The Basics of Agricultural Tile Drainage

Basic Engineering Principals 2

John Panuska PhD, PE

Natural Resources Extension Specialist
Biological Systems Engineering Department
UW Madison

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.

NOTE: ASABE Standards, Engineering Practices, and Data are informational and advisory only. Their use by anyone engaged in industry or trade is entirely voluntary. The ASABE assumes no responsibility for results attributable to the application of ASABE Standards, Engineering Practices, and Data. Conformity does not ensure compliance with applicable ordinances, laws and regulations. Prospective users are responsible for protecting themselves against liability for infringement of patents.

ASABE Standards, Engineering Practices, and Data initially approved prior to the society name change in July of 2005 are designated as "ASAE", regardless of the revision approval date. Newly developed Standards, Engineering Practices and Data approved after July of 2005 are designated as "ASABE".

Standards designated as "ANSI" are American National Standards as are all ISO adoptions published by ASABE. Adoption as an American National Standard requires verification by ANSI that the requirements for due process, consensus, and other criteria for approval have been met by ASABE.

Consensus is established when, in the judgment of the ANSI Board of Standards Review, substantial agreement has been reached by directly and materially affected interests. Substantial agreement means much more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered, and that a concerted effort be made toward their resolution.

CAUTION NOTICE: ASABE and ANSI standards may be revised or withdrawn at any time. Additionally, procedures of ASABE require that action be taken periodically to reaffirm, revise, or withdraw each standard.

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

UW Extension

ASABE Tile Drain Standards

Construction Standard

ASAE EP481 FEB03
Construction 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.

NOTE: ASABE Standards, Engineering Practices, and Data are informational and advisory only. Their use by anyone engaged in industry or trade is entirely voluntary. The ASABE assumes no responsibility for results attributable to the application of ASABE Standards, Engineering Practices, and Data. Conformity does not ensure compliance with applicable ordinances, laws and regulations. Prospective users are responsible for protecting themselves against liability for infringement of patents.

ASABE Standards, Engineering Practices, and Data initially approved prior to the society name change in July of 2005 are designated as 'ASAE', regardless of the revision approval date. Newly developed Standards, Engineering Practices and Data approved after July of 2005 are designated as 'ASABE'.

Standards designated as 'ANSI' are American National Standards as are all ISO adoptions published by ASABE. Adoption as an American National Standard requires verification by ANSI that the requirements for due process, consensus, and other criteria for approval have been met by ASABE.

Consensus is established when, in the judgment of the ANSI Board of Standards Review, substantial agreement has been reached by directly and materially affected interests. Substantial agreement means much more than a simple majority, but not necessarily unanimity. Consensus requires that all views and objections be considered, and that a concerted effort be made toward their resolution.

CAUTION NOTICE: ASABE and ANSI standards may be revised or withdrawn at any time. Additionally, procedures of ASABE require that action be taken periodically to reaffirm, revise, or withdraw each standard.

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

ASAE EP481 FEB03

Construction of subsurface Drains in Humid Areas

UW Extension

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 NRCS Web calculator.

UW Extension

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. (telescoping the size of main)
- 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

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

UW Extension

I. The Drain Outlet

- ✓ MUST have sufficient grade for gravity flow !

  < set preliminary grade>

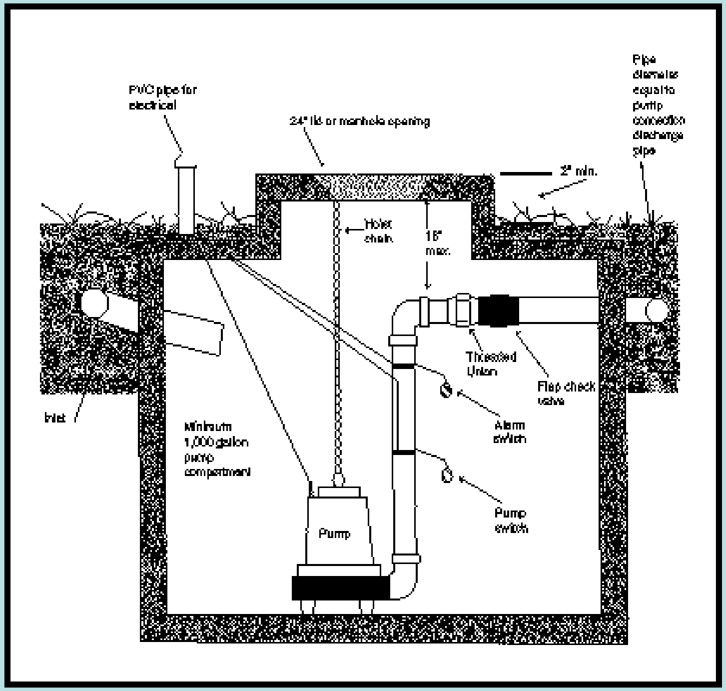
  - If not, a pump station will be necessary.

- ✓ Receiving water must have adequate capacity.

- ✓ Provide guards to keep animals out.

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

Drainage Pump Stations



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

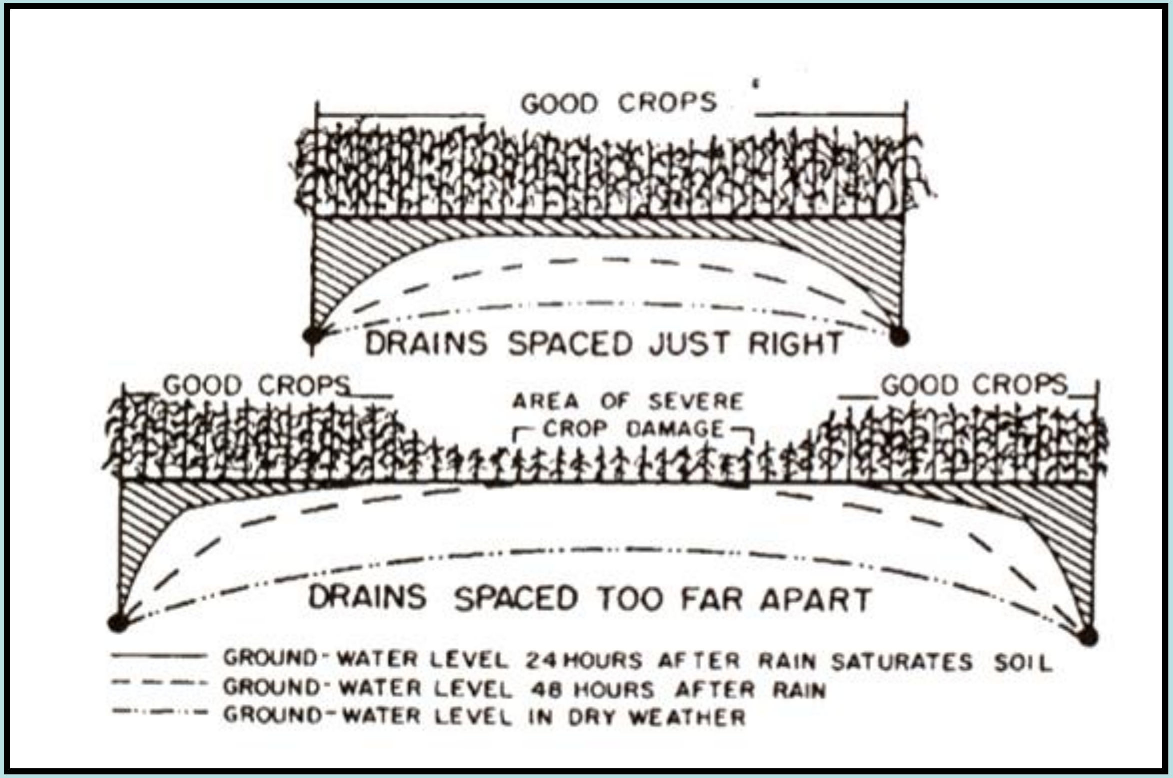
II. Determine K_{sat} for Soil

- ✓ 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).

