# The Basics of Agricultural Tile Drainage

## Basic Engineering Principals 2


**John Panuska PhD, PE**

**Natural Resources Extension Specialist**
**Biological Systems Engineering Department**
**UW Madison**


**Date**
**Location**


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# ASABE Tile Drain Standards

## Design Standard

ASAE EP480 MAR1998 (R2008)
Design of Subsurface Drains in Humid Areas

ASABE

American Society of
Agricultural and Biological Engineers

STANDARD

ASABE is a professional and technical organization, of members worldwide, who are dedicated to advancement of engineering applicable to agricultural, food, and biological systems. ASABE Standards are consensus documents developed and adopted by the American Society of Agricultural and Biological Engineers to meet standardization needs within the scope of the Society; principally agricultural field equipment, farmstead equipment, structures, soil and water resource management, turf and landscape equipment, forest engineering, food and process engineering, electric power applications, plant and animal environment, and waste management.

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ASABE, 2950 Niles Road, St. Joseph, MI 49085-9659, USA, phone 269-429-0300, fax 269-429-3852, hq@asabe.org

**ASAE EP480 MAR1998 (R2008)**

**Design of subsurface Drains in Humid Climates**

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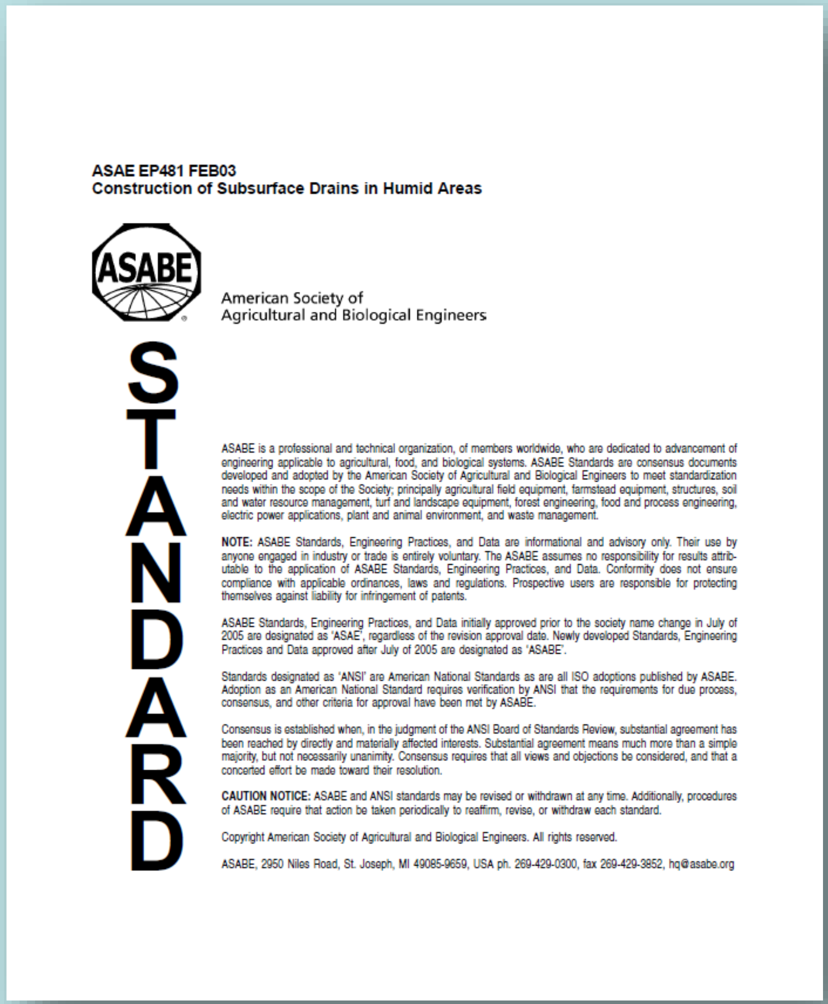
# ASABE Tile Drain Standards

## Construction Standard


**ASAE EP481 FEB03**
**Construction of Subsurface Drains in Humid Areas**

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**ASAE EP481 FEB03**

**Construction of subsurface Drains in Humid Areas**

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# Drain Design Procedure

I. Determine if and where an adequate outlet can be installed!

II. Estimate hydraulic conductivity (K) based on soil type.

III. Select drainage coefficient (Dc) based on crop and soil type.

# Drain Design Procedure

IV. Select suitable depth for drains
- o Typical range 3 to 6 ft.
- o Cover greater than 2.5 ft
- o Depth / spacing balance to minimize cost

V. Determine spacing
- o Use soil textural table guidelines
- o Use iGrow Web-based calculator.

# Drain Design Procedure

VI. Size laterals and mains to accommodate the design flow.

– Maintain minimum velocity to clean pipe. (0.5 ft / s - No silt; 1.4 ft / sec - w/silt)

– Match pipe size to design flow. (telescope the size of main as drained area increases)

– Properly design outlet.

# Design Challenges

- ✓ The design process results in a design for a 2 to 5 year event, controlling larger events too costly.
- ✓ Every soil will be different and crop type matters.
- ✓ Costs/benefits will vary from year to year.
- ✓ Climate trends are unpredictable.

# Drain Tile Installation Equipment

Tractor Backhoe

Tile Plow

Chain Trencher

Wheel Trencher

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# Drain Tile Materials

Clay Tile (organic soils)

Concrete Tile (mineral soils)

# Drain Pipe Materials
## - Polyethylene Plastic -

**Single wall corrugated**

**Dual wall (smooth wall)**

Water enters the pipe through slots in wall

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# I. The Drain Outlet

- ✓ MUST have sufficient grade for gravity flow !

  < set preliminary grade>

  - If not, a pump station will be necessary.

- ✓ Receiving water must have adequate capacity.

- ✓ Provide guards to keep animals out.

- ✓ Daylight outlet pipe 1 ft above base flow in receiving channel

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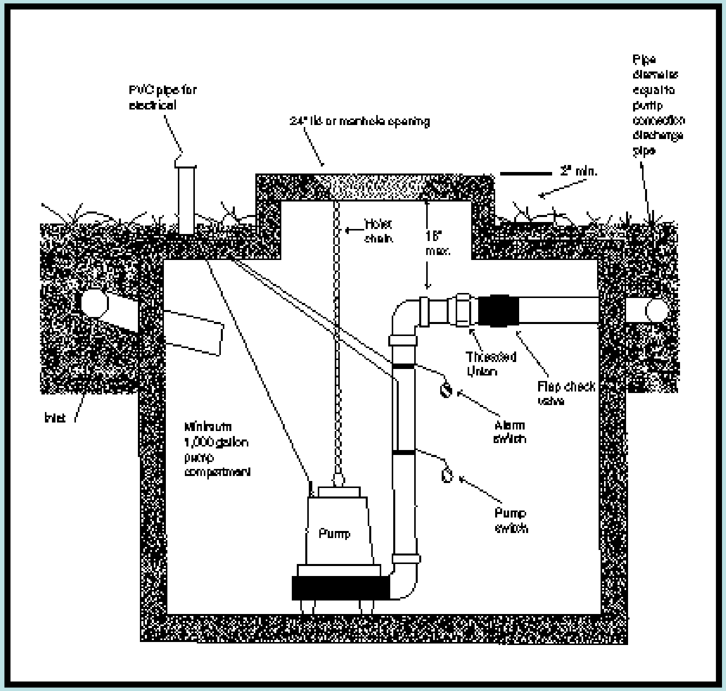
# Drainage Pump Stations




**When you don’t have the fall to use gravity ….**

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# II. Determine $K_{sat}$ for Soil

- ✓ Use web soil survey for site in question.
- ✓ Conduct site specific soil survey (test pit).
- ✓ Use values base on soil texture.
- ✓ Ask local experts (county staff, NRCS, drainage contractors).

