Missouri One Call 1-800-DIG RITE
(800-344-7483) *or* 811 *or* mo1call.com

Be Careful When Digging

- Digging can be very **DANGEROUS**
- There are many dangers **UNDERGROUND**
- Use Best Practices to **BE SAFE**

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The Most **Common Causes of Damages**

1. Working without a locate request.
2. Failing to confirm the response of all utilities before beginning excavation.
3. Working outside the area described on the locate request.
4. Beginning excavation before the start date and time.
5. Beginning work before all utilities at the site have marked or responded.
6. Neglecting to place a "No Response" ticket.
7. Assuming the depth of a facility.
8. Failure to exercise due care while digging, blind boring or directional drilling in the "approximate location" of underground facilities.
9. Assuming that the "Approximate Location" marks are exactly accurate and mechanically digging right up to the marks

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An excavator is anyone performing a digging operation.

An excavator can be:

- A homeowner
- A professional contractor
- An underground facility owner

Missouri state law requires EVERY person, whether digging on public or private property, to make notification prior to starting that excavation.

The EXCAVATOR is responsible for making notification:

- At least TWO working days before beginning the excavation *(The two working day period begins at midnight on the day the call is made).*
- But not more than TEN working days before beginning excavation.

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Provide Key Information

When making notification it is essential to provide **detailed** information about the location of the excavation. Give:

- Specific address, or GPS coordinates if available
- Distances and directions from the nearest intersection of a posted, numbered, lettered, or named street, road, or highway.

Also describe where you are excavating at the site in relation to a landmark of the site

The following is the information necessary to complete your locate request.

It is essential that all contact information is correct and current in order to receive utility response.

Caller Information

Name and Telephone number

Excavator Information

Excavator Name

Office Phone number

Recording Device

Mailing Address:

Email Address:

Fax Number

Onsite Contact Information

First & Last Name: Cell Number

Excavation Information

Type of Work:

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Ticket Types

ROUTINE
This is a regular locate request.

NO RESPONSE
To be requested when one or more utilities fail to respond to the original locate request. *(See page 36)*

EMERGENCY
Only to be requested when the situation meets the legal definition of an emergency. *(See page 39)*

DIG UP
Excavator legally required to only notify MOCS when damage to facilities has occurred. If damage involves pipeline or natural gas facilities, both 911 and the affected utility must also be notified. *(See page 38)*

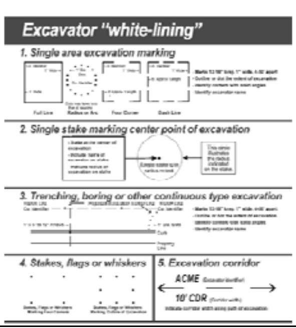
RENEWAL
To be used when previous marks are not visible and need to be remarked due to weather, construction or work not starting. *(See page 31)*

PRELIMINARY DESIGN
To be requested to determine what facilities are present when planning a project. Contact names and phone numbers will be supplied. No markings will be made.

DESIGN
To be requested when planning a project. Will generate actual markings at the site. Utilities allowed 5 working days to respond. Excavation cannot take place on a design ticket. A routine locate request must be placed before beginning work. *(See page 32)*

White Lining

Marking the dig site with white flags or paint is strongly recommended. "White Lining" improves the utilities ability to do a fast and accurate locate, directly benefiting the excavator.



Call Timeline Chart

(dark)	Date of call – does not count.
(light)	Two working days waiting period for locates.
(medium)	Date digging may begin. *See "No Response" below*

Call Timeline:

	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu
Mon		1	2								
Tue			1	2							
Wed				1	2						
Thu					1			2			
Fri								1	2		
Sat								1	2		
Sun								1	2		

The two working days shall begin at 12 midnight following the receipt of the request by the notification center. The day of the call does not count as a "working day". "Working days" do not include weekends and holidays.

The state law says excavators must give notice at least two but not more than ten working days before the work is to begin. It also says that when markings have been provided, excavators may continue to work within the area described in the notice for as long as the markings are visible. *(See page 31, #6)*

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Color Codes

White	PROPOSED EXCAVATION
Fluorescent Pink	TEMPORARY SURVEY MARKINGS
Red	ELECTRIC POWER LINES, CABLES, CONDUIT AND LIGHTING CABLES
Yellow	GAS, OIL, STEAM, PETROLEUM OR GASEOUS MATERIALS
Orange	COMMUNICATION, ALARM OR SIGNAL LINES, CABLES OR CONDUIT
Blue	POTABLE WATER
Purple	RECLAIMED WATER, IRRIGATION AND SLURRY LINES
Green	SEWERS AND DRAIN LINES

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Wait time exception if the utility fails to complete the locate:

- Excavator must make a second "NO RESPONSE" ticket request.
  - Utility will have 2 hours to respond if Excavator calls by 2 pm.

    OR
  - Utility will have until 10 am the following day if Excavator calls after 2 pm.

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17	18	19	20	21	22 CALL	23 Wait
24 Wait	25 X-MAS Wait	26 Wait (1)	27 Wait (2)	28 No Locate Call after 2 pm	29 Wait until 10 am	30 Start Work Maybe ?
31	1 New Years Day	2	3	4	5	6

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Free Educational Packets

Free educational packets are available on the MOCS website.

Each packet contains the MOCS Excavator Manual, a Locate Request pad, Quick Reference card, Color Code card, sticker and a pen.

Keep the packet in your truck for field reference.

To order the packets go to the MOCS website www.mo1call.com.
Click on "Excavator Information" then "Order MOCS Materials" to submit your order.

Planning a Subsurface Drainage System

NRCS

Marty Comstock, P.E.
Agricultural Engineer

Drainage System Layout

- In this presentation, we'll look at:
  - Factors affecting the layout
  - Layout alternatives
  - Selecting the lateral drain spacing

Drainage System Layout

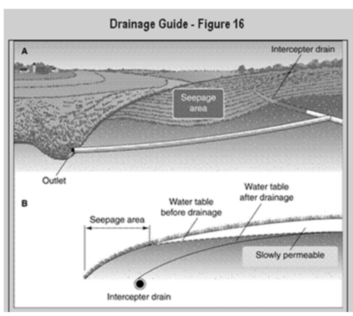
- Factors affecting layout
  - Operator's goals
  - Field topography
    - Low spots
    - High spots
    - Slope
  - Outlet location & depth

Drainage System Layout

- Possible Operator Goals:
  - Removing water from an isolated problem area
  - Improving drainage in an entire field
  - Water table management (Controlled drainage)
  - Sub irrigation
  - Economics $ $ $ $ $ $ $ $
  - Increase yields & profits

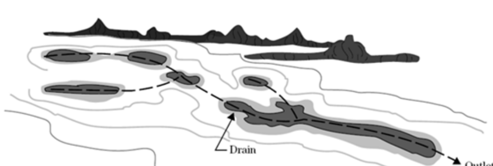
Layout Alternatives

- Interceptor Drain used to drain hillside seeps.
- Drain is installed parallel to slope above seepage area.