UW Extension

III. Proper Lateral Depth and Spacing

Drain spacing, water table depth and crop response



UW Extension

Drain depth and spacing integrate the water removal rate (Dc) and soil* permeability *(K)

Drain Depth / Spacing - Equation

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

Hooghoudt Equation, 1940

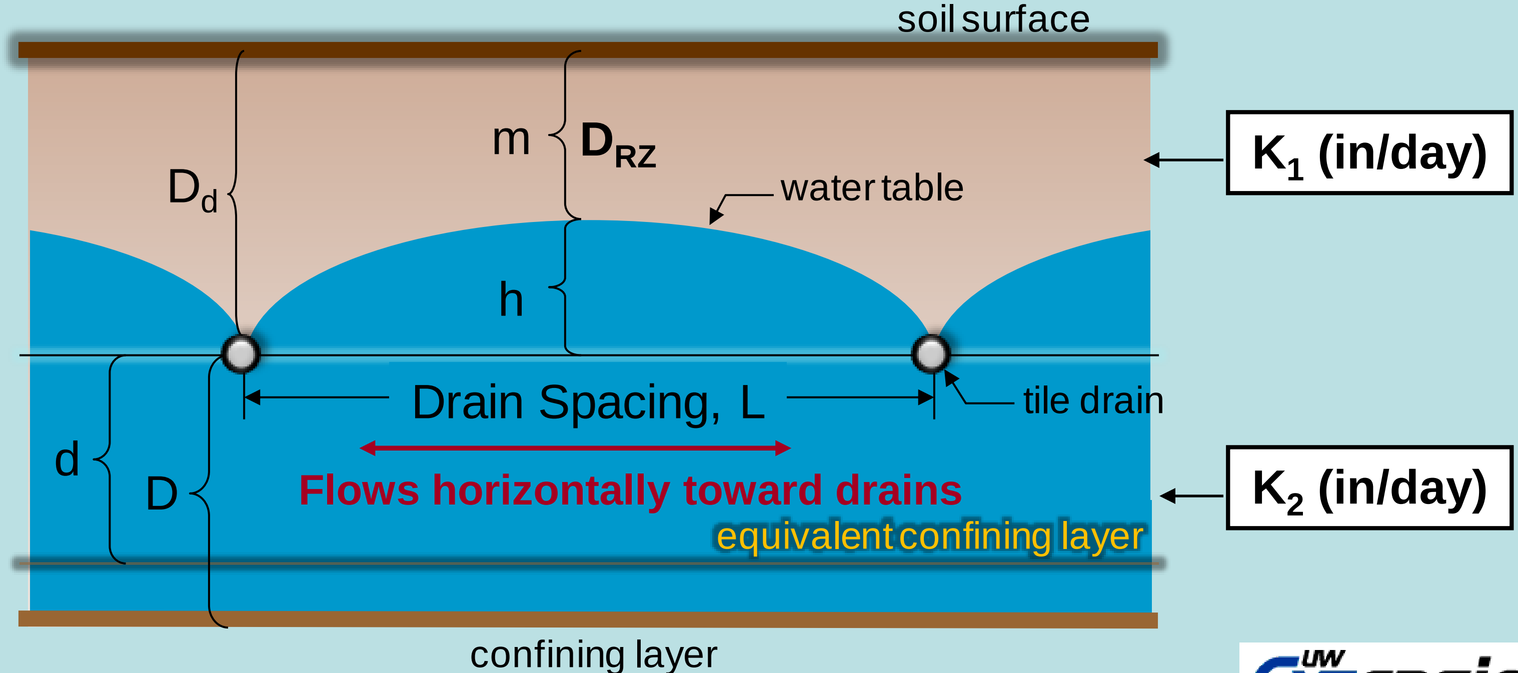
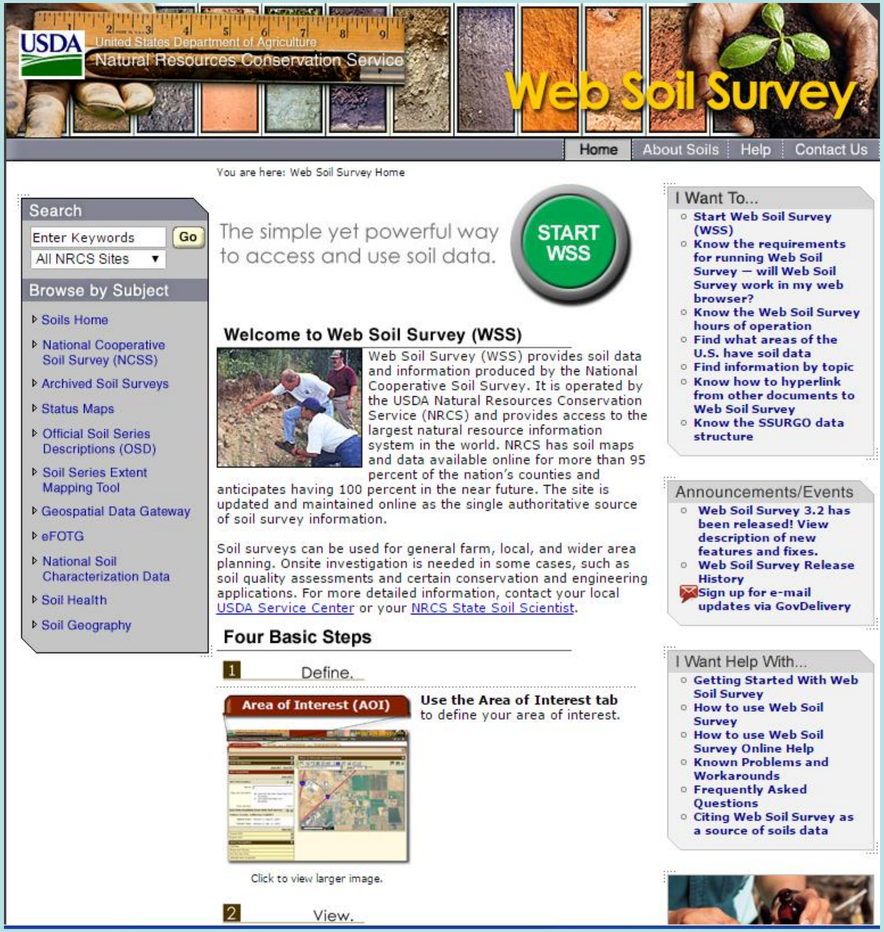


Image from Gary Sands – U of MN

UW Extension

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

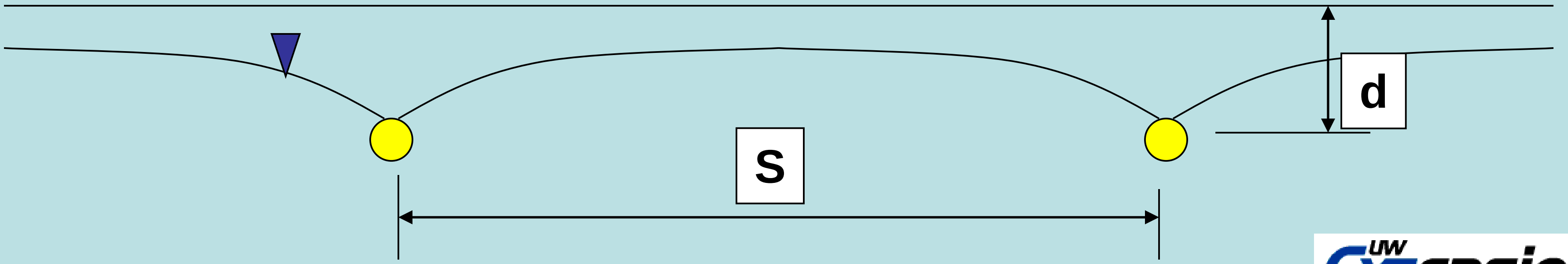
Layer Options (Horizon Aggregation Method): All Layers (Weighted Average)