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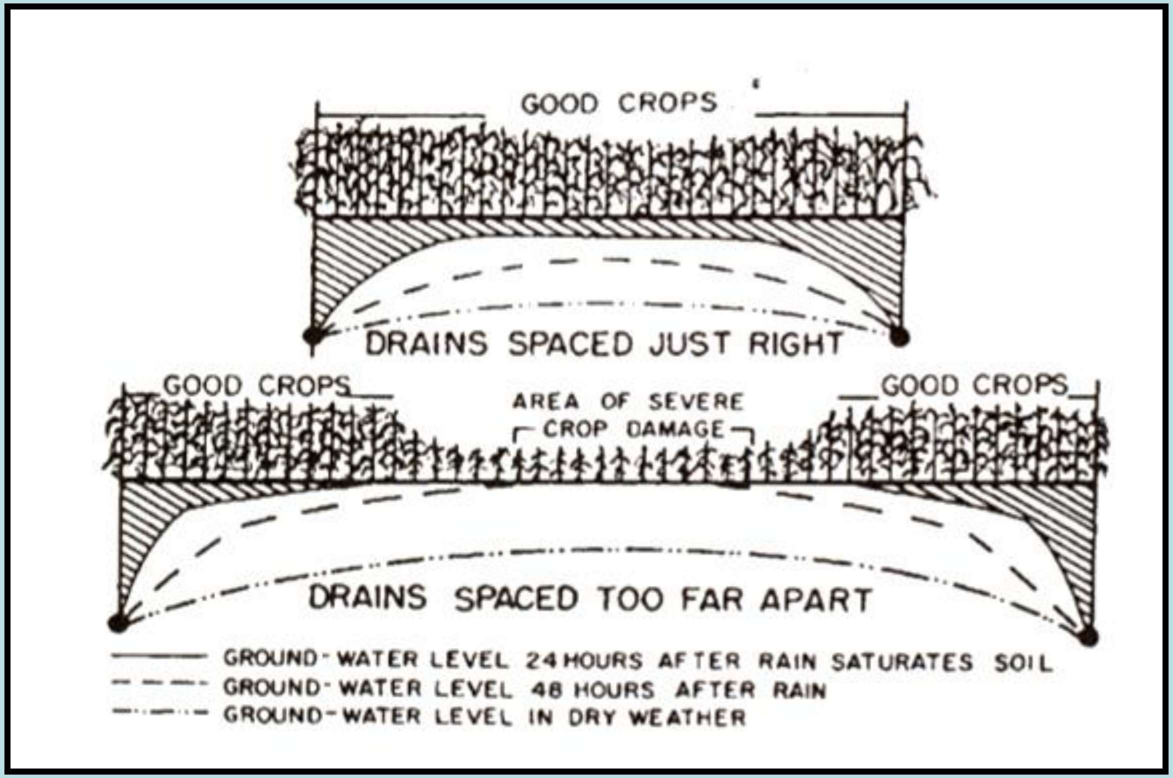
# III. Proper Lateral Depth and Spacing

**Drain spacing, water table depth and crop response**

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**_Drain depth and spacing integrate the water removal rate (Dc) and soil_ permeability _(K)_**

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# Drain Depth / Spacing - Equation

$$DC = \frac{(8 * K_2 * d * h)}{L^2} + \frac{(4 * K_1 * h^2)}{L^2}$$

**Hooghoudt Equation, 1940**

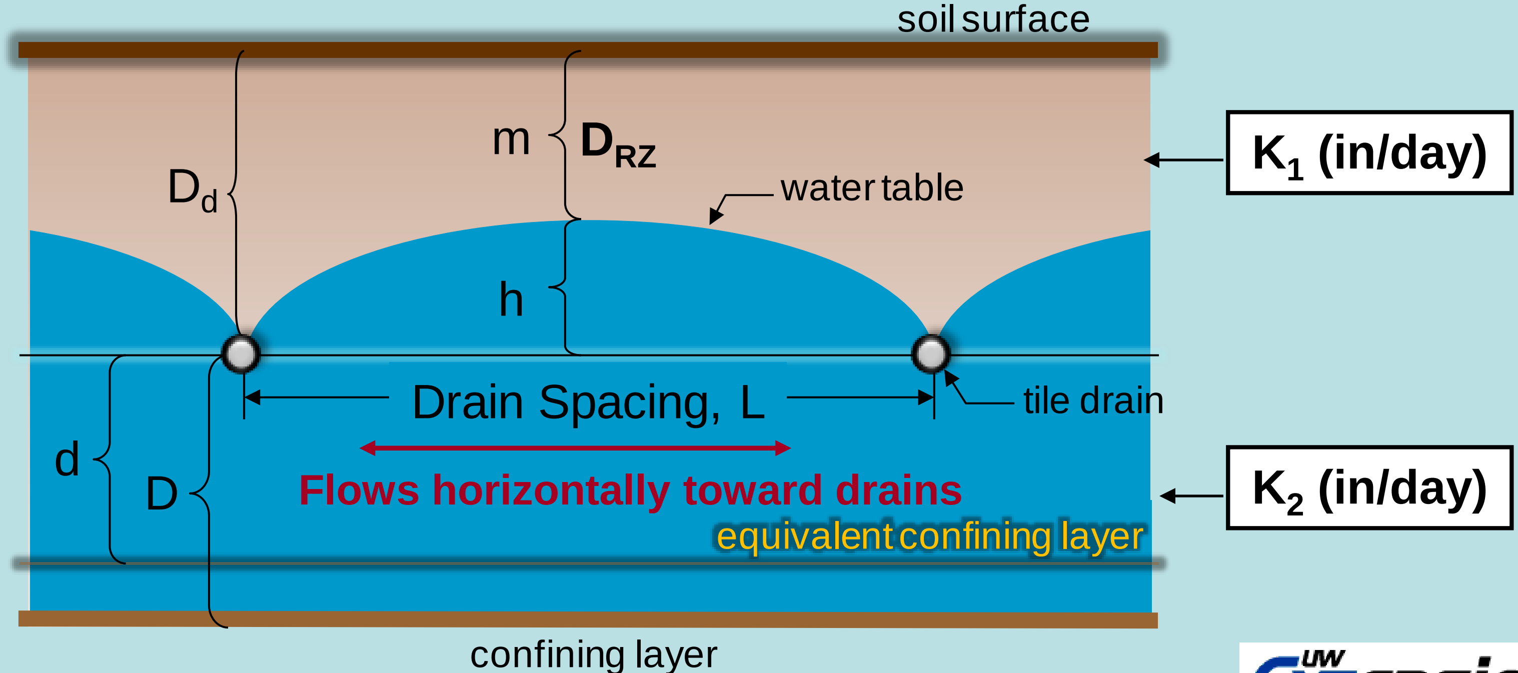


Image from Gary Sands – U of MN

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# Determination of Soil K


The WSS can calculate a depth weighted K value

**Tables — Saturated Hydraulic Conductivity (Ksat) — Summary By Map Unit**

**Summary by Map Unit — Brown County, Wisconsin (WI009)**

| Map unit symbol | Map unit name | Rating (micrometers per second) | Acres in AOI | Percent of AOI |
|---|---|---|---|---|
| KhB2 | Kewaunee silt loam, 2 to 6 percent slopes, eroded | 2.0931 | 0.1 | 86.6% |
| McA | Manawa silty clay loam, 0 to 3 percent slopes | 1.1856 | 0.0 | 13.4% |
| **Totals for Area of Interest** | | | **0.1** | **100.0%** |

**Description — Saturated Hydraulic Conductivity (Ksat)**

Saturated hydraulic conductivity (Ksat) refers to the ease with which pores in a saturated soil transmit water. The estimates are expressed in terms of micrometers per second. They are based on soil characteristics observed in the field, particularly structure, porosity, and texture. Saturated hydraulic conductivity is considered in the design of soil drainage systems and septic tank absorption fields.

For each soil layer, this attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

The numeric Ksat values have been grouped according to standard Ksat class limits.

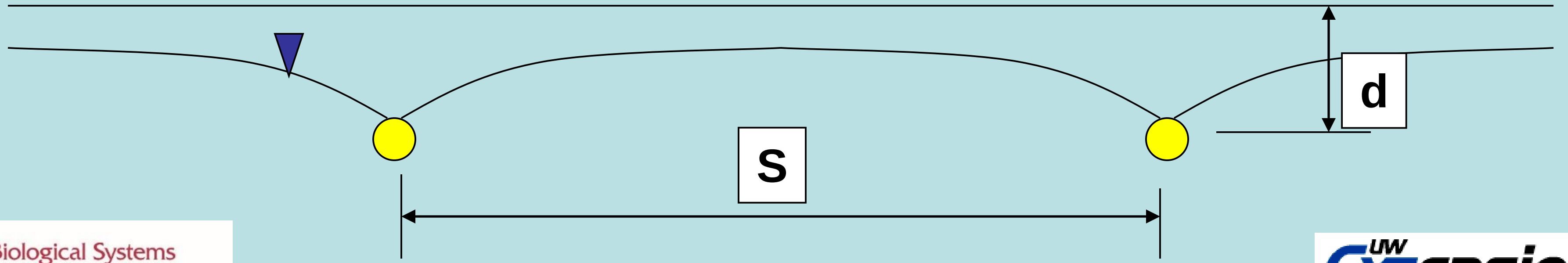
**Rating Options — Saturated Hydraulic Conductivity (Ksat)**