Source: Illinois Drainage Guide, University of Illinois

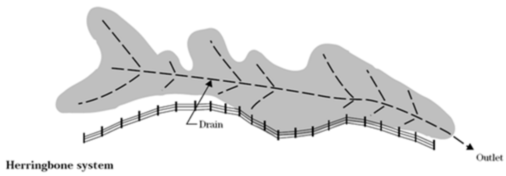
Layout Alternatives



Random system

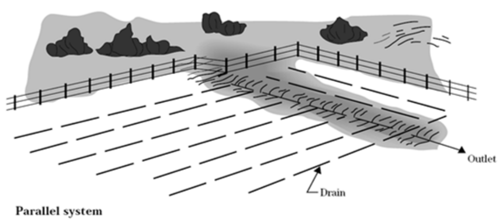
- Random Systems are used to drain isolated wet depressional areas.

Layout Alternatives



- Herringbone Systems are used to drain wet swale areas with land sloping to it from both sides.
- It provides “double drainage” along the main.
- Also used to optimize lateral line grades.

Layout Alternatives



- Parallel Systems are used to drain entire field areas.
- Can also provide controlled drainage and sub irrigation.

Pattern Drainage Components

- Main Lines
- Lateral Lines
- Surface Inlets
- Water Control Structures
- Junction Boxes
- Outlets

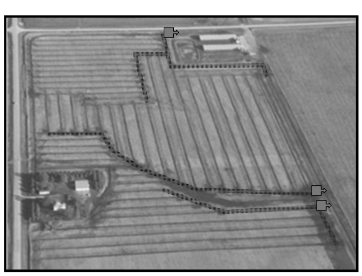
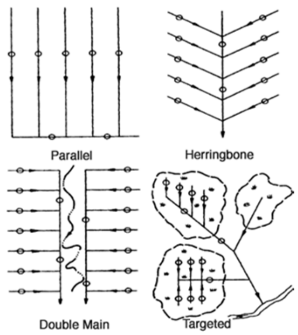


Photo Credit: www.gpsdrainage.com

Layout Alternatives

- Elements of Parallel systems can be incorporated into the Random (Targeted) and Herringbone systems.
- In general, the more lateral connections, the higher the cost.



Topography Considerations Pattern System Layout

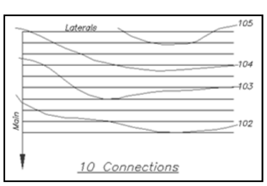
Laterals should be oriented with the field's contours as much as possible

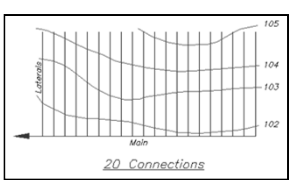
a. Desirable: laterals are aligned with field contours

b. Undesirable: laterals cross field contours at right angles

- <u>Advantages</u>:
  - Laterals will intercept more down slope seepage.
  - Usually results in more grade on mains.
  - Will be easier to "zone" for drainage management.

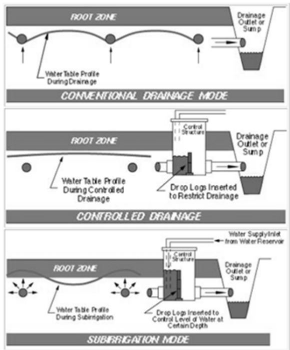
Topography Considerations Pattern System Layout





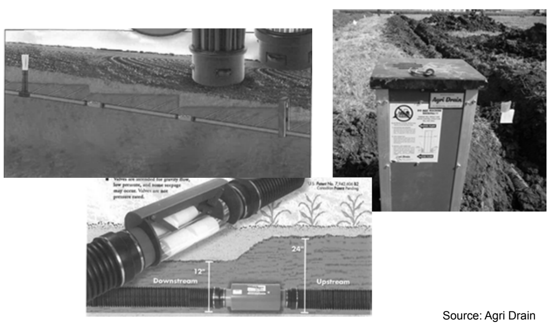
- Long Laterals and Short Mains
  (Minimize connections)

Drainage Water Management



Source: Extension Bulletin 871-98, The Ohio State University

DWM Structures



Source: Agri Drain

Drainage Water Management

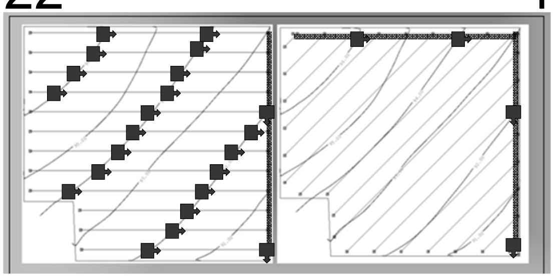
- Field must be managed in zones where the water table has less than 2 feet of variation.
- Works best on flat uniform fields (slope less than 0.5 %)
- Can work on steeper fields if the laterals are located with the contour of the land.

Drainage Water Management

- Drainage water management can be added to existing drainage systems.
  - Requires a map of the drainage system layout.
  - Requires knowing the sizes and grades of mains and laterals.

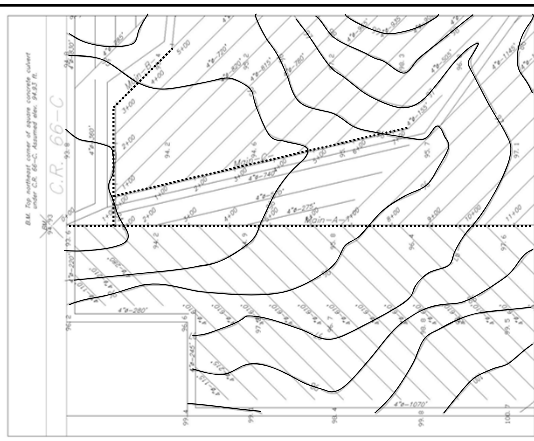
Topography Considerations Pattern System Layout

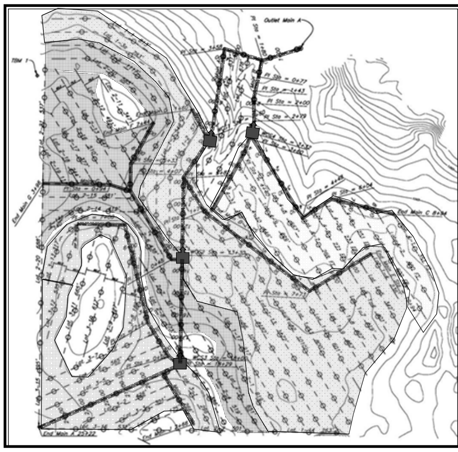
22 4



Which would work best for Drainage Water Management?