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

UW Extension

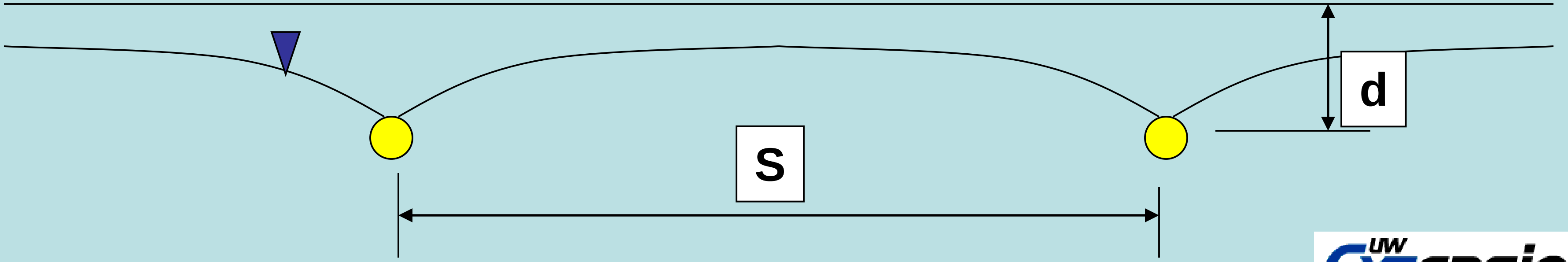
Lateral Depth and Spacing

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



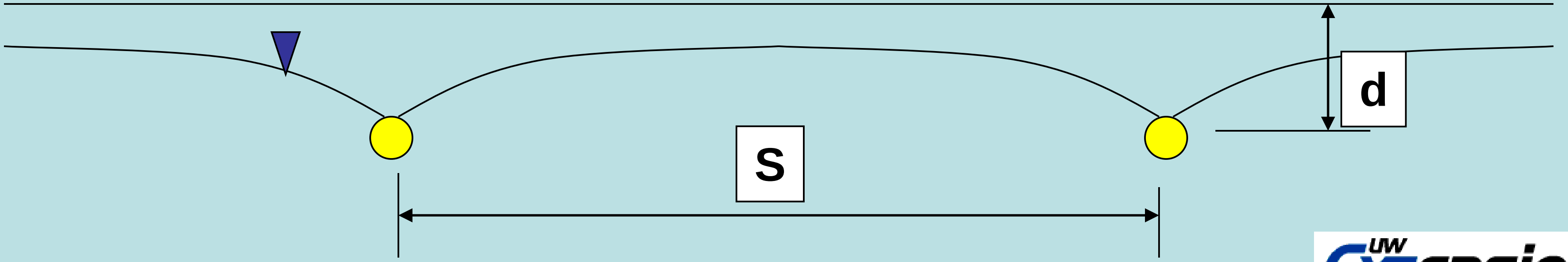
Lateral Depth and Spacing

- ✓ 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.



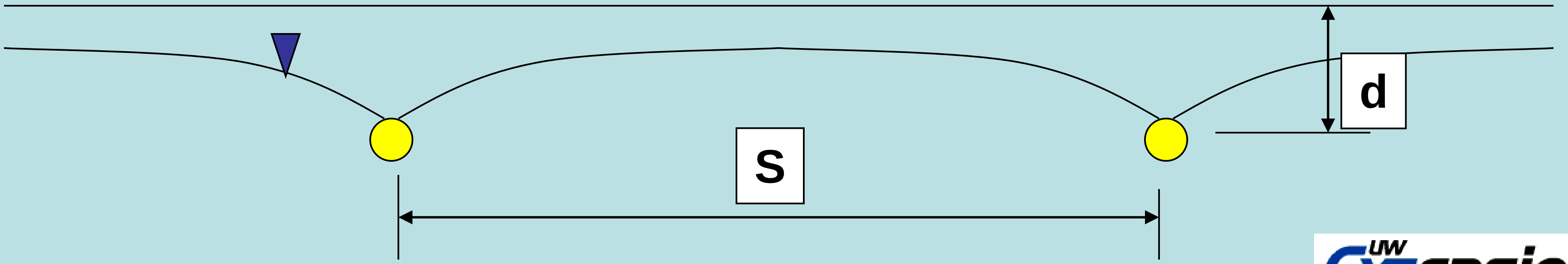
Lateral Depth and Spacing

- ✓ 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.



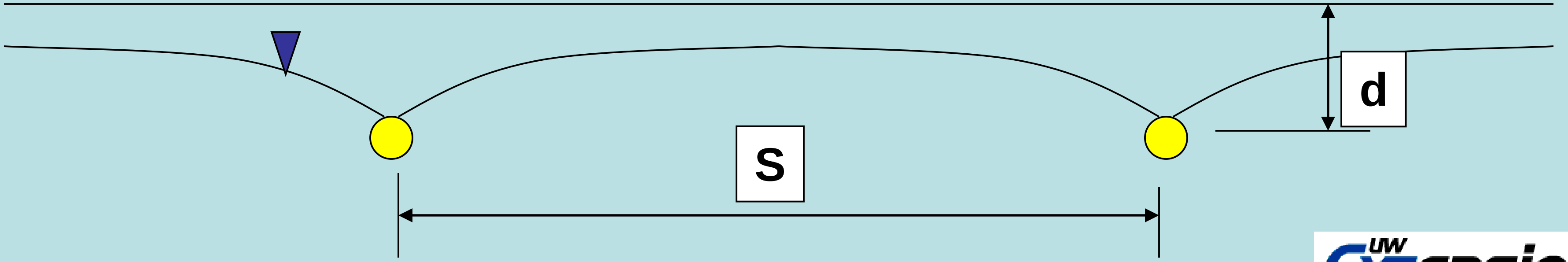
Lateral Depth and Spacing

- ✓ 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.



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.



Lateral Depth and Spacing

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

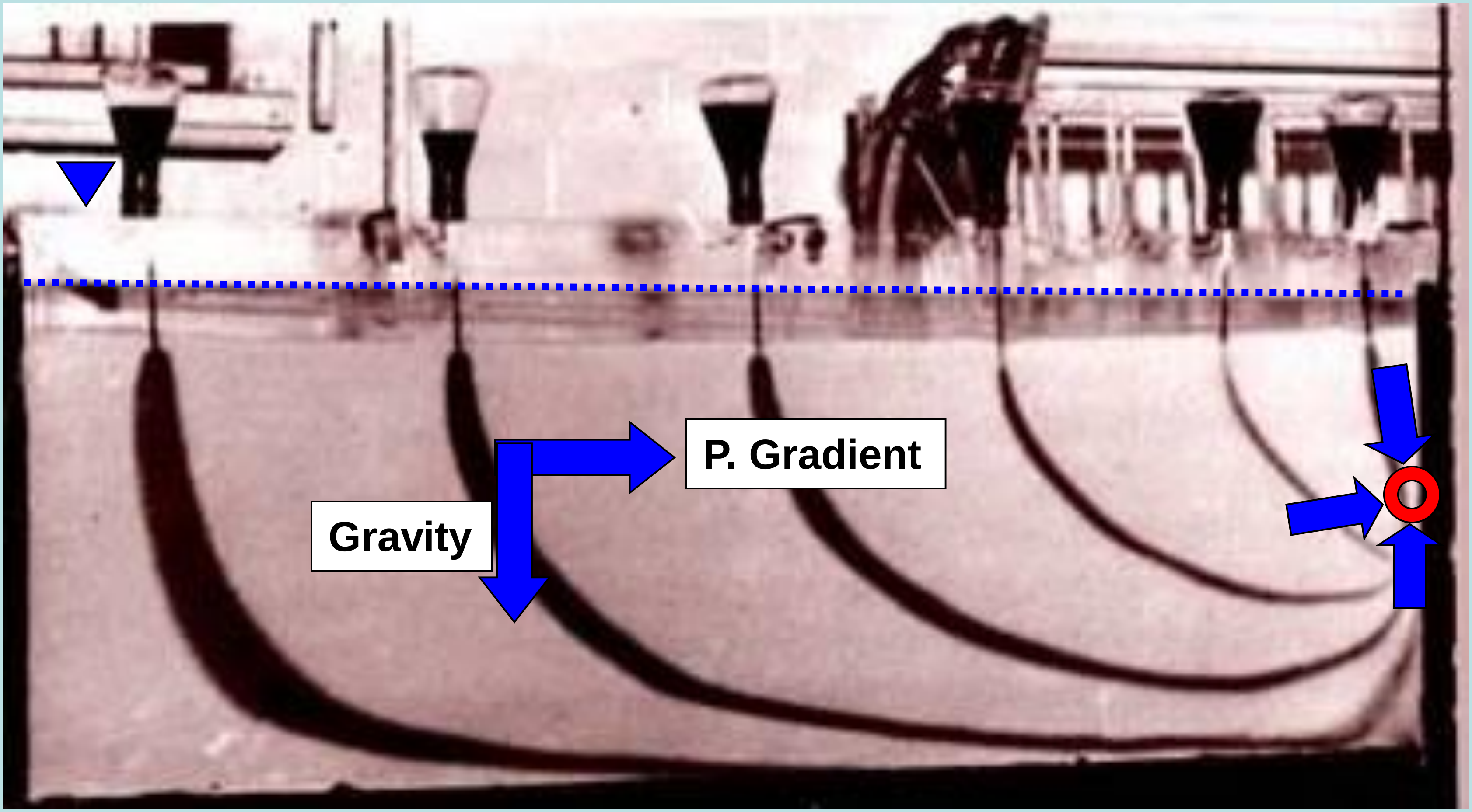
Typical drain depth range = 3 to 6 ft.