**Units of Measure:** micrometers per second
**Aggregation Method:** Dominant Component
**Component Percent Cutoff:** *None Specified*
**Tie-break Rule:** Fastest
**Interpret Nulls as Zero:** No
**Layer Options (Horizon Aggregation Method):** All Layers (Weighted Average)

https://websoilsurvey.sc.egov.usda.gov/

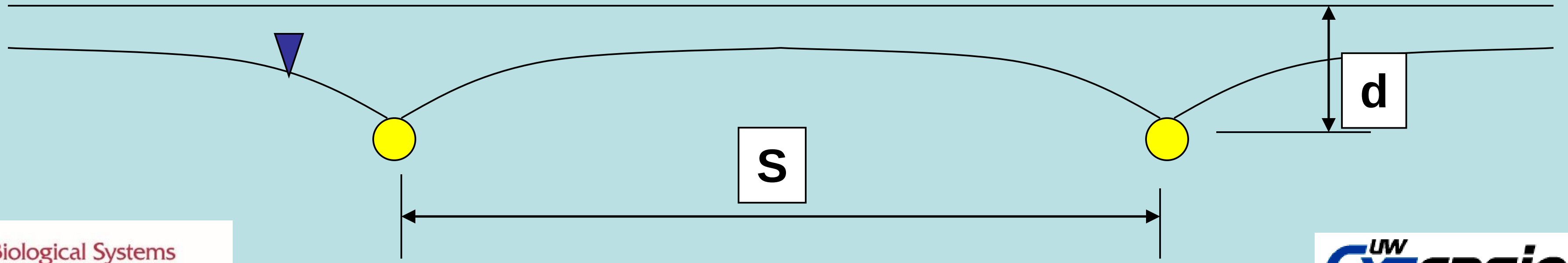
# Lateral Depth and Spacing

The goal is to maintain as consistent a Dc value across the field as possible.



# Lateral Depth and Spacing

- ✓ A relationship exists between depth and spacing of drains.
- ✓ For soils of uniform permeability, the deeper the drains, the wider the spacing (within limits).
- ✓ Higher permeability soils can have greater spacing
- ✓ Need to provide adequate root depth above the saturated zone.

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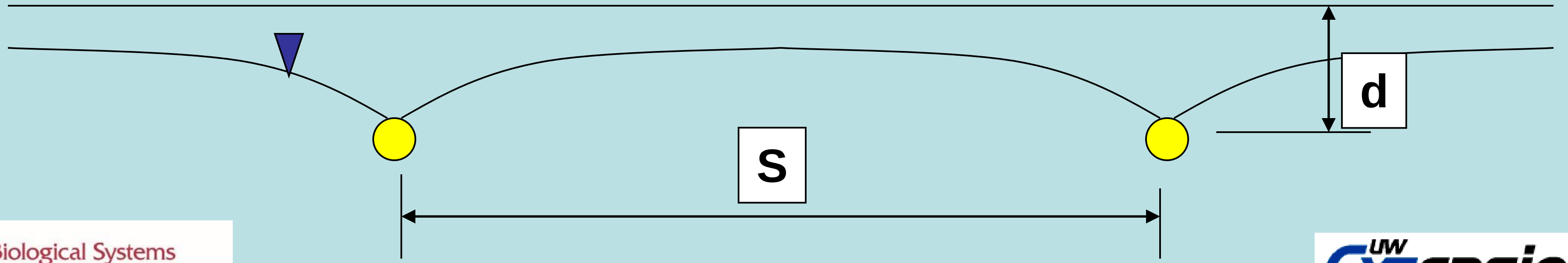


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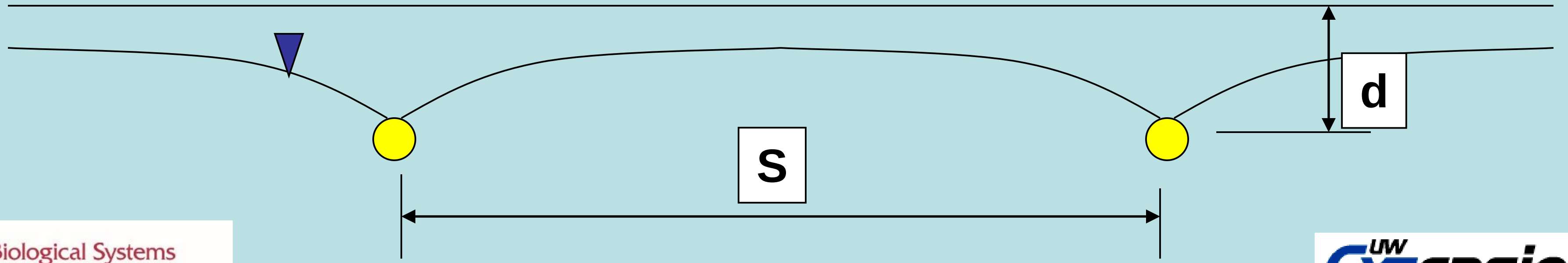


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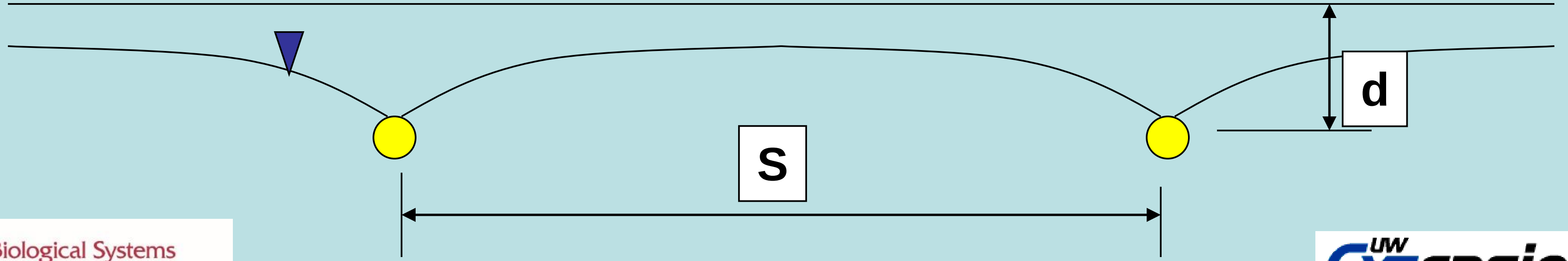


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# Lateral Depth and Spacing

Varies with soil permeability, crop and soil, kind of management practices crop, extent of surface drainage.

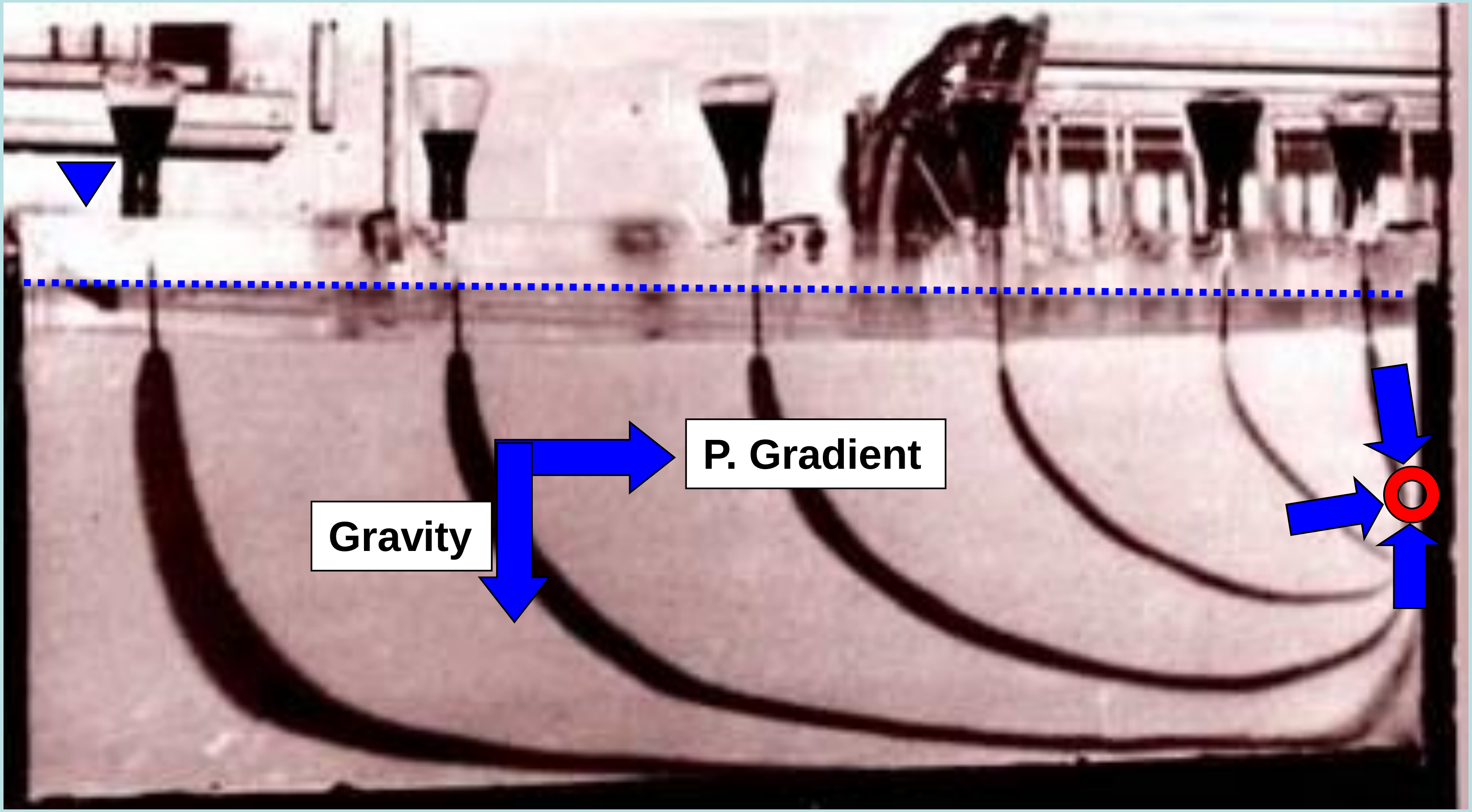
Typical drain depth range = 3 to 6 ft.