Source: Illinois Drainage Guide, University of Illinois





QUESTIONS

Drain Outlets

Drain Outlets

- Provide a "free" (not restricted) outlet with adequate capacity.
- Discharge flow without erosion damage.
- Have adequate depth of cover (frost action and traffic loads).
- Protected from rodents and animals.
- Structurally sound.
- Prevent back flooding.

Drain Outlets

Free Outlet without Erosion:

Drainage Guide - Figure 4

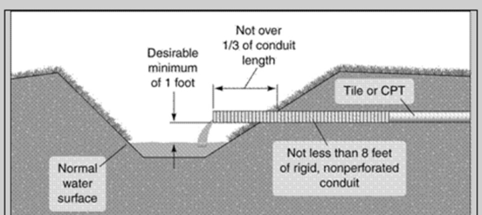
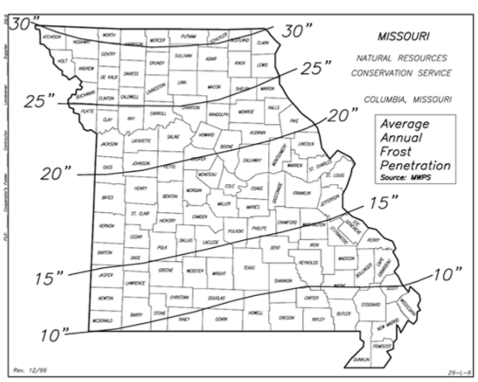


Figure 4. Entrance of a subsurface drain into an outlet channel.

Source: Illinois Drainage Guide, University of Illinois

Drain Outlets



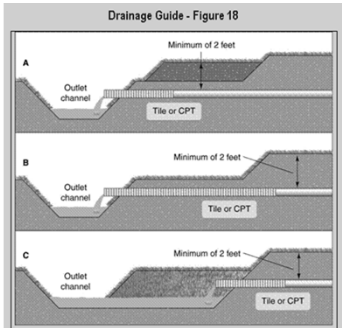
Drain Outlets

Adequate Cover Depth:

A. Add more fill.

B. Use stronger outlet pipe.

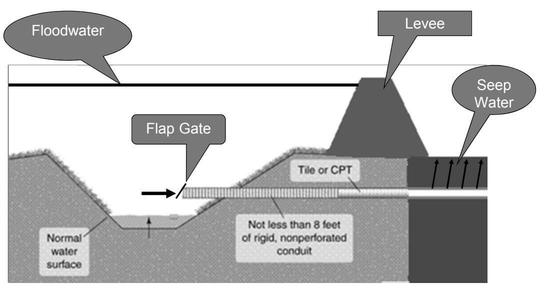
C. Recess outlet in bank.



Source: Illinois Drainage Guide, University of Illinois

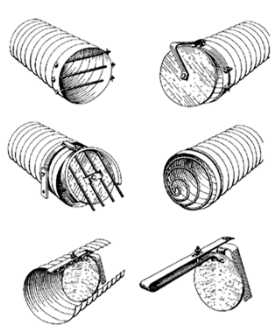
Drain Outlets

Preventing Back Flooding:



Drain Outlets

Animal Guards:

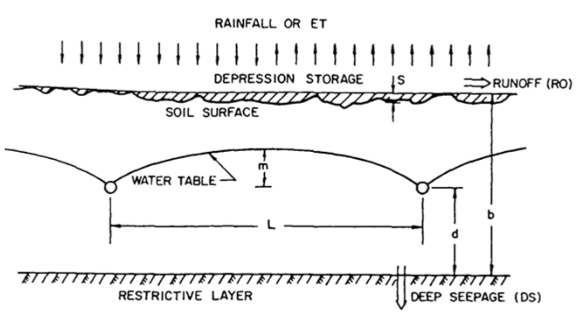


Drain Outlets

ANY CONCERNS ??

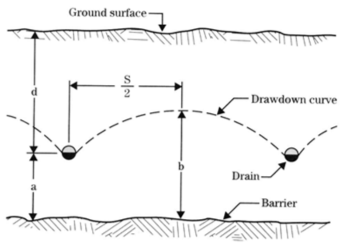
QUESTIONS

Water Movement to Drains



Ellipse Equation

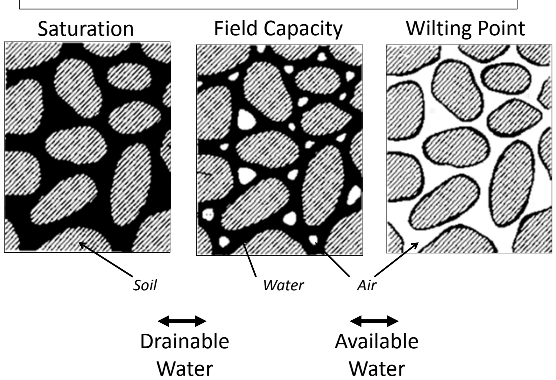
$$S = (4K(b^2-a^2)/q)^{0.5}$$

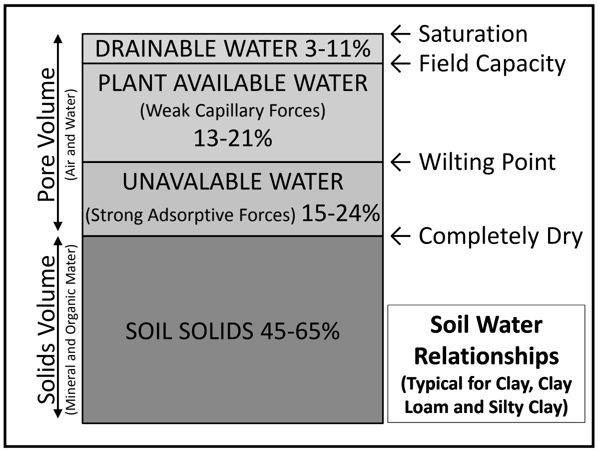


Ellipse Equation Variables

- q, Required drainage rate (in/hr), Drainage Coefficient
  - Based on climate, crop, soils, drainable soil water volume . . .
- K, Hydraulic conductivity (in/hr)
  - Field investigation
  - Soil survey
  - Predict from other properties, such as soil texture
- d, Drain tile depth (ft)
  - Minimum cover requirements
  - Restrictive layer
- b, Vertical distance of water table above drain at midpoint (ft)
  - Typical design value to meet goals for crop growth
- a, Depth of impermeable layer (ft)
  - Soil Survey verified with field investigation