Typical spacing = 30 to 100 ft.

Depth / spacing balance to minimize cost.

Minimum cover greater than 2.5 ft.

Flow Though Porous Media



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	Spacing (ft)	Depth (ft)
Clay	30 – 50	3.0 – 3.6
Clay Loam	39 – 69	3.0 – 3.6
Average Loam	59 – 98	3.6 – 4.0
Fine Sandy Loam	98 – 120	4.0 – 4.6
Sandy Loam	98 – 197	4.0 – 5.0
Peat and Muck	98 – 295	4.0 – 5.0
Irrigated Soils	148 - 590	4.0 – 9.8

UW Extension

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

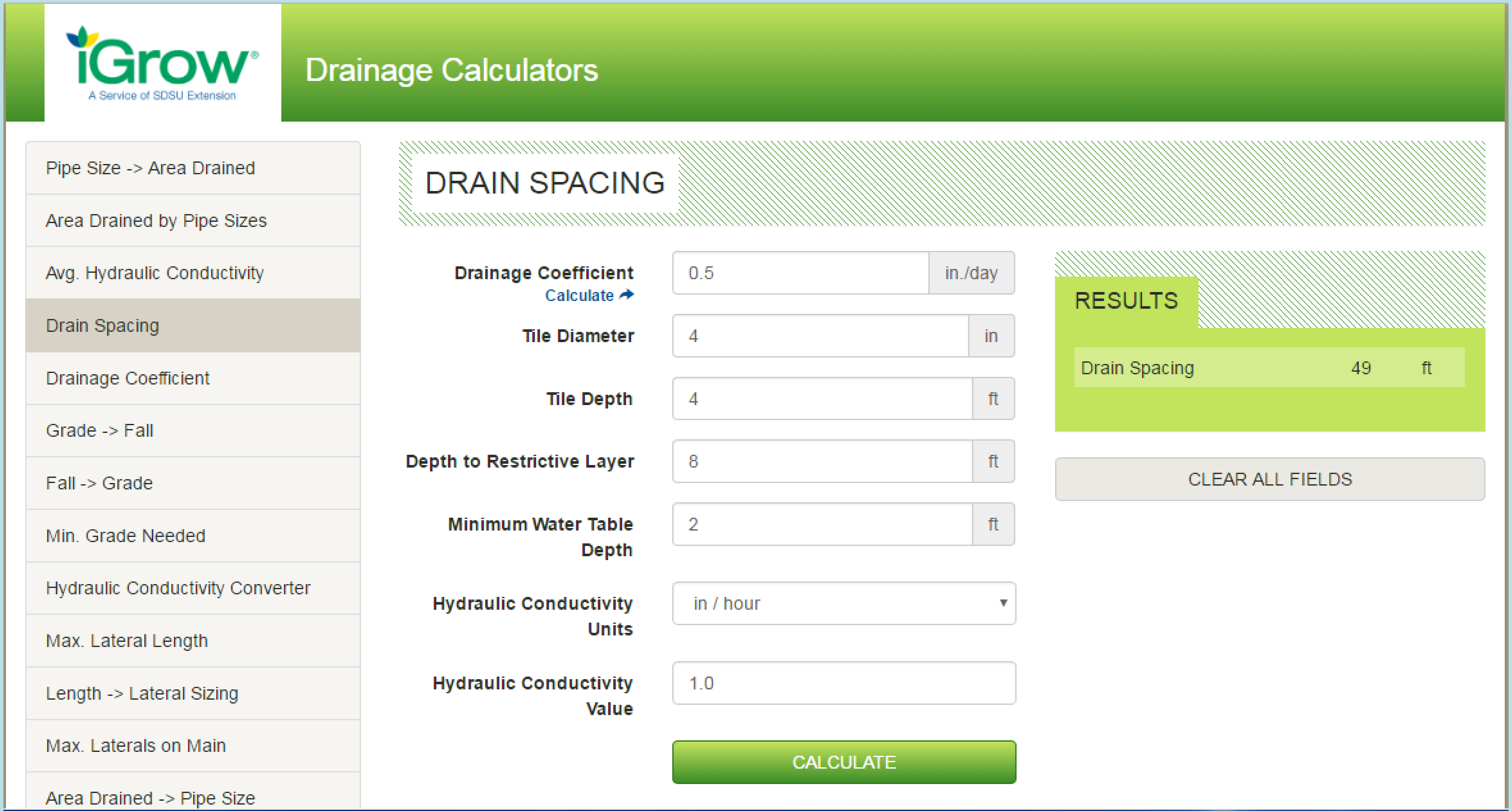
Pipe Size -> Area Drained	Area Drained by Pipe Sizes	Avg. Hydraulic Conductivity	Drain Spacing
Drainage Coefficient	Grade -> Fall	Fall -> Grade	Min. Grade Needed
Hydraulic Conductivity Converter	Max. Lateral Length	Length -> Lateral Sizing	Max. Laterals on Main
Area Drained -> Pipe Size	Pump Size	Subirrigation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