Typical spacing = 30 to 100 ft.

Depth / spacing balance to minimize cost.

Minimum cover greater than 2.5 ft.

# Drain Water Flow Patterns




From Gary Sands – U of MN

# Drain Depth / Spacing - Table

**Varies with soil permeability, crop and soil management practices, kind of crop, extent of surface drainage.**

| Soil Texture | Hyd. Cond (in/hr) | Spacing (Ft) | Depth (Ft) |
|---|---|---|---|
| Clay | 0.02 - 0.04 | 10 - 20 | 3.0 - 3.6 |
| Clay Loam | 0.04 - 0.20 | 16 - 33 | 3.0 - 3.6 |
| Loam | 0.02 - 0.79 | 33 - 82 | 3.6 - 4.0 |
| Fine sandy loam | 0.79 - 2.6 | 82 - 164 | 4.0 - 4.6 |
| Sandy loam | 2.6 - 5.1 | 164 - 230 | 3.6 - 5.0 |
| Peat and Muck | 5.1 - 9.8 | 230 - 330 | 3.6 - 5.0 |

Source: Soil & Water Conservation Engineering 5th Ed., 2006

# Depth / Spacing - Calculator

iGrow
A Service of SDSU Extension

Drainage Calculators

Utilize these calculators to address common drainage questions. Additional information is available on iGrow

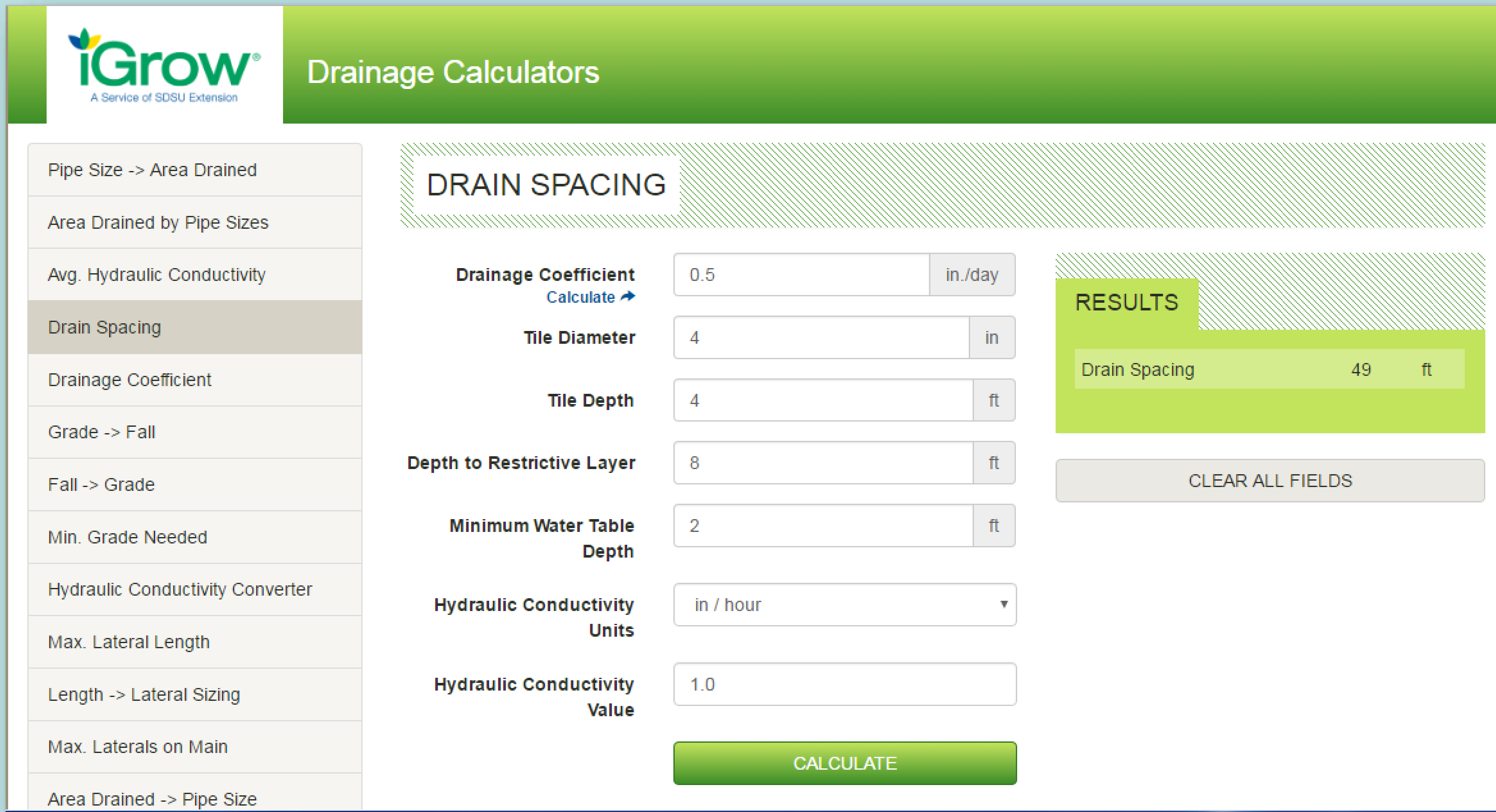
| | | | |
|---|---|---|---|
| Pipe Size -> Area Drained | Area Drained by Pipe Sizes | Avg. Hydraulic Conductivity | Drain Spacing |
| Drainage Coefficient | Grade -> Fall | Fall -> Grade | Min. Grade Needed |
| Hydraulic Conductivity Converter | Max. Lateral Length | Length -> Lateral Sizing | Max. Laterals on Main |
| Area Drained -> Pipe Size | Pump Size | Subirrigation Spacing | Sump Storage |

Visit iGrow.org for the latest information from SDSU Extension. This tool was developed in collaboration with University of Minnesota Extension