Soil Water

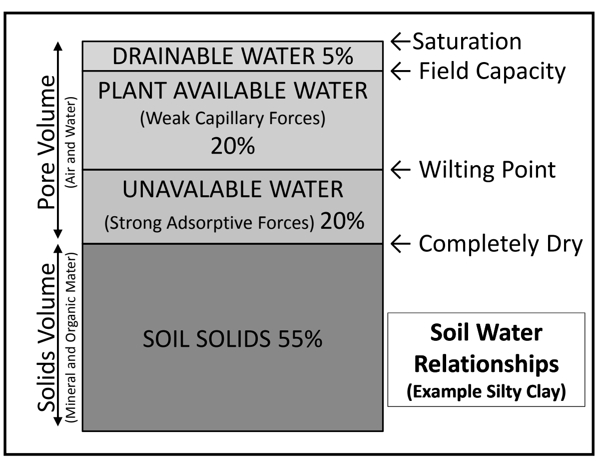




Typical Soil Water Relationships

Soil Texture	Wilting Point (% by vol.)	Available Water (% by vol.)	Drainable Water (% by vol.)
clays, clay loams, silty clays	15-24	15-26	3-11
well structured loams	8-17	12-22	10-15
sandy	3-10	6-15	18-35

Source: University of Minnesota BU-07644-S, Soil Water Concepts, Gary Sands



How much water do I need to remove?

Given a soil (silty clay) with a drainable porosity of 5% with the goal of draining the top 12 inch layer in 48 hours.

Volume of drainable water
= 5% x 12 inch depth
= 0.6 inches

Rate of removal
= 0.6 inch ÷ 2 day
= 0.3 inch/day

How much water do I need to remove?

Given a soil (loam) with a drainable porosity of 12% with the goal of draining the top 12 inch layer in 48 hours.

Volume of drainable water
= 12% x 12 inch depth
= 1.4 inches

Rate of removal
= 1.4 inch ÷ 2 day
= 0.7 inch/day

Selecting a Drainage Coefficient (D.C.)

- D.C. is the depth of water to be removed from the drained area in 24 hours.
- D.C. is a function of:
  - Organic vs. mineral soils
  - Soil texture and drainable water
  - Sensitivity of crop to high water table
  - Topography and surface drainage
  - Presence of surface inlets
- Reference NRCS Practice Standard 606 for Missouri

Drainage Coefficient

Ref: *Missouri* NRCS *Subsurface* Drain Standard 606

SOIL	FIELD CROPS	TRUCK CROPS
Mineral	⅜" to ½"	½" to ¾"
Organic	½" to ¾"	¾" to 1½"

Converting the D.C. to cfs

- D.C. units are inch / day
- Pipe flow rates are cfs (cubic feet per second)
- To convert in/day to cfs:
  - Q = 0.042 x DC x DA
- Example: DC= 3/8 in/day, DA = 1 acre

  Q = 0.042 x 0.375 in/day x 1 ac

  Q = <u>0.0158 cfs</u>

Your Turn
Converting the D.C. to cfs

- Given: DC= 1/2 in/day, DA = 80 acres

What is the total drainage rate, Q, needed?

Q = 0.042 x DC x DA

Q = 0.042 x 0.5 in/day x 80 ac

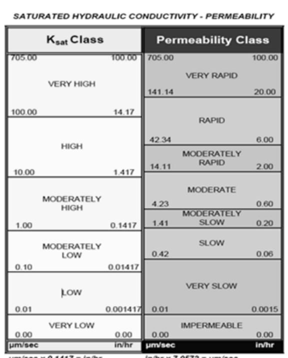
Q = <u>1.68 cfs</u>

Soils Investigation

Field Investigation:

- Water table depth
- Soil texture profile
- Saturated Hydraulic Conductivity, K_{sat}
- Restrictive layer

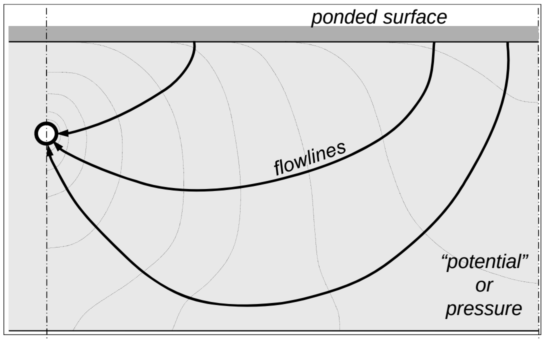
K, Hydraulic conductivity



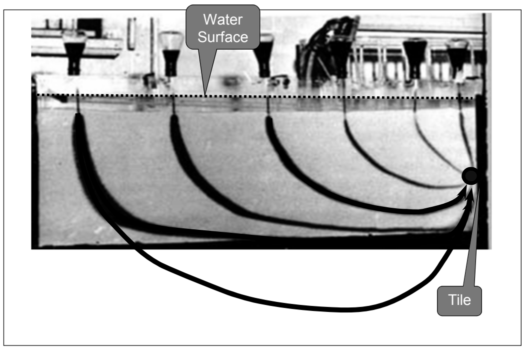
Soil Variability

- Soil Survey only provides typical values for predominate soils mapped.
- Point measurements don't necessarily represent field well
- Installing test drain can provide information about "effective" field hydraulic conductivity

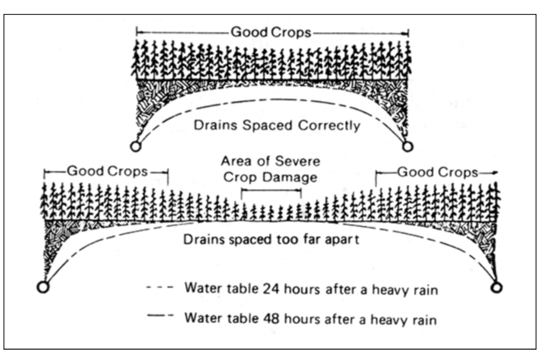
Drainage Flow to a Tile



Drainage Flow to a Tile



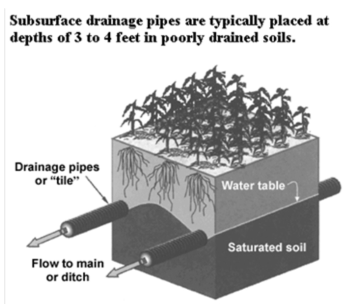
Drain Spacing



Drain Depth

- Depth does influence drain capacity.
- Minimum and maximum ranges.
  - Pipe material *(minimum is 2' for CPT)*
  - Pipe size
  - Bedding and backfill conditions
  - Traffic loading
- Installing machine capabilities.