UW Extension

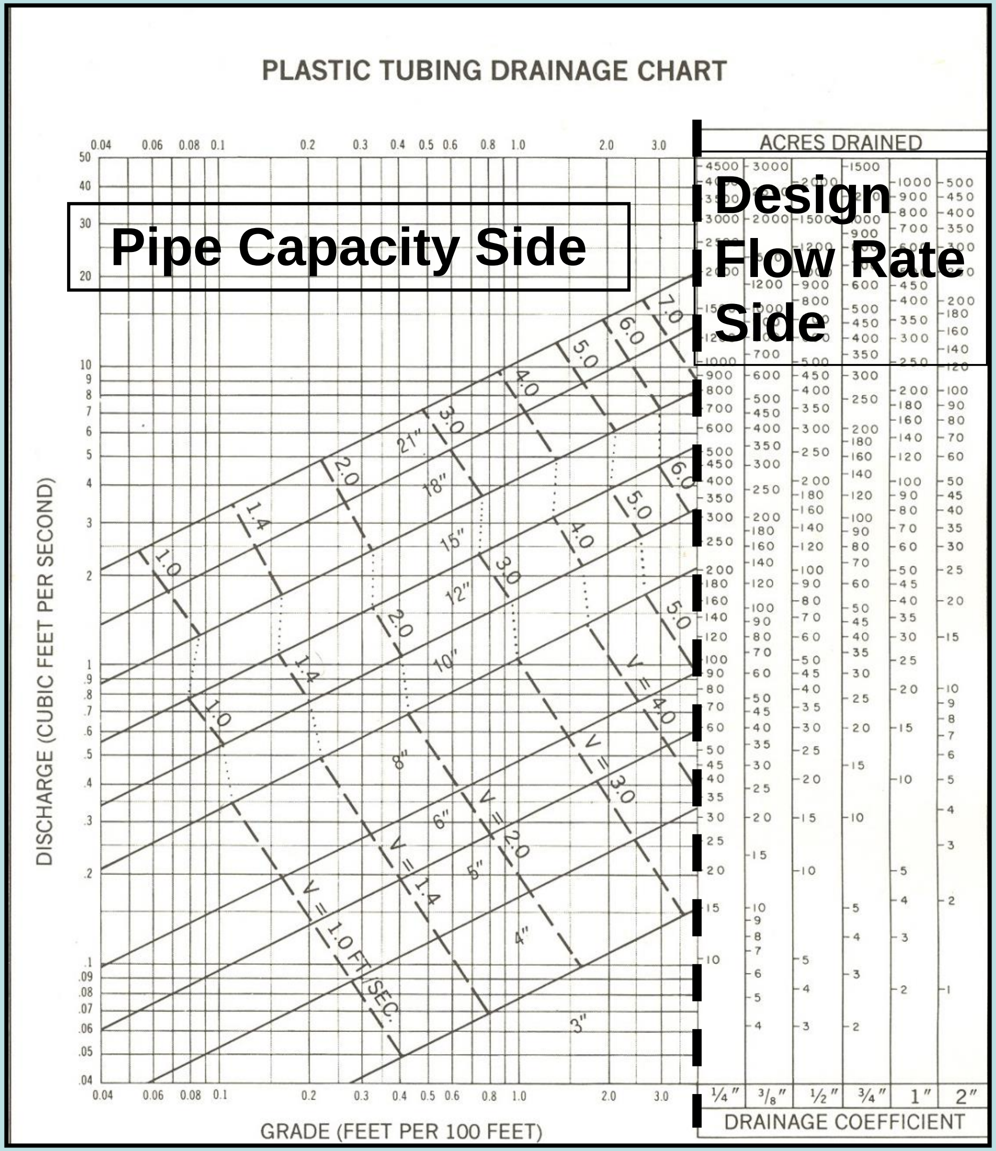
Depth / Spacing - Calculator



UW Extension

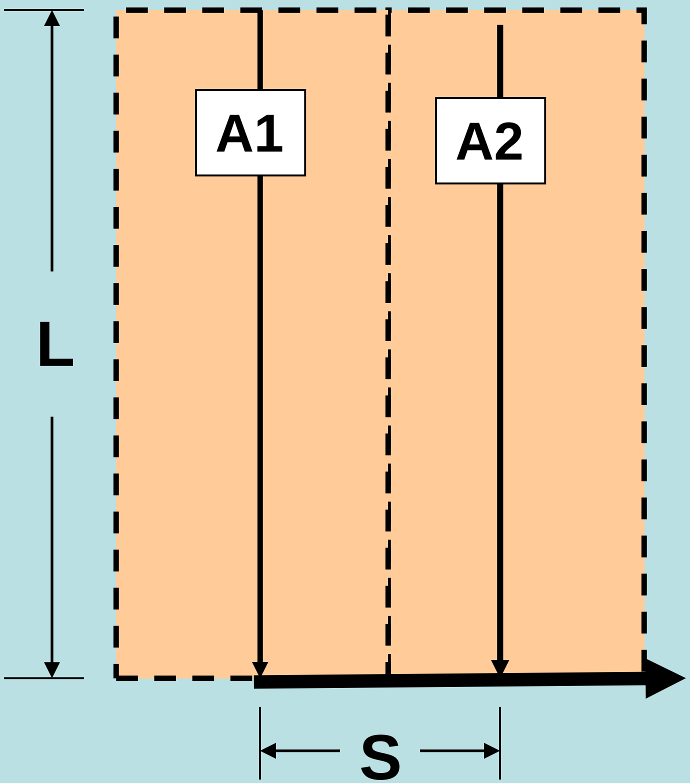
Engineering Design Aids

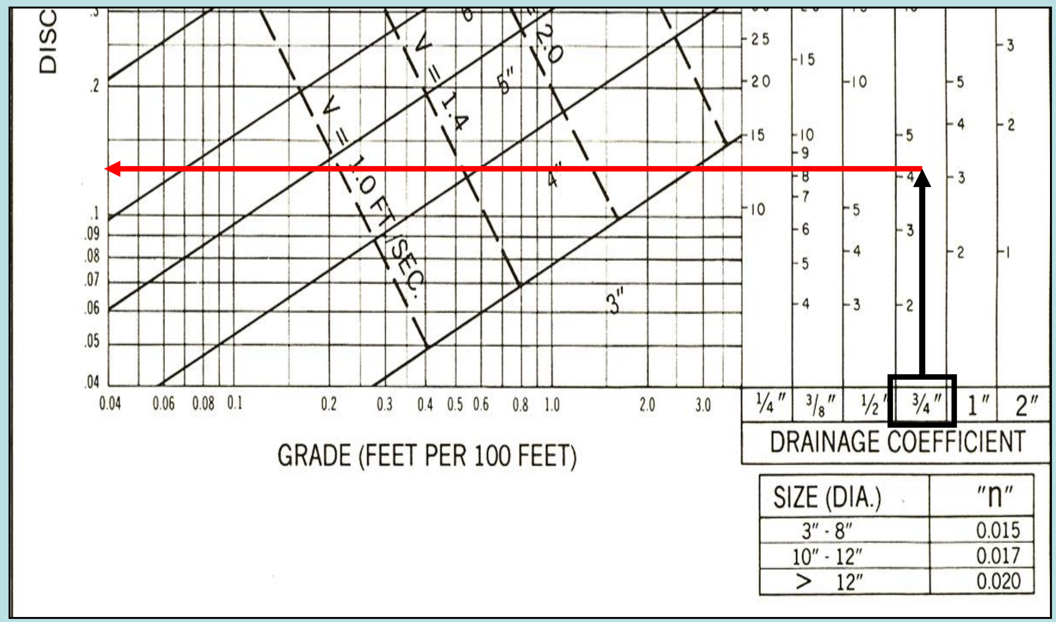
- Tubing Drainage Chart -



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. Pipe Hydraulic Capacity

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

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.