http://www.igrowdrainage.org/

# Depth / Spacing - Example

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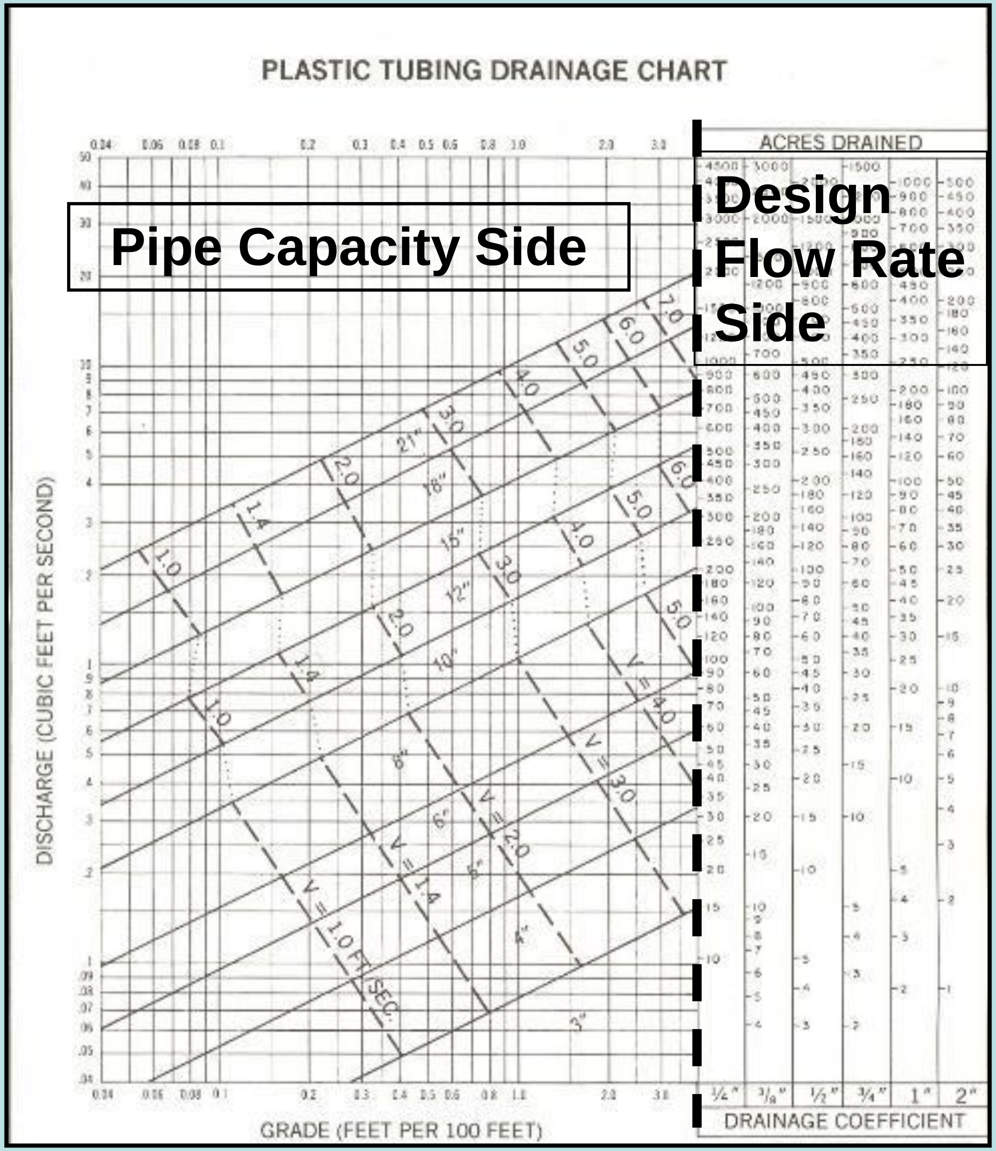
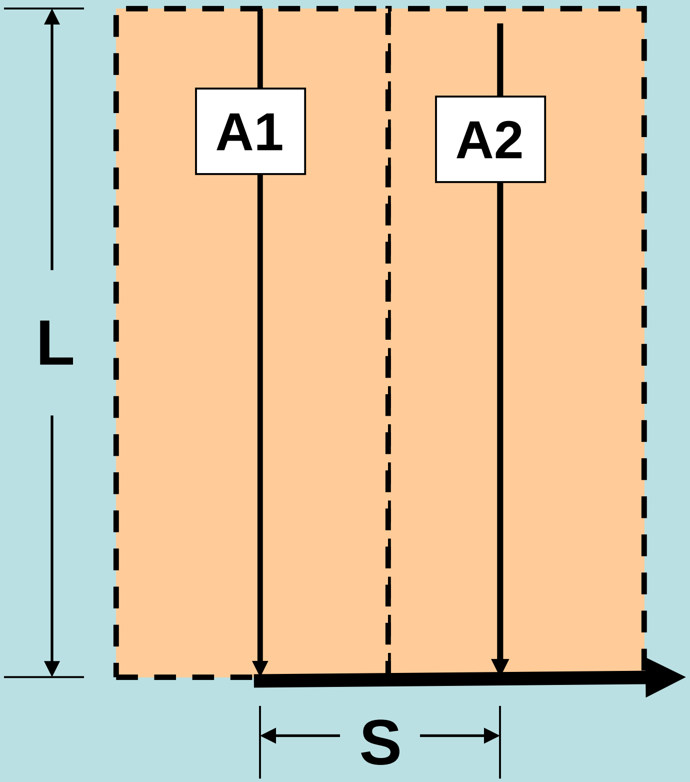
# Engineering Design Aids

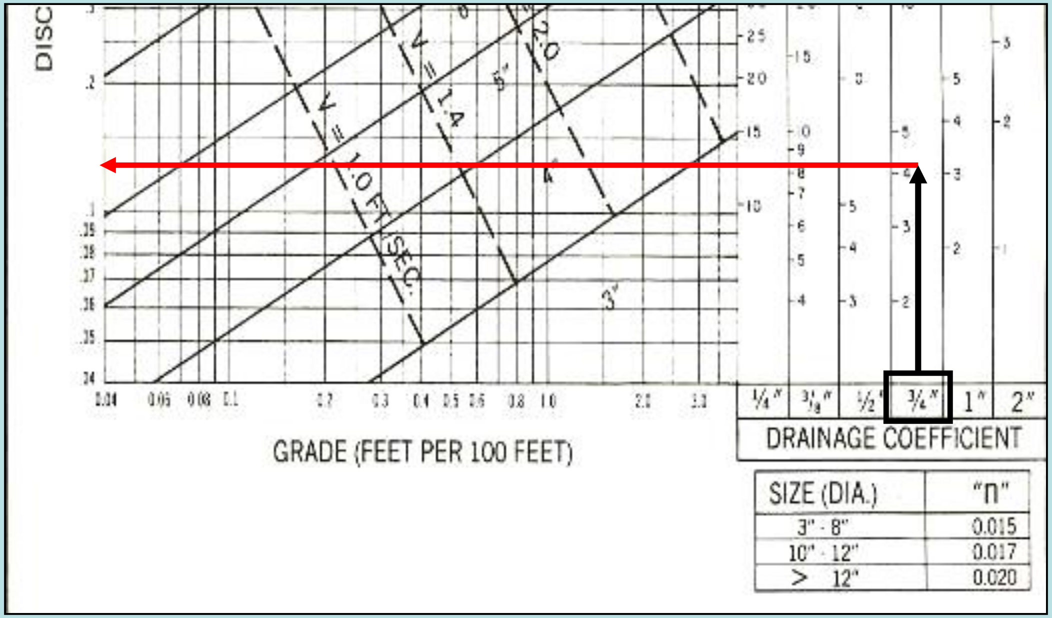
## - Tubing Drainage Chart -



# Flow into laterals

**Area drained = L x S; L = 1,500 ft; S = 61 ft;**
**$A_T$ = (1,500 x 122) / 43,560 = 4.2 ac; Dc = ¾ in.**




**0.14 cubic feet / second = 63 gpm**

# VI. Sizing Laterals and Mains

**Dc (in/day) x Area (ac) = Flow rate (ac • in/day)**

**(ac • in/day) / 23.8 = Flow rate ($ft^3$/sec)**

Manning's equation for gravity pipe flow

$$\text{Pipe capacity (cfs)} = \frac{0.4631}{n} \times D^{2.667} \times S^{1/2}$$

**D = pipe diameter (ft) and S = pipe slope (ft/ft)**

n = .009 smooth interior pipe
.015 3" to 8" sizes
.017 9" to 12"
.020 > 12"

From Gary Sands U of MN

# Pipe Capacity

**Read pipe flow capacity for pipe size from the scale on the left.**

**----------------------------------------**

**See your drainage design chart.**

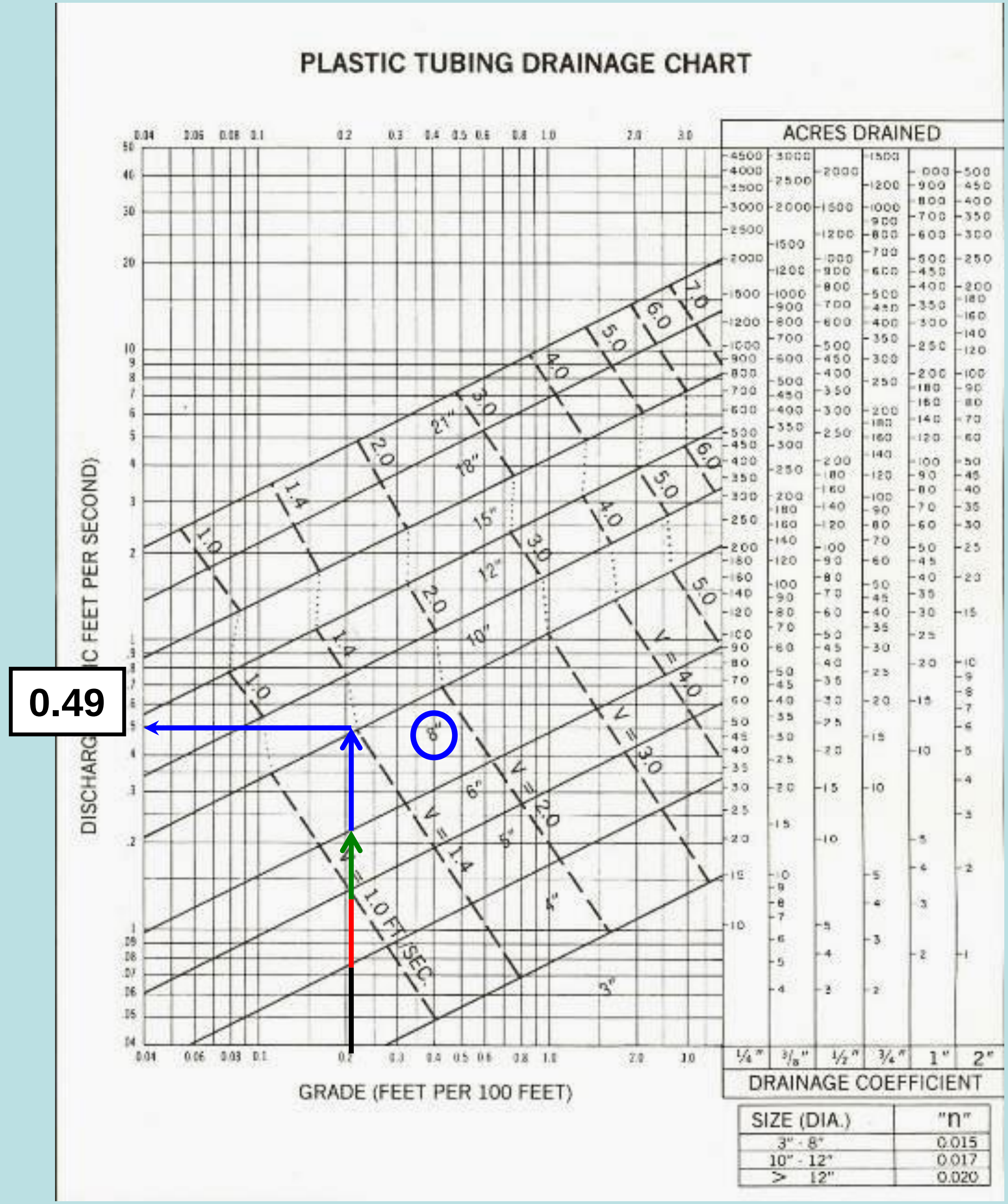
**----------------------------------------**