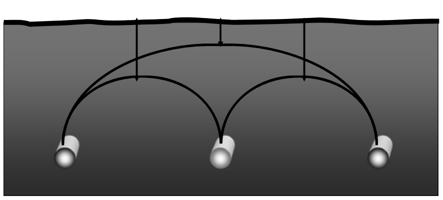
Drain Depth



Source: Agricultural Drainage Series, University of Minnesota

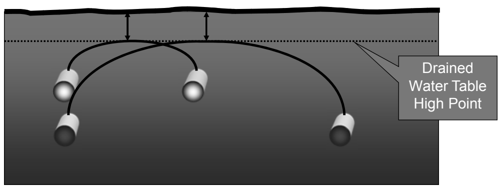
Drain Spacing and Depth

- For a given Tile Depth, decreasing the Tile Spacing will result in an increased rate of drainage.



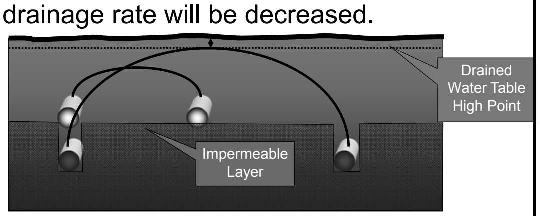
Depth vs. Spacing

- For a <u>uniform</u> soil profile, if Tile Depth is increased then the spacing can be increased to provide same drainage rate.



Depth vs. Spacing

- BUT,
  if the Tile Depth is increased beyond the depth of an impermeable layer, then the drainage rate will be decreased.



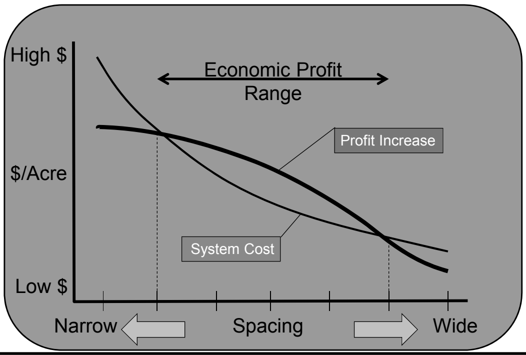
Drain Spacing Economics

- Optimum yield 
  <u>or</u>
- Optimum return on investment 

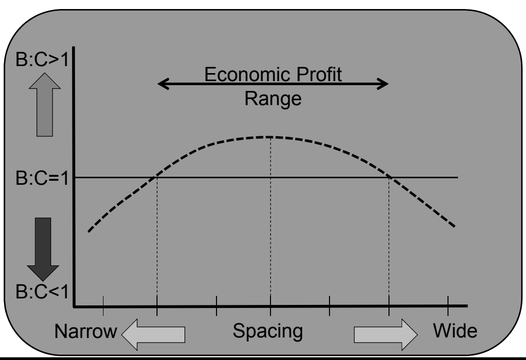
MUDS
Research
Plot, 2005

Subirrigation,
20' drain
spacing

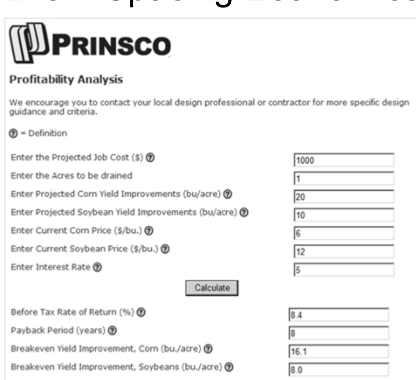
Drain Spacing Economics



Drain Spacing Economics



Drain Spacing Economics



PRINSCO

Profitability Analysis

We encourage you to contact your local design professional or contractor for more specific design guidance and criteria.

? = Definition

Enter the Projected Job Cost ($) ?	1000
Enter the Acres to be drained	1
Enter Projected Corn Yield Improvements (bu/acre) ?	20
Enter Projected Soybean Yield Improvements (bu/acre) ?	10
Enter Current Corn Price ($/bu.) ?	6
Enter Current Soybean Price ($/bu.) ?	12
Enter Interest Rate ?	5

Calculate

Before Tax Rate of Return (%) ?	8.4
Payback Period (years) ?	8
Breakeven Yield Improvement, Corn (bu./acre) ?	16.1
Breakeven Yield Improvement, Soybeans (bu./acre) ?	8.0

Drain Spacing Extras

- Systems that include Drainage Water Management require a higher level of design thought.
- Sub Irrigation systems require even more design with care and detail.
  - Site specific soils investigation
  - Detailed topographic surveys
  - Crop water requirements

Drain Spacing

In practice, most drainage only system designs are based on:

- A constant drain spacing for an area

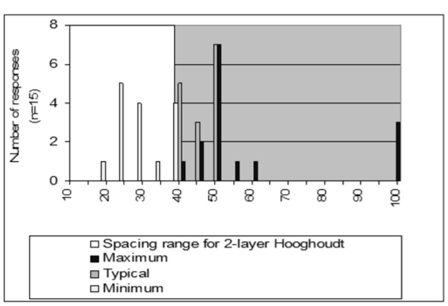
  or

- General soil characteristics with a recommended drain spacing for each soil series

Wayne Skaggs, North Carolina, 1987

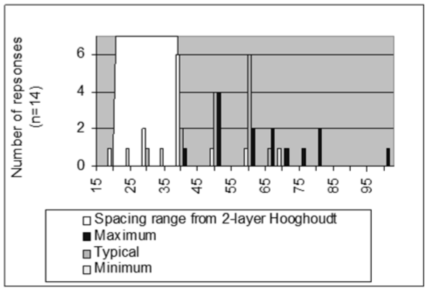
Drain Spacing Values for Blount Series

Silt Loam, poorly drained with clay layer 12" to 24"



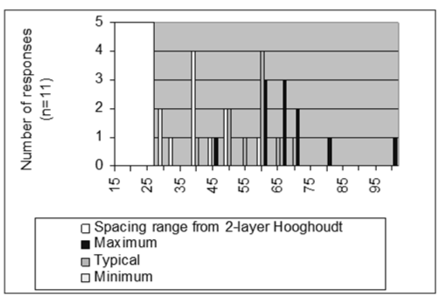
Drain Spacing Values (ft) for Brookston Series

Loam, poorly drained with clay loam layer 23" to 41"



Drain Spacing Values (ft) for Crosby Series

Silt Loam, poorly drained with silt clay loam layer 36" to 56"

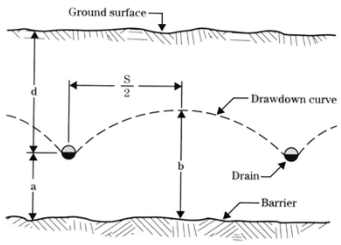


Why use standard spacing?