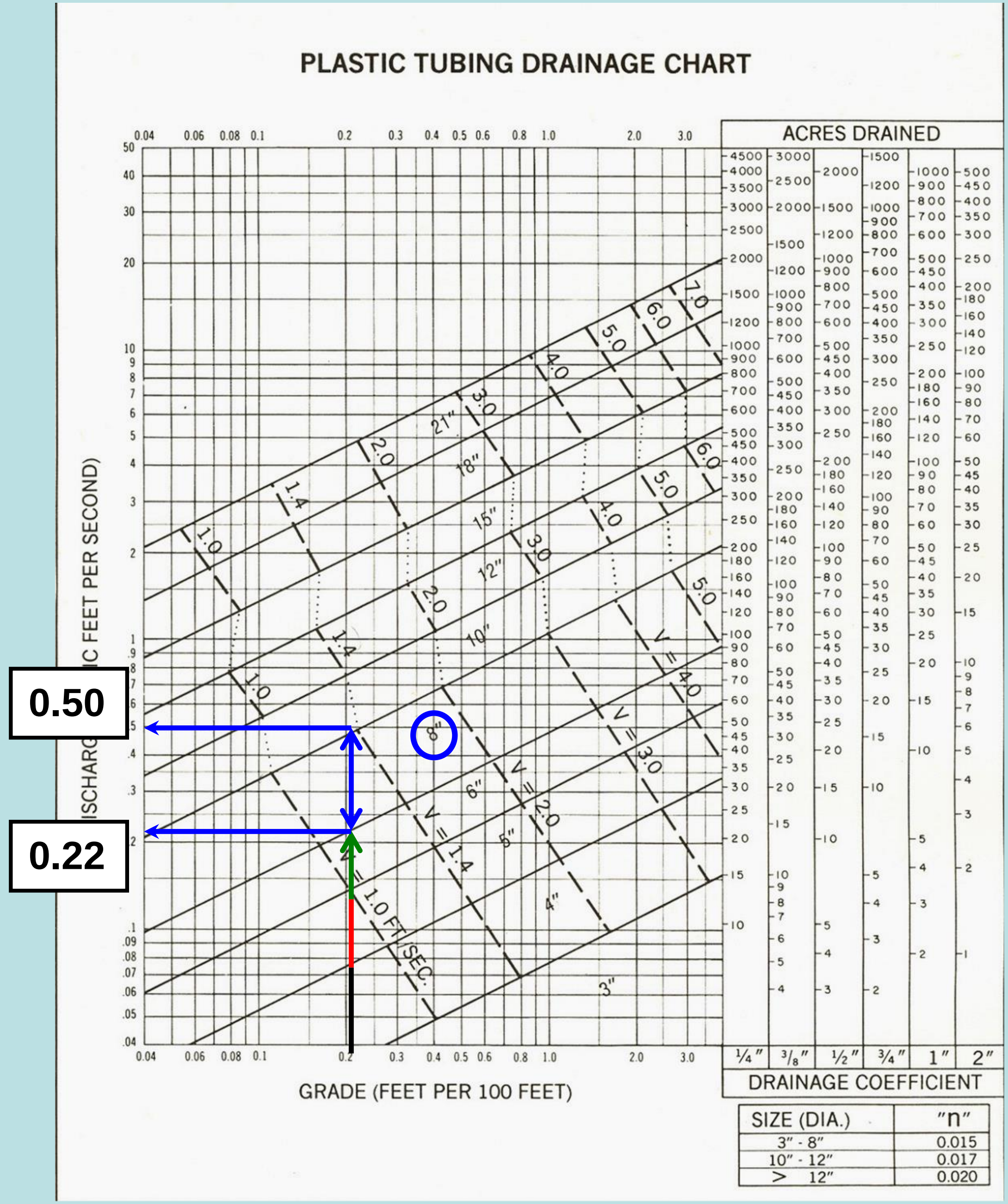
--

8 in diameter pipe @ 0.22 %

= 0.22 to 0.50 cfs
= 99 to 220 gpm

--

cfs x 448.83 = gpm



UW Extension

Example: Drain Size

Determine the diameter of corrugated plastic tubing and the slope needed to drain a 4.3 ac area with a drainage coefficient is ¾ inch.

Pipe Flow Capacity

For Dc = 3/4 in / day

Area = 4.3 ac

Requires:

