sands and silts, which flow when water-saturated would eventually plug the tile. With trenching machines, the exact location of the sand is observable and special precautions can be taken. With the mole plow, this is not possible.

Costs of Tile Drainage

In calculating costs of a tile drainage system, it is necessary to recognize the design and engineering costs as well as those for the tile and installation. Engineering and supervision costs vary from five to ten percent of the total. It is not unusual for installation costs to exceed $400 per acre. This may seem high but in reality is low when considering acre values of crops over a period of years. To substantiate this statement, consider the Ohio data, previously discussed, where costs were recovered in 5 years.

Figure 9. The mole plow is now used extensively to "plow in" to the soil corrugated plastic tubing. There are many advantages to this method, and some concern because the trench is not observed; hence presence of fine sands and silts cannot be detected until the tiles fill and stop drainage.

Maintenance and Troubleshooting

Inadequate outlets and failure to discover problems and thereby make timely repairs are the major maintenance problems on most farms. Well designed and installed drainage systems require very little expense and time in maintenance. The most common problems include:

1) **Roots** from deep rooted crops such as alfalfa or sugarbeets and from perennial brush and trees may grow into the tile and obstruct the water flow, especially if the tile are fed by springs that continue to flow through the summer. A good rule of thumb to follow is not to allow brush and trees to grow within 100 feet of the tile.

2) **Silt and fine or medium sand** on occasions may plug a line. This occurs when soil conditions have not been properly evaluated before installation or when clay or concrete tile have gotten out of alignment, as sometimes occurs on organic soils.

3) **Iron** and **manganese** are reported on occasions to precipitate in tile joints or openings, thus sealing the drains so that they no longer receive gravitational water.

4) **Blowouts** occur when sufficient pressure builds up in a drainage line to force the water to the surface of the soil. Plugging is the most common cause of a blowout and has been observed in "do-it-yourself" systems where a change in grade occurred.

5) **Broken concrete** or clay tile or deformed plastic tubes are occasionally a problem in deeply tilled fields. Use subsoilers and chisel plows with care and come no closer than 12 inches from the tile.

Concrete tile installed years ago in acid soils have broken. It is not known whether the tile were of inferior quality or soil acids caused the breakdown. Numerous examples of water not entering tile or moving slowly to tile have been seen recently. Invariably, these are linked to field operations on wet soil. Some soils are so compact that water moves very slowly into a subsurface drain system.

A detailed field map of the tile location and characteristics is of value in troubleshooting. Such a map should be made and filed when fields are drained or when modifications of drainage systems are made. An alternative to the map is an aerial photo taken a short time after the drainage job is completed. However, when the laterals are plowed in, there is an absence of mixed soil colors which identify the tile line location on an aerial photo.

Summary

This bulletin deals primarily with the agronomic aspects of tile drainage. Consult other references on engineering and legal considerations before taking action to improve drainage on your farm.

Too much or too little water are problems that occur every year in Michigan. Disposing of excess water, whether by means of surface drainage, subsoil drainage or a complete drainage system, is primarily an engineering problem. Therefore, to design and install an adquate drainage system, consult a drainage engineer or specialist.

Water infiltration is slow on many farms. Tile drainage invariably results in higher yields due in part to improved drainage and in part to the improved management, such as earlier planting, closely associated with improved drainage.

Related Soil Management Publications

SOILS

E-471 Lime for Michigan Soils (Free)
E-486 Secondary and Micronutrients for Vegetables and Field Crops (30¢)
E-498 Sampling Soils (Free)
E-525 Wind Erosion Control on Upland Soils (Free)
E-906 No Till Corn: 3—Soils (Free)
E-937 Understanding the MSU Soil Test Report (Free)
E-994 Essential Secondary Elements: Magnesium (Free)
E-996 Essential Secondary Elements: Calcium (Free)
E-997 Essential Secondary Elements: Sulfur (Free)
E-1012 Essential Micronutrients: Zinc (Free)
E-1031 Essential Micronutrients: Manganese (Free)
E-1037 Essential Micronutrients: Boron (Free)
E-1041 Part 1 Tillage Systems: Deep, Primary, Supplemental and No Till (25¢)
E-1042 Part 2 Tillage Systems: Secondary Tillage and Cultivation (25¢)
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