- Farmers and contractors are comfortable with rules of thumb for their area.
- Soil inputs can be difficult to determine and
  Soil properties vary across a field.
- Expertise to do a site-specific design is not readily available or cost "*too much*".

Ellipse Equation

$$S = (4K(b^2-a^2)/q)^{0.5}$$

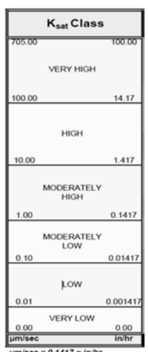


K_{sat}, Hydraulic Conductivity

8 in/hr ►

0.8 in/hr ►

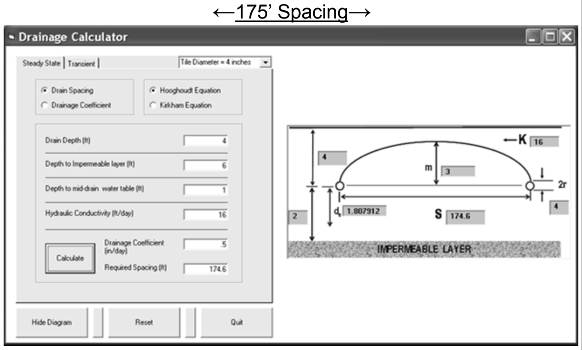
0.08 in/hr ►



Spacing Equations

High Hydraulic Conductivity (Ksat) 8 in/hr = 16 ft/day

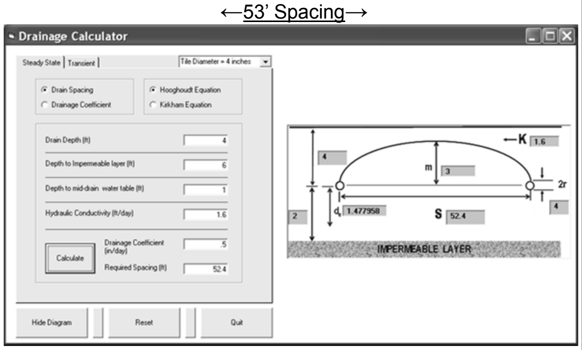
←175' Spacing→



Spacing Equations

Moderately High Hydraulic Conductivity (Ksat) 0.8 in/hr = 1.6 ft/day

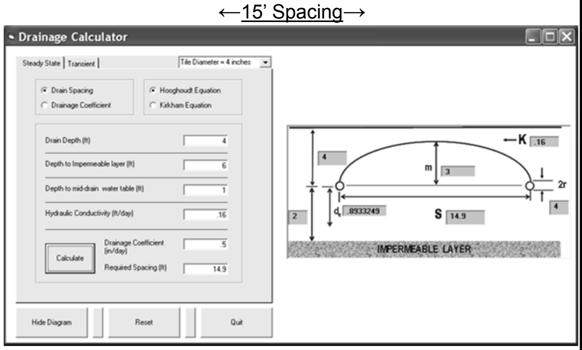
←<u>53' Spacing</u>→



Spacing Equations

Moderately Low Hydraulic Conductivity (Ksat) 0.08 in/hr = 0.16 ft/day

←<u>15' Spacing</u>→

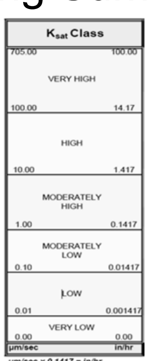


Spacing Summary

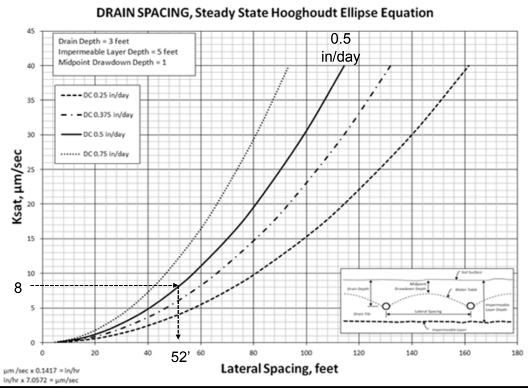
8 in/hr ► ◄ 175 ft

0.8 in/hr ► ◄ 50 ft

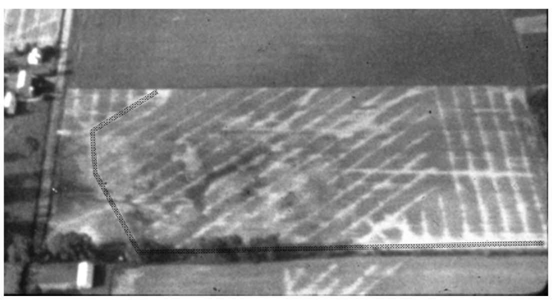
0.08 in/hr ► ◄ 15 ft



Spacing Charts



Can you see a pattern developing?



Planning a Drainage System

The End (aka the outlet)

NRCS Natural Resources Conservation Service

United States Department of Agriculture

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Planning a Subsurface Drainage System

Freeland C. Ives

In order to plan an economic drainage system, you should make full use of information from field surveys, soil borings, and other sources. Study this information carefully and thoroughly in planning your system. See Table 1 for information on soils and drainage recommendations.

The Drain Outlet

Location and type of drainage outlet. The first thing to do in planning a subsurface drainage system is to choose a location for the outlet. Outlets can be made to drain water by gravity or pumps into natural or artificial channels or tile outlet mains. Any of these approaches is suitable provided that the outlet is deep enough and has sufficient capacity to take away all the drainage water from the tile line. Before proceeding with the design of the system, determine whether the outlet is adequate.

Capacity and depth of open channel outlets. The outlet channel should be large enough to remove the drainage runoff from the watershed quickly enough to prevent crop damage. It should be deep enough that when drain lines are laid at the specified depth there is at least 1 foot of clearance between the flow line of the tile outlet and the low-water stage in the channel. This clearance may be reduced where the outlet channel is on a grade such that silting will not occur and where the stream recedes to the low-water stage a few hours after a storm.