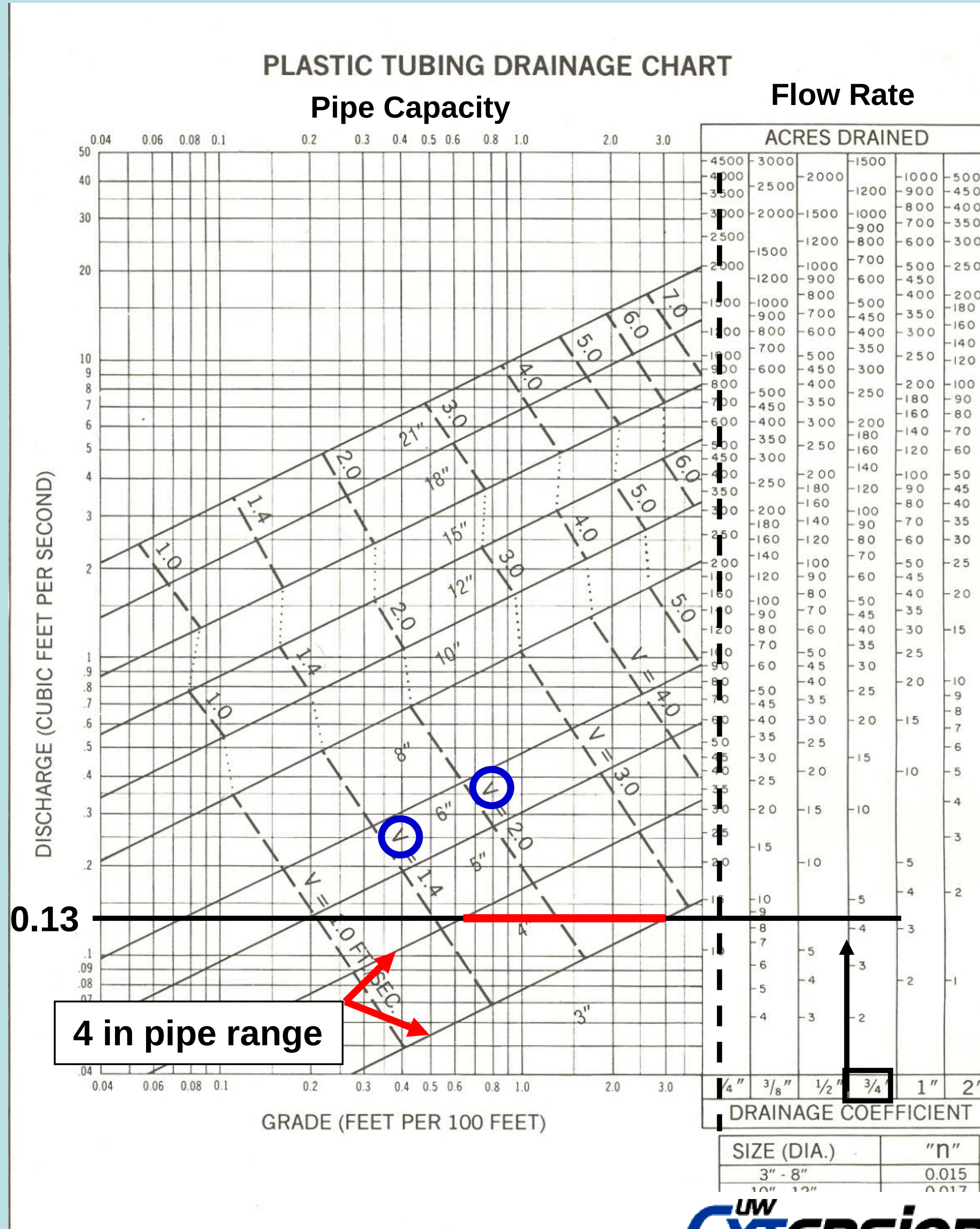
4 in diameter line

Q = 0.13 cfs

Slope range = 0.64 - 3.0 %

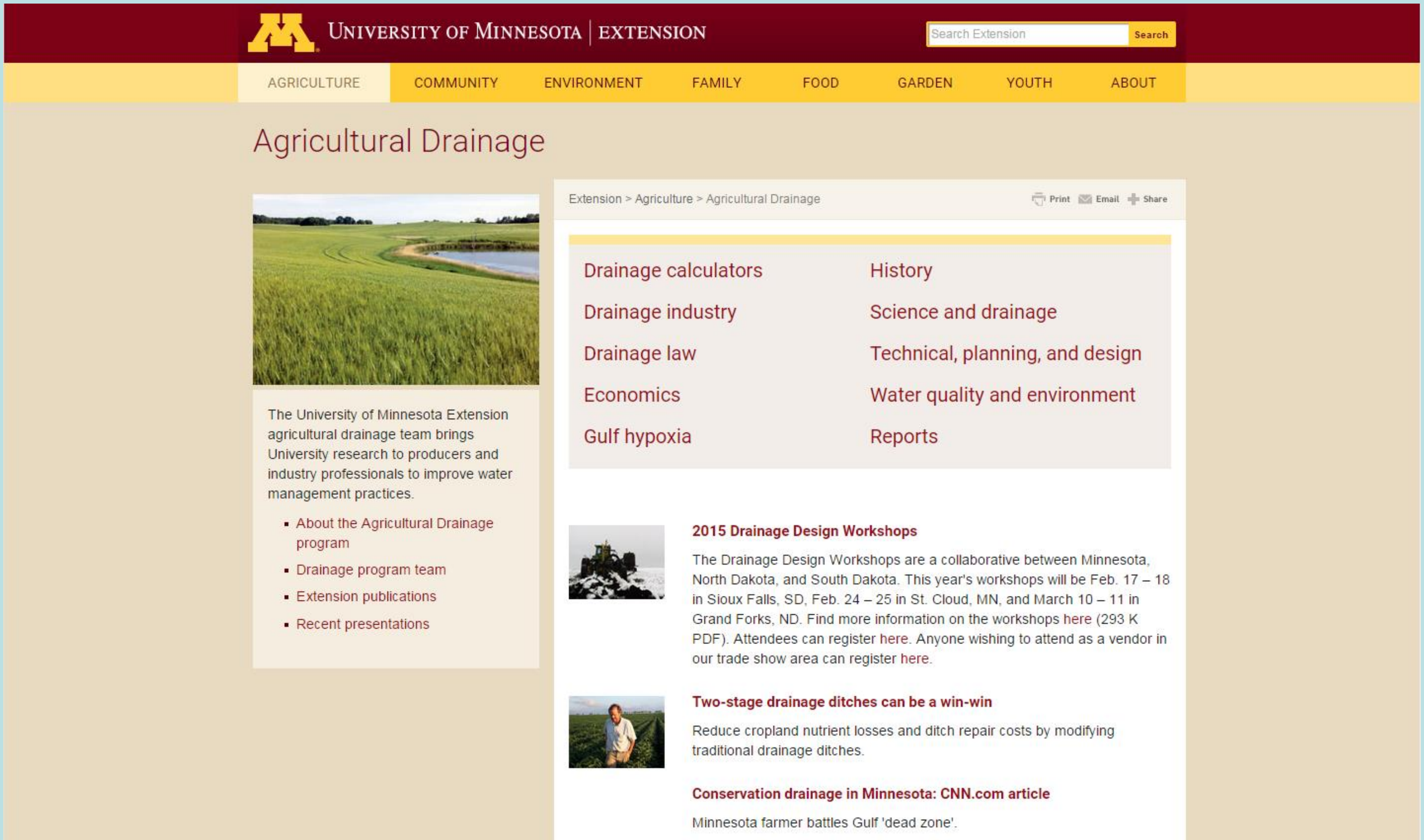
Velocity range = 1.6 – 2.8 ft/sec

Use across different scales to telescope the pipe size



Drainage Resources

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



UNIVERSITY OF MINNESOTA | EXTENSION

Search Extension Search

AGRICULTURE COMMUNITY ENVIRONMENT FAMILY FOOD GARDEN YOUTH ABOUT

Agricultural Drainage

The University of Minnesota Extension agricultural drainage team brings University research to producers and industry professionals to improve water management practices.

- About the Agricultural Drainage program
- Drainage program team
- Extension publications
- Recent presentations

Extension > Agriculture > Agricultural Drainage

Print Email Share

Drainage calculators	History
Drainage industry	Science and drainage
Drainage law	Technical, planning, and design
Economics	Water quality and environment
Gulf hypoxia	Reports

2015 Drainage Design Workshops

The Drainage Design Workshops are a collaborative between Minnesota, North Dakota, and South Dakota. This year's workshops will be Feb. 17 – 18 in Sioux Falls, SD, Feb. 24 – 25 in St. Cloud, MN, and March 10 – 11 in Grand Forks, ND. Find more information on the workshops here (293 K PDF). Attendees can register here. Anyone wishing to attend as a vendor in our trade show area can register here.

Two-stage drainage ditches can be a win-win

Reduce cropland nutrient losses and ditch repair costs by modifying traditional drainage ditches.

Conservation drainage in Minnesota: CNN.com article

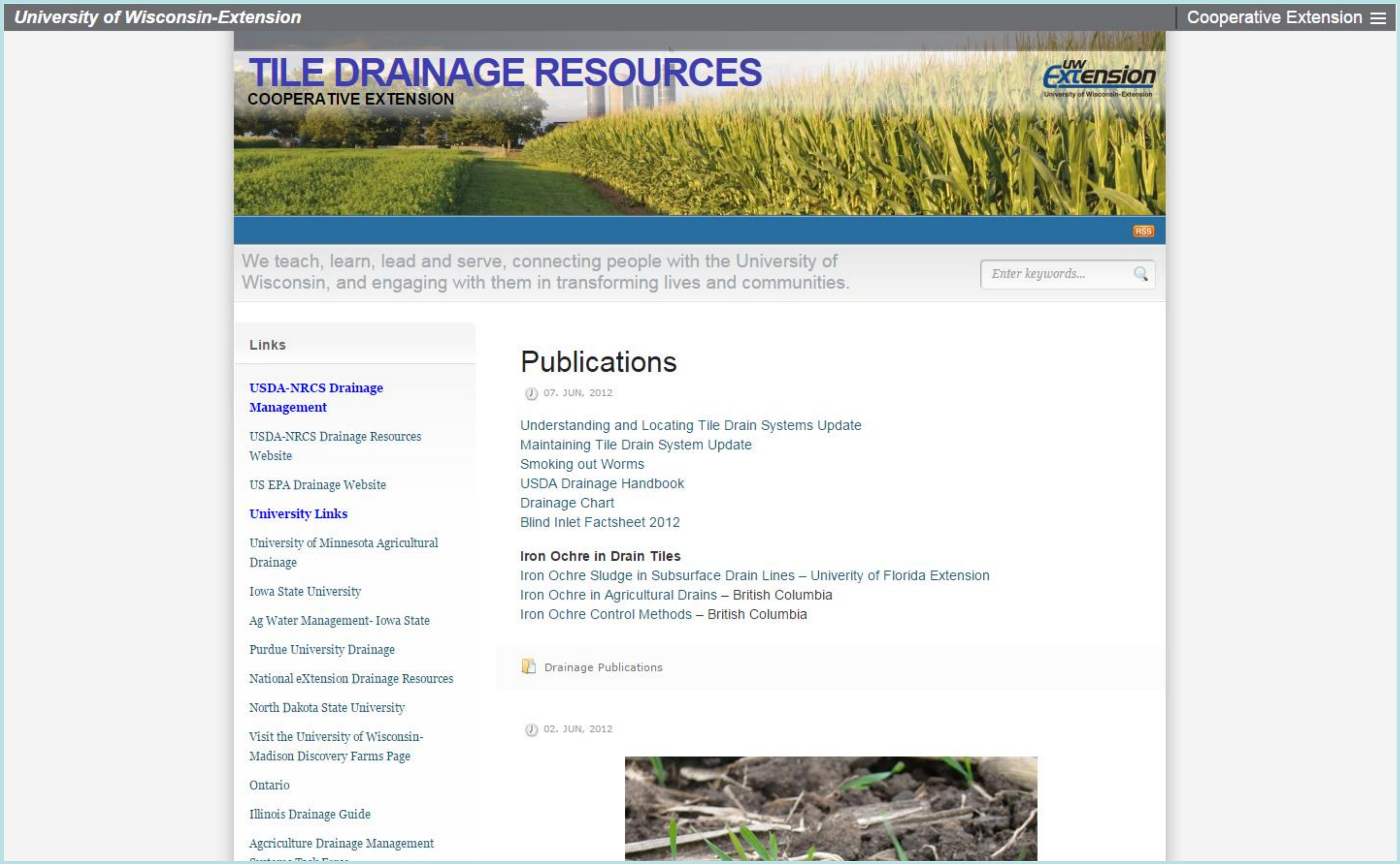
Minnesota farmer battles Gulf 'dead zone'.

From Gary Sands U of MN

UW Extension

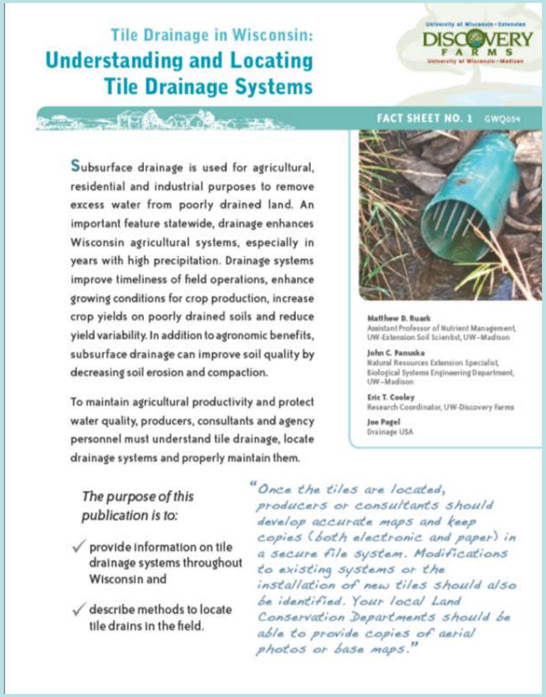
Drainage Resources

http://fyi.uwex.edu/drainage/



Drainage Resources

Learningstore.uwex.edu/



Tile Drainage in Wisconsin:
Understanding and Locating Tile Drainage Systems

DISCOVERY FARMS — University of Wisconsin–Extension, University of Wisconsin–Madison

FACT SHEET NO. 1 GWQ054

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
Assistant Professor of Nutrient Management, UW-Extension Soil Scientist, UW–Madison

John C. Panuska
Natural Resources Extension Specialist, Biological Systems Engineering Department, UW–Madison