**Full flow capacity of a**
**8 in diameter pipe @ 0.22 %**

**= 0.49 cfs**
**= 220 gpm**

**----------------------------------------**

**cfs x 448.83 = gpm**



# Example Problem

**For Dc = 1/2 in / day**

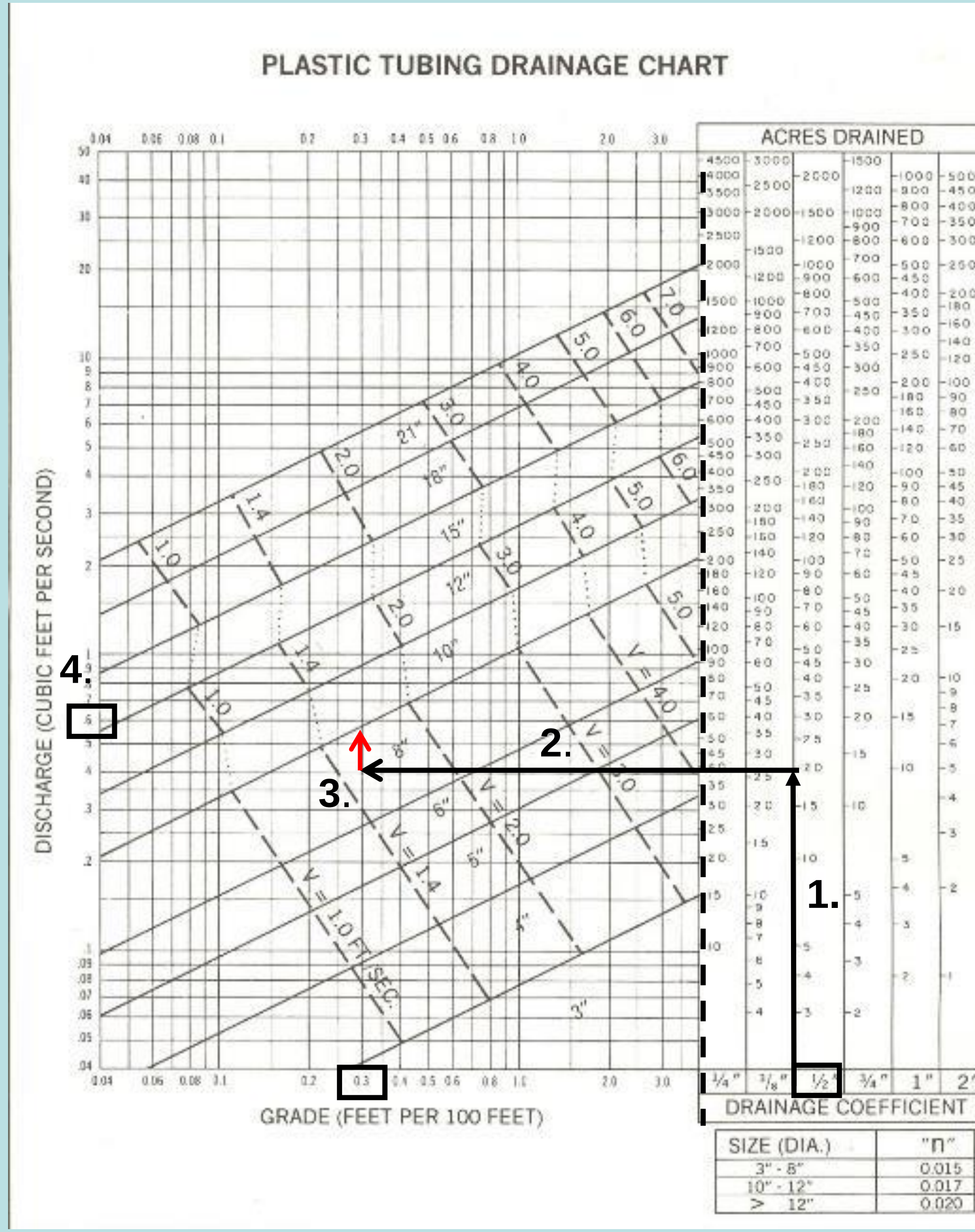
**Area = 20 ac**

**Pipe Slope = 0.30%**
**= 0.0030 ft/ft**

**Requires:**

**Pipe needs to carry 0.42 cfs (use next highest standard size) of 8 in diameter which has full flow capacity of 0.57 cfs & V ~ 1.6 ft /sec.**

Use across different scales to telescope the pipe size

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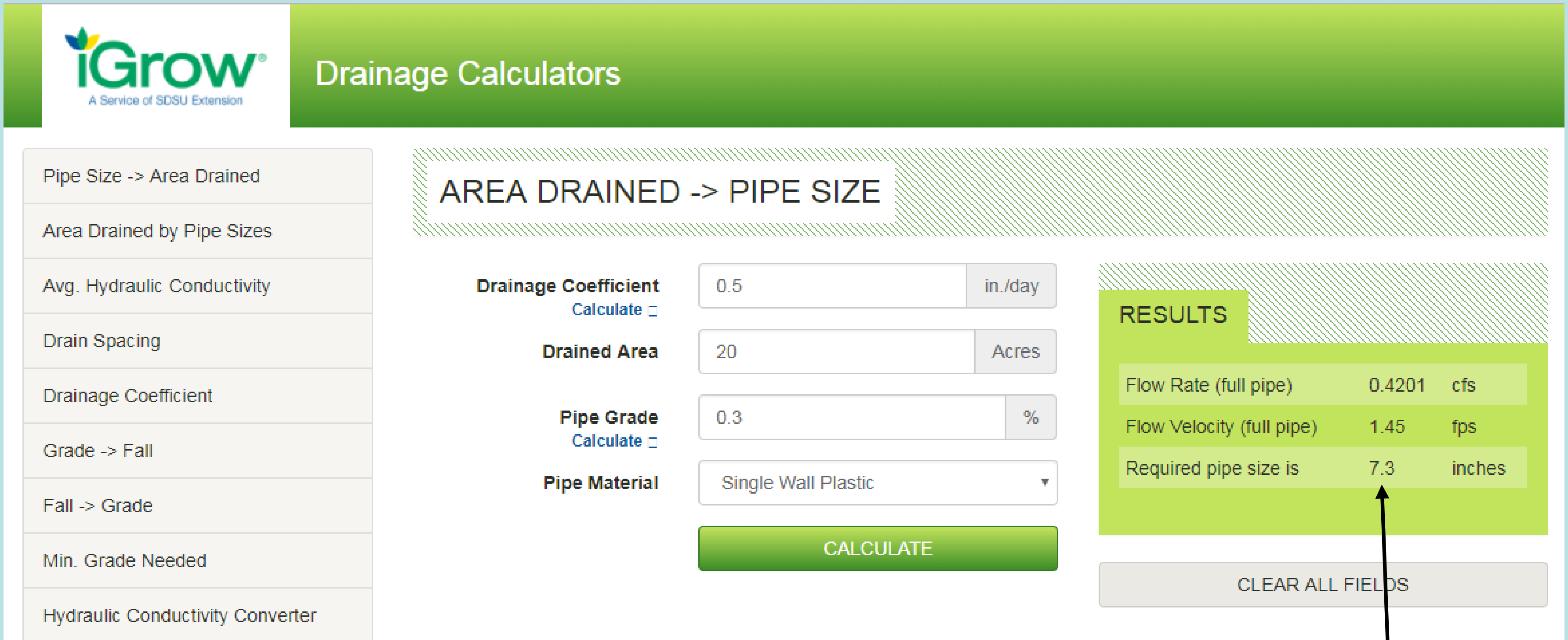
# Area / Pipe Size - Example




Note the non-standard pipe diameter. Select 8” diameter.