Capacity and depth of existing tile mains. When tile mains are used as the outlet, they should be in good working condition. The main should have sufficient capacity to handle the proposed tile drainage system for the entire area it is intended to serve, and it should be deep enough that the new tile system can be laid at the depth specified for good tile drainage (exceptions can be made where there are small depressions; in these areas a minimum cover of 2 feet is permissible). The graph shown in Figure 1 can be used to determine the capacity of a tile line that is partially clogged with silt if the slope and size of the line are known.

Outlet by pumping. Where a gravity outlet is not available, you should consider pumping. See section VI for details.

General Planning Principles

The success of the subsurface drainage system depends upon the efficiency with which the laterals remove free water from the soil. Determine carefully the proper depth and spacing of the laterals and their relation to the main.

Freeland C. Ives is retired Engineering Specialist, Soil Conservation Service, Champaign, Illinois.

Lateral-main length ratio. The laterals should be as long as the topography permits. A good rule to follow is to make the laterals long and the mains and submains short.

Pattern. The laterals should enter the mains nearly at right angles whenever possible. Long, slanting junctions should be avoided because they result in double drainage. Designs like that of the herringbone system, in which the laterals enter a main or submain from both sides, also cause double drainage. They should be used only where they are absolutely necessary for good drainage.

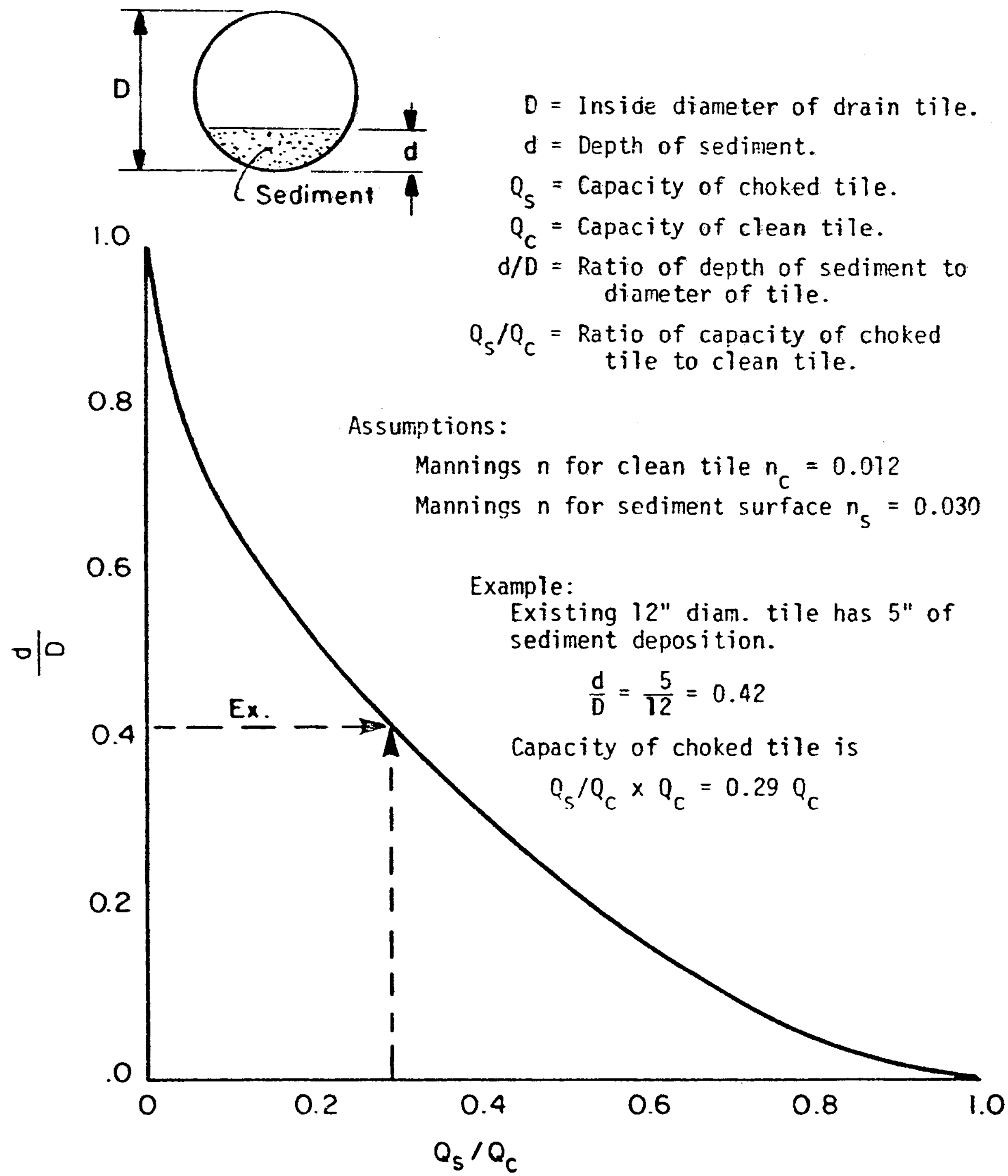

Figure 1. Capacity of sediment-choked drain tile.

Design and Layout Procedures for Drainage Systems

James P. Jensen

General

Surface Drainage

Surface drainage involves removal of excess surface water by developing a slope to the free water surface. This may be accomplished by open ditches and the shaping of the land surface to move water to disposal ditches. Drainage by this method applies to flatland sites with the following conditions:

1. Soils are slowly permeable throughout their profiles, such as slowly permeable clays.

2. Soils are shallow, 8 to 20 inches deep, over slowly permeable subsoil or rock.

3. Soils are responsive to subsurface drainage but lack free subsurface outlet.

4. Subsurface drainage is not economically feasible.

5. Surface drainage supplements subsurface drainage.

Subsurface Drainage

Subsurface drainage involves the removal of excess groundwater within the soil. Tile, pipe, and mole drains are used in many cases. Open ditches constructed to adequate depths and properly located are used frequently to provide subsurface drainage. Subsurface drainage is applicable to wet sites and to soils of sufficient porosity located where a free outlet is available or where an outlet can be obtained by pumping. It is also used to facilitate the leaching of salts from the soil and to maintain a salt balance.

Drainage Outlet

The first major engineering survey job is to determine the location and adequacy of the drainage outlet. Enough level readings and measurements should be made to enable the technician to reach a sound decision. The proper functioning of the entire drainage system hinges upon this point. An engineer should be consulted if there is any doubt regarding the adequacy of the outlet.

