The Basics of Agricultural Tile Drainage

Basic Engineering Principals 2

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ASABE Tile Drain Standards

Design Standard

ASAE EP480 MAR1998 (R2008)

Design of subsurface Drains in Humid Climates
ASABE Tile Drain Standards

Construction Standard

ASABE EP481
FEB03

Construction of subsurface Drains in Humid Areas
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.
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.
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.
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
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).
III. Proper Lateral Depth and Spacing

Drain spacing, water table depth and crop response
Drain depth and spacing integrate the water removal rate ($Dc$) and soil permeability ($K$).
Drain Depth / Spacing - Equation

\[ DC = \frac{(8 \times K_2 \times d \times h)}{L^2} + \frac{(4 \times K_1 \times h^2)}{L^2} \]

Hooghoudt Equation, 1940

Image from Gary Sands – U of MN
Determination of Soil K

The WSS can calculate a depth weighted K value

https://websoilsurvey.sc.egov.usda.gov/
The goal is to maintain as consistent a $D_c$ value across the field as possible.
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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Lateral Depth and Spacing

- A relationship exists between depth and spacing of drains.
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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.

<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>Spacing (ft)</th>
<th>Depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay</td>
<td>30 – 50</td>
<td>3.0 – 3.6</td>
</tr>
<tr>
<td>Clay Loam</td>
<td>39 – 69</td>
<td>3.0 – 3.6</td>
</tr>
<tr>
<td>Average Loam</td>
<td>59 – 98</td>
<td>3.6 – 4.0</td>
</tr>
<tr>
<td>Fine Sandy Loam</td>
<td>98 – 120</td>
<td>4.0 – 4.6</td>
</tr>
<tr>
<td>Sandy Loam</td>
<td>98 – 197</td>
<td>4.0 – 5.0</td>
</tr>
<tr>
<td>Peat and Muck</td>
<td>98 – 295</td>
<td>4.0 – 5.0</td>
</tr>
<tr>
<td>Irrigated Soils</td>
<td>148 - 590</td>
<td>4.0 – 9.8</td>
</tr>
</tbody>
</table>
## Depth / Spacing - Calculator

**Drainage Calculators**

Utilize these calculators to address common drainage questions. Additional information is available on [iGrow](http://www.igrowdrainage.org/)

<table>
<thead>
<tr>
<th>Pipe Size -&gt; Area Drained</th>
<th>Area Drained by Pipe Sizes</th>
<th>Avg. Hydraulic Conductivity</th>
<th>Drain Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage Coefficient</td>
<td>Grade -&gt; Fall</td>
<td>Fall -&gt; Grade</td>
<td>Min. Grade Needed</td>
</tr>
<tr>
<td>Hydraulic Conductivity Converter</td>
<td>Max. Lateral Length</td>
<td>Length -&gt; Lateral Sizing</td>
<td>Max. Laterals on Main</td>
</tr>
<tr>
<td>Area Drained -&gt; Pipe Size</td>
<td>Pump Size</td>
<td>Subirrigation Spacing</td>
<td>Sump Storage</td>
</tr>
</tbody>
</table>

Visit [iGrow.org](http://www.igrowdrainage.org/) for the latest information from SDSU Extension. This tool was developed in collaboration with [University of Minnesota Extension](http://www.extension.umn.edu/).  
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http://www.igrowdrainage.org/
Engineering Design Aids
- Tubing Drainage Chart -
Area drained = L x S; L = 1,500 ft; S = 61 ft;
$A_T = \frac{(1,500 \times 122)}{43,560} = 4.2 \text{ ac}$; $Dc = \frac{3}{4} \text{ in.}$

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 (ft³/sec)

Manning’s equation for gravity pipe flow

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

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
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 $\frac{3}{4}$ 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/

Agricultural Drainage

Drainage calculators
Drainage industry
Drainage law
Economics
Gulf hypoxia

History
Science and drainage
Technical, planning, and design
Water quality and environment
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
Drainage Resources

Learningstore.uwex.edu/

Tile Drainage in Wisconsin: Understanding and Locating Tile Drainage Systems

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.

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 department should be able to provide copies of aerial photos or late maps."

Tile Drainage in Wisconsin: Maintaining Tile Drainage Systems

The 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. Waterlogged 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.

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

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.

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

<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>Max. Velocity ft/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand &amp; sandy loam</td>
<td>3.5</td>
</tr>
<tr>
<td>Silt &amp; silt Loam</td>
<td>5.0</td>
</tr>
<tr>
<td>Silty clay loam</td>
<td>6.0</td>
</tr>
<tr>
<td>Clay &amp; Clay loam</td>
<td>7.0</td>
</tr>
<tr>
<td>Course sand or gravel</td>
<td>9.0</td>
</tr>
</tbody>
</table>
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.

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 ?? ??