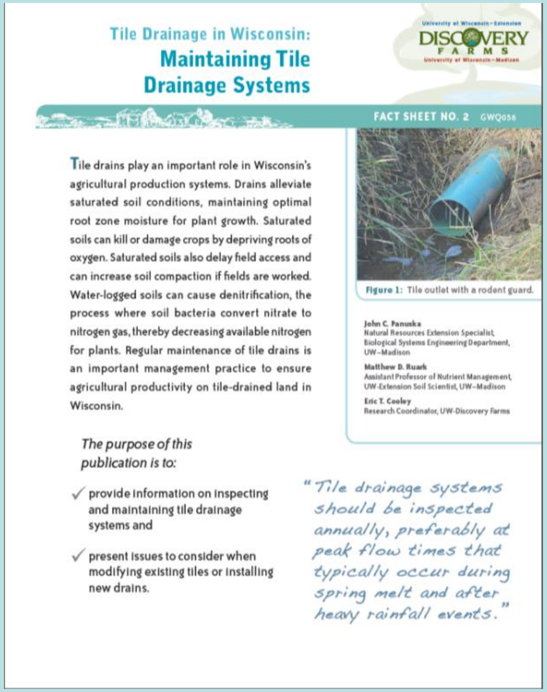
Eric T. Cooley
Research Coordinator, UW-Discovery Farms

Joe Pagel
Drainage USA

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

DISCOVERY FARMS — University of Wisconsin–Extension, University of Wisconsin–Madison

FACT SHEET NO. 2 GWQ056

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.

Figure 1: Tile outlet with a rodent guard.

John C. Panuska
Natural Resources Extension Specialist, Biological Systems Engineering Department, UW–Madison

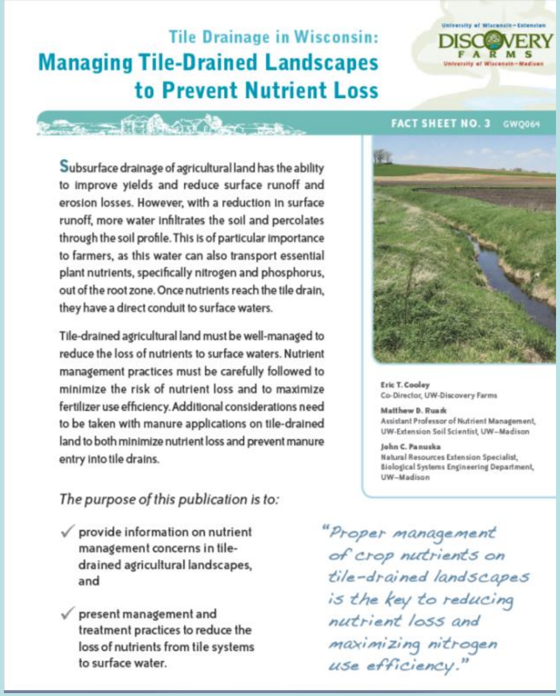
Matthew D. Ruark
Assistant Professor of Nutrient Management, UW-Extension Soil Scientist, UW–Madison

Eric T. Cooley
Research Coordinator, UW-Discovery Farms

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

DISCOVERY FARMS — University of Wisconsin–Extension, University of Wisconsin–Madison

FACT SHEET NO. 3 GWQ064

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
Co-Director, UW-Discovery Farms

Matthew D. Ruark
Assistant Professor of Nutrient Management, UW-Extension Soil Scientist, UW–Madison

John C. Panuska
Natural Resources Extension Specialist, Biological Systems Engineering Department, UW–Madison

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."

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).

UW Extension

Pipe Size and Grades

- Design Boundary Conditions -

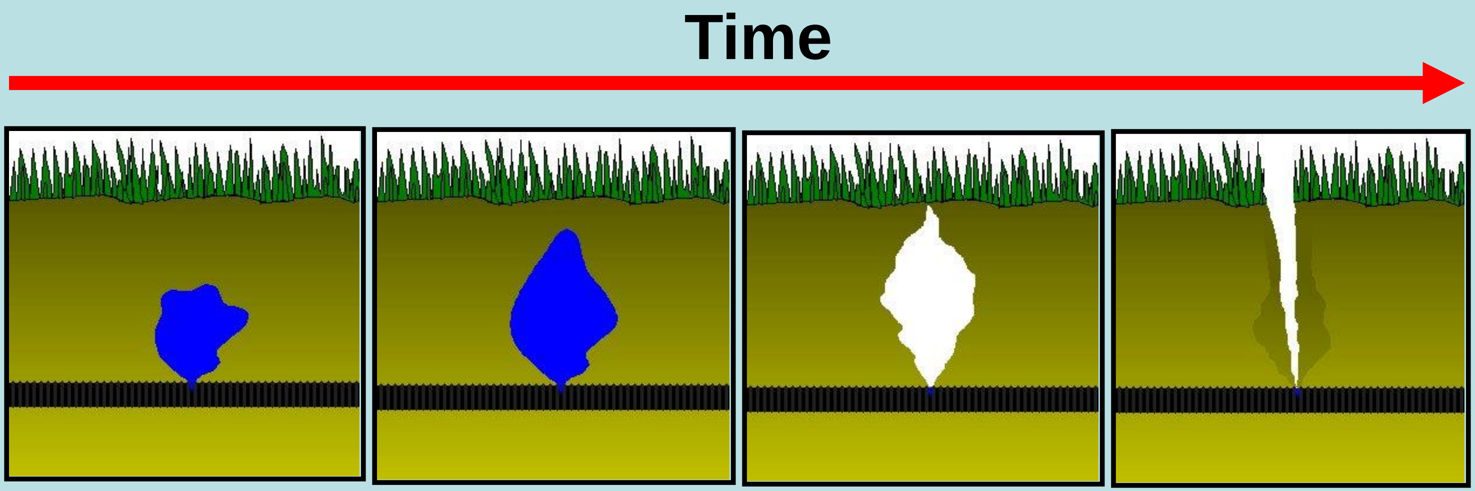
- ✓ Very high velocities can cause "sink holes" when soil is actually pulled into the tile line.
- ✓ "Blowouts" can occur when lines become pressurized.

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 !

UW Extension

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.

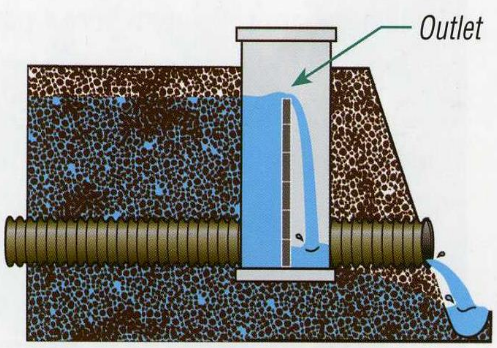


Figure 1. The outlet is raised after harvest to reduce nitrate delivery.

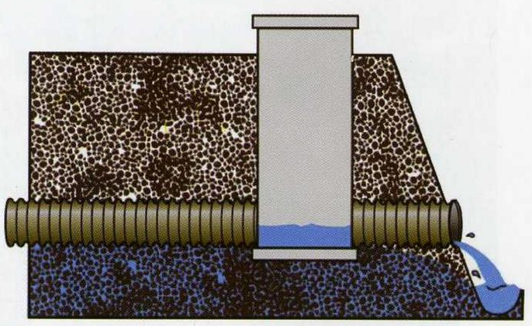


Figure 2. The outlet is lowered a few weeks before planting and harvest to allow the field to drain more fully.

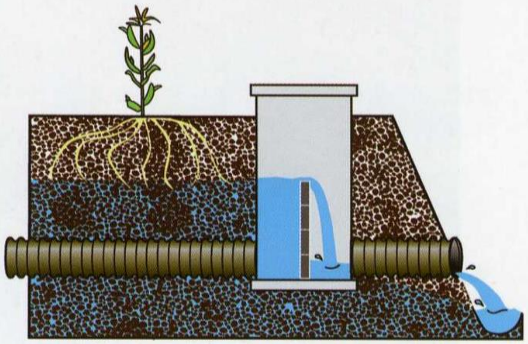


Figure 3. The outlet is raised after planting to potentially store water for crops.

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

UW Extension

Drainage System Cost

- Approximate ! -

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

Rough Range

~ $800 - 1,000 / ac

QUESTIONS ? ? ?