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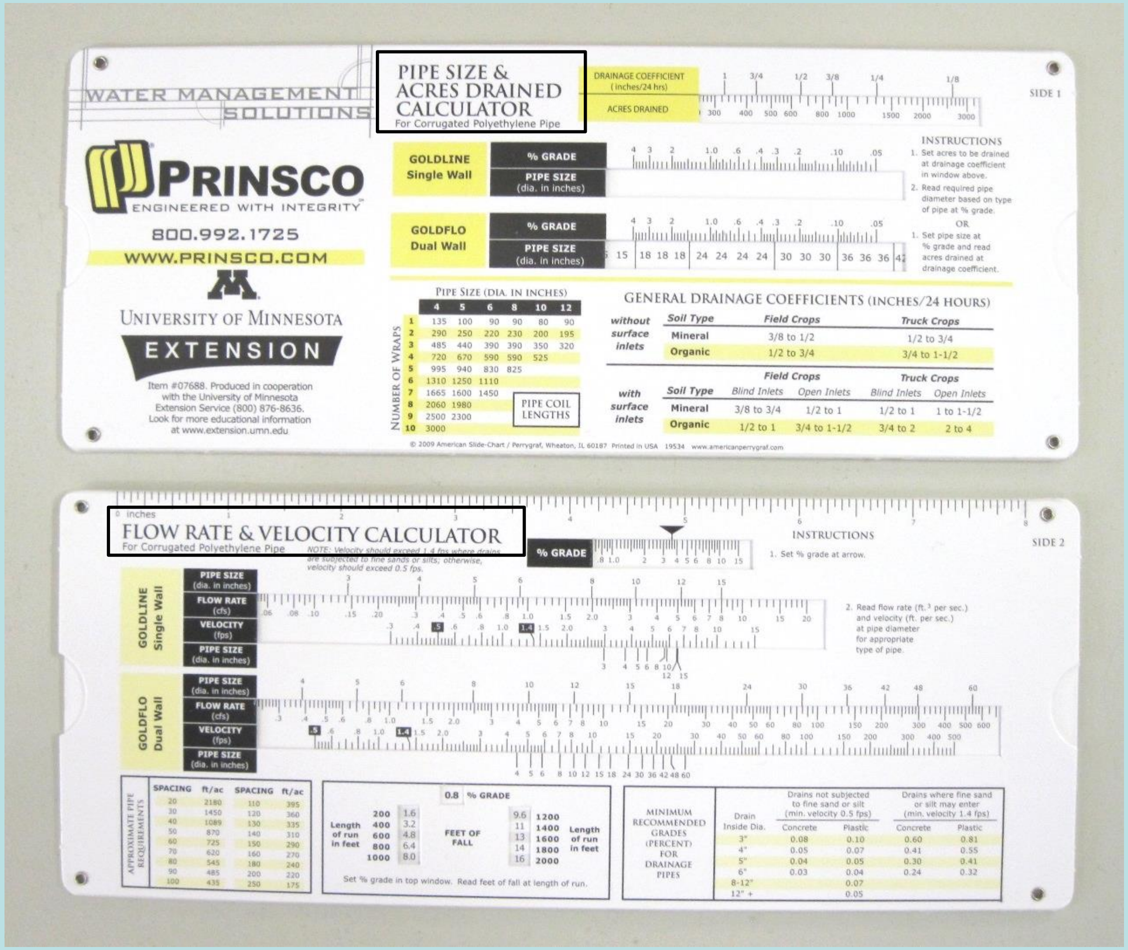
# Slide Rule Design Tool

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# Drainage Resources

## fyi.uwex.edu/drainage/

*University of Wisconsin-Extension* | Cooperative Extension

Search ...

Tile Drainage Resources

Cooperative Extension

UW Extension
University of Wisconsin-Extension

Home | Trainings & Workshops | University & Agency Links | Video Resources | Web Resources

This site is designed to provide farmers, conservationists, and agronomists with a variety of information and resources related to agricultural tile drainage.

### Workshops

Understanding Agricultural Drainage Mapping Tile Drainage Systems Controlled or Managed Drainage Systems Research Update – What we've learned from WI Farms Drainage District Overview Enabling no-till yields to increase with earthworms, drainage Corps Regulatory Process

PAGES

- Trainings & Workshops
- University & Agency Links
- Video Resources
- Web Resources

UW DISCOVERY FARMS

- UW Discovery Farms

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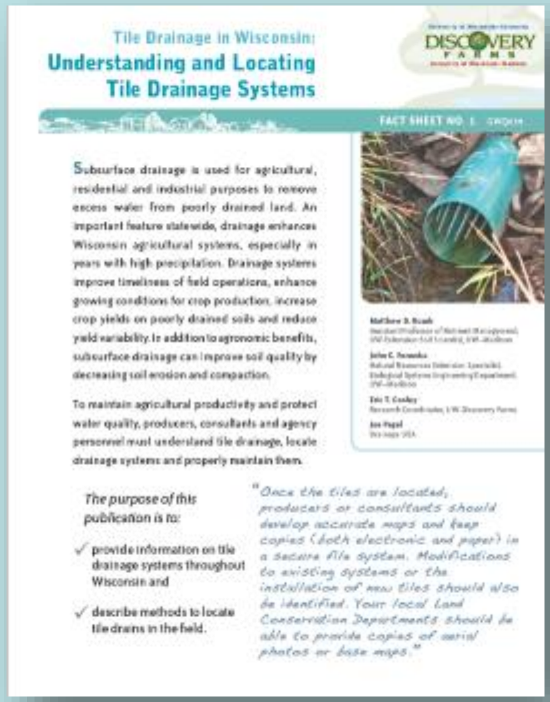
# Drainage Resources

## Learningstore.uwex.edu



Tile Drainage in Wisconsin:
**Understanding and Locating Tile Drainage Systems**

FACT SHEET NO. 1

Subsurface drainage is used for agricultural, residential and industrial purposes to remove excess water from poorly drained land. An important feature statewide, drainage enhances Wisconsin agricultural systems, especially in years with high precipitation. Drainage systems improve timeliness of field operations, enhance growing conditions for crop production, increase crop yields on poorly drained soils and reduce yield variability. In addition to agronomic benefits, subsurface drainage can improve soil quality by decreasing soil erosion and compaction.

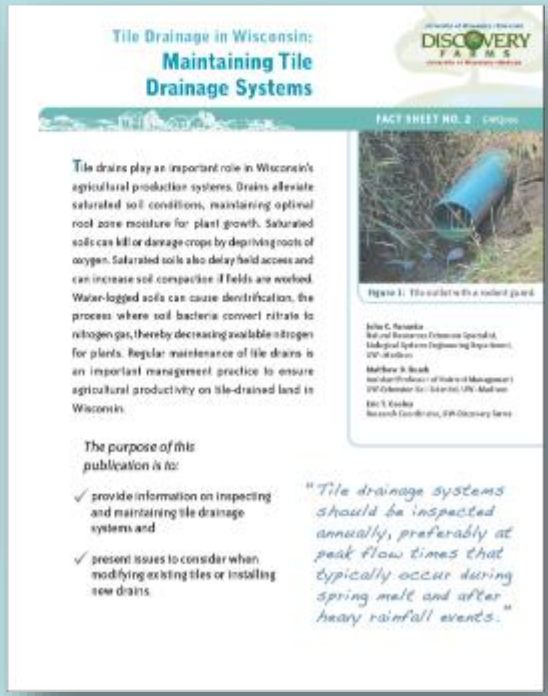
To maintain agricultural productivity and protect water quality, producers, consultants and agency personnel must understand tile drainage, locate drainage systems and properly maintain them.

Matthew D. Ruark
John C. Panuska
Eric T. Cooley

*The purpose of this publication is to:*

- ✓ provide information on tile drainage systems throughout Wisconsin and
- ✓ describe methods to locate tile drains in the field.

"Once the tiles are located, producers or consultants should develop accurate maps and keep copies (both electronic and paper) in a secure file system. Modifications to existing systems or the installation of new tiles should also be identified. Your local Land Conservation Departments should be able to provide copies of aerial photos or base maps."



Tile Drainage in Wisconsin:
**Maintaining Tile Drainage Systems**

FACT SHEET NO. 2

Tile drains play an important role in Wisconsin's agricultural production systems. Drains alleviate saturated soil conditions, maintaining optimal root zone moisture for plant growth. Saturated soils can kill or damage crops by depriving roots of oxygen. Saturated soils also delay field access and can increase soil compaction if fields are worked. Water-logged soils can cause denitrification, the process where soil bacteria convert nitrate to nitrogen gas, thereby decreasing available nitrogen for plants. Regular maintenance of tile drains is an important management practice to ensure agricultural productivity on tile-drained land in Wisconsin.

John C. Panuska
Matthew D. Ruark
Eric T. Cooley

*The purpose of this publication is to:*

- ✓ provide information on inspecting and maintaining tile drainage systems and
- ✓ present issues to consider when modifying existing tiles or installing new drains.

"Tile drainage systems should be inspected annually, preferably at peak flow times that typically occur during spring melt and after heavy rainfall events."

Tile Drainage in Wisconsin:
**Managing Tile-Drained Landscapes to Prevent Nutrient Loss**

FACT SHEET NO. 3

Subsurface drainage of agricultural land has the ability to improve yields and reduce surface runoff and erosion losses. However, with a reduction in surface runoff, more water infiltrates the soil and percolates through the soil profile. This is of particular importance to farmers, as this water can also transport essential plant nutrients, specifically nitrogen and phosphorus, out of the root zone. Once nutrients reach the tile drain, they have a direct conduit to surface waters.

Tile-drained agricultural land must be well-managed to reduce the loss of nutrients to surface waters. Nutrient management practices must be carefully followed to minimize the risk of nutrient loss and to maximize fertilizer use efficiency. Additional considerations need to be taken with manure applications on tile-drained land to both minimize nutrient loss and prevent manure entry into tile drains.

Eric T. Cooley
Matthew D. Ruark
John C. Panuska

*The purpose of this publication is to:*

- ✓ provide information on nutrient management concerns in tile-drained agricultural landscapes, and
- ✓ present management and treatment practices to reduce the loss of nutrients from tile systems to surface water.

"Proper management of crop nutrients on tile-drained landscapes is the key to reducing nutrient loss and maximizing nitrogen use efficiency."

# Drainage Resources

**www.extension.umn.edu/agriculture/water/**


See the UWEX drainage site for other web sites

From Gary Sands U of MN

UW Extension

# Pipe Size and Grades

- ✓ Desirable minimum working grade is 0.2 %
- ✓ Typical minimum pipe size is 3” - 4” in humid regions and 5”- 6” for organic soils.
- ✓ Minimum grade sufficient to maintain 0.5 ft /sec (1.4 ft / sec with sand and silt in flow).

# Pipe Size and Grades

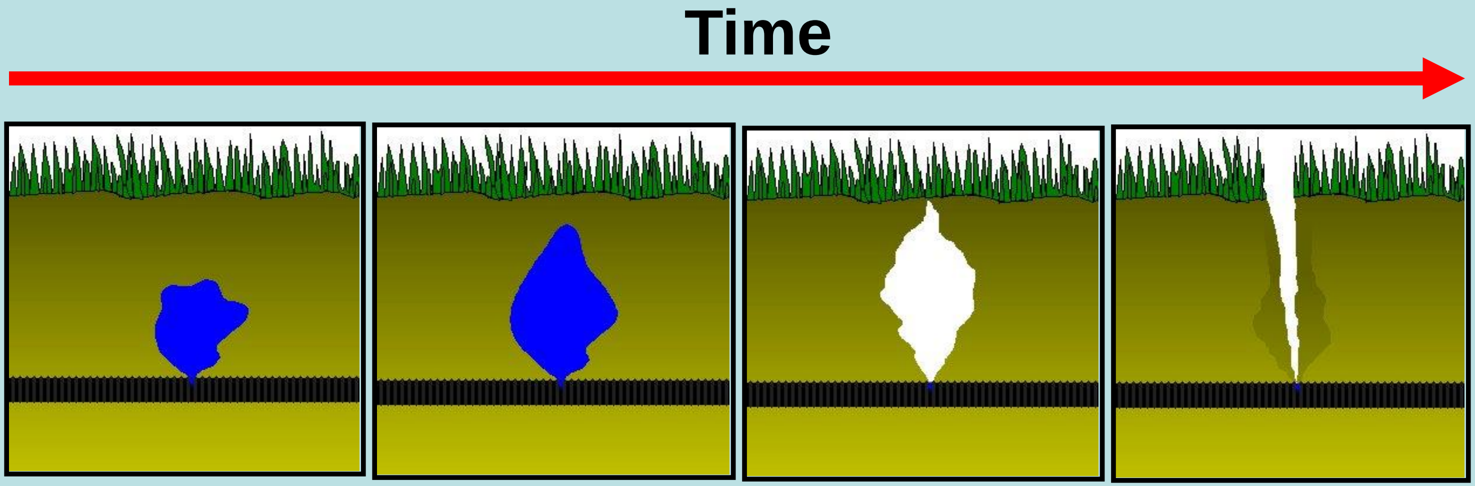
- Design Boundary Conditions -

- ✓ Very high velocities can cause “sink holes” when soil is actually pulled into the tile line.
- ✓ “Blowouts” can occur when lines become pressurized.

| Soil Texture | Max. Velocity ft/sec |
|---|---|
| Sand & sandy loam | 3.5 |
| Silt & silt Loam | 5.0 |
| Silty clay loam | 6.0 |
| Clay & Clay loam | 7.0 |
| Course sand or gravel | 9.0 |

- ✓ Watch out for steep-to-flat grade changes and overloading mains …. Blowouts !

# Tile Line Blowouts




During storm event

After storm event

Photos from: Eric Cooley, UW Discovery Farms

# Sub-surface Water Management

- ✓ **Reduces the total water export.**
- ✓ **Annual nitrate load reductions ~ 15 to 75%.**
- ✓ **There are still a number of unknowns about performance, research is on-going.**
- ✓ **Requires on-going management.**

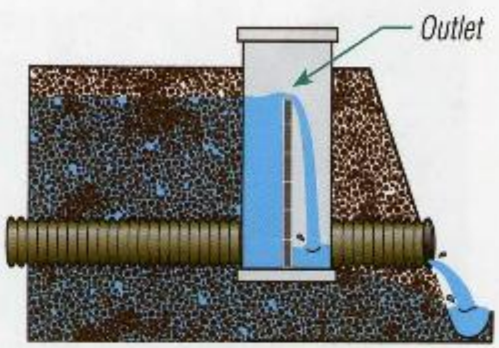



**Figure 1**. *The outlet is raised after harvest to reduce nitrate delivery.*

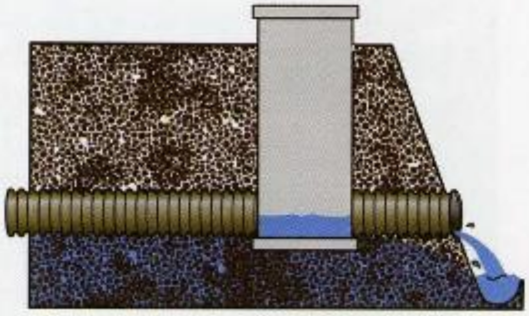


**Figure 2**. *The outlet is lowered a few weeks before planting and harvest to allow the field to drain more fully.*

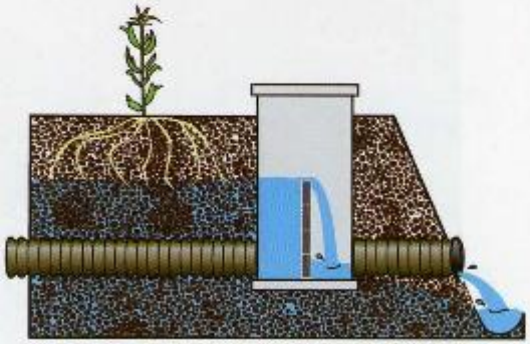


**Figure 3**. *The outlet is raised after planting to potentially store water for crops.*

**Source: Drainage Water Management for the Midwest, Purdue Extension Service, http://www.ces.purdue.edu/new**

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# Maintenance Issues

## - Iron Ochre -

- ✓ Iron ochre is a red, yellow or tan gelatinous material adhering to drain wall openings or forms outside of buried tiles

- ✓ Ochre is a filamentous bacterial slime composed of organic masses and iron oxides.

# Maintenance Issues

## - Iron Ochre -

- ✓ Iron ochre formation is most common in sandy and organic muck soils (Ford and Harmon, 1993) or alternating wet and dry soils, such as those under irrigation.

- ✓ Bacterial growth supported by soluble (ferrous) iron in ground-water.

- ✓ On-going maintenance is the only economical option for con-trolling iron ochre formation.

# Drainage System Cost

- Approximate ! -

Drainage system installation costs can vary ***significantly*** based on terrain, soils, outlet availability, etc.

Rough Range

~ $1,000 - 1,500 / ac

# QUESTIONS ? ? ?

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