In determining whether outlets are adequate, the following basic requirements should be met:

1. The capacity of the outlet should be such that the design flow can be discharged at an elevation equal to or less than that of the hydraulic gradeline used for

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James P. Jensen is Area Engineer with the Soil Conservation Service, Sterling, Illinois.

design of the project. Where the outlet is a channel, the stage-discharge relationship should be determined. This should take into consideration the runoff from the entire watershed, computed in the same manner as for the project design.

2. The capacity of the outlet also must be such that the discharge from the project area after making the drainage improvements will not result in damaging stage increases below the end of the project channel.

3. The depth of the outlet should allow any needed subsurface drains to discharge into it above normal low waterflow.

4. Flow conditions in the outlet should be capable of maintaining equilibrium with the sediment transport for the project channel. There should not be excessive scour or sediment deposited in the outlet.

If the outlet is found to be inadequate, and it is not feasible under present conditions to improve it or to pump, then it is useless to make further surveys.

Factors Affecting Drainage

The topography, geology, man-made obstructions, or soils of a site and its surrounding area may result in conditions that block or retard water movement and cause poorly drained sites. Site factors can be placed in several categories and they may exist separately or in various combinations. Following are some of the more important site factors:

1. Lack of a natural drainageway or other depression to serve as an outlet. Such sites are common in glaciated and Coastal Plain areas where natural drainage systems are still in the process of development.

2. Lack of sufficient land slope to cause water to flow to an outlet. Such sites can be found in the irregular and pitted surfaces of glaciated land, above constrictions and natural barriers of valley flood plains, or above dams.

3. Soil layers of low permeability that restrict the downward movement of water trapped in small surface depressions or absorbed in the soil profile. Many soils have a heavy subsoil, rock formation, or compact (hardpan) layer below the surface within the normal root zone of plants.

4. Man-made obstructions such as roads, fence rows, dams, dikes, bridges, and culverts with insufficient capacity and depth that obstruct or limit the flow of water.

5. Natural surface barriers that cause enough local concentrations of water to aggravate the drainage problem.

6. Subsurface drainage problems in irrigated areas caused by deep percolation losses from irrigation and seepage losses from the canal and ditch systems serving the irrigated lands. Deep percolation losses from irrigation fall in the general range of 20 to 40 percent of the water applied. Seepage losses from canals and ditches vary widely and may be in the ranges of 0 to 50 percent of the water applied.

Most soils in arid areas contain salts that vary in concentration from slight to strong. High water table conditions caused by deep percolation from irrigation tend to concentrate salt accumulations in the root zone. One of the primary functions of subsurface drainage is to lower the water table and keep the level of salt concentration below the root zone area. Much of the subsurface drainage work in arid regions is actually salinity control.

There is no danger of overdraining most soils that have poor internal drainage. On soils in poor physical condition, close spacing of drains aids in the establishment and growth of vegetation needed for soil conditioning. This intensity of drainage may not be needed on the same soil in good physical condition. The removal of free water in the soil eliminates moisture in excess of that held by capillary action. Drainage does not remove the capillary water used by growing plants. The depth of the drains does control the height of the water table. If the water table is too low in soils with a low capillary "pull," moisture may not move upward into the root zone. This is a desirable condition in irrigated saline, saline-alkali, and alkali soils.

There is a possibility of overdraining some extremely sandy soils and some peat and muck areas. These soils have a particular depth of water table that is best for plant growth, and this should be considered in designing the drainage system.

Planning

Consider all of the following points during the preliminary planning stages of the drainage system.

1. The areas on which crops show damage, as pointed out by the farmer or as indicated by the aerial photograph or by personal observations. Elevations of these areas will generally be low control points in the design of the system.

2. Topography and size of the watershed area.

3. Size, extent, and ownership of the area needing drainage.

4. Location of the drainage outlet and its condition.

5. Location, condition, and approximate size of waterways.

6. General character of soil throughout the area needing drainage, including land capability, land use, crops and yields, and salinity or alkalinity.

7. High-water marks of damaging floods and dates of floods.

8. Pipelines, roads, culverts, bridges, and irrigation facilities and their possible effect on the drainage system.

9. Problems of outside water from hill land or floods and possible disposal areas and control methods.

10. Condition of the areas contributing outside water and possible treatment needed on these areas to reduce runoff or erosion debris.

11. Condition of any existing drainage system and reasons for failure or inadequacy.

12. Estimate of surveys needed.

13. Type of construction equipment available.

14. Feasibility.

Engineering Surveys

General

The size and complexity of the area to be drained determines the kinds and number of surveys needed. For the smaller, simple jobs a few lines of levels at key locations, a few soil borings to determine water table levels and the need for subsurface drainage, determination of the approximate drainage area, and a rough cost estimate frequently are all that the technician needs to obtain.

The objective of a survey for design purposes is to obtain elevations, topography, and other field information necessary to design the system and prepare plans, specifications, and estimates of quantities of work to be performed. Gather only that field information needed for these purposes.

Drainage Outlet

The first major engineering survey job is to determine the location and adequacy of the drainage outlet. Enough level readings and measurements should be made to enable the designer to reach a sound decision. The proper functioning of the entire drainage system hinges upon this point.

Establishing Bench Marks

Begin the level work by tying into an established bench mark or establishing a convenient temporary bench mark (TBM) based on survey needs. As the survey progresses, establish other bench marks as needed. Properly located bench marks will be helpful and timesaving during the layout and construction of the job. Temporary bench marks such as spikes or large nails in notches of large tree roots should be used. Use of wood stakes or nails in small fenceposts for the more important bench marks is poor practice.

Topographic Survey

Topographic information on the area to be drained is necessary except on fields with sufficient slope so that the general lay of the land is obvious. This information is used on the flatter areas for planning land grading or locating field ditches, drains, or other facilities. The amount and kind of topographical survey depends upon the drainage problem and the topography of the land, varying from a detailed grid or contour map to random elevations, valley cross sections, and locating important features. Following are some of the details to observe in obtaining topographic information for drainage:

1. Obtain elevations at 100- to 300-foot horizontal intervals on flatland depending on how nearly level the land is and whether the drainage pattern is apparent from inspection. Take additional elevations in all low or depressed areas. The flatter the land, the more important it is to take elevations at relatively close intervals.

2. Where random ditches and tile drains are to be used to drain depressions or pockets, vary the amount of survey data according to ground conditions.

Elevations at close intervals will be necessary if depressed areas are numerous, while in areas with few depressions, a skeleton topographic map may suffice. In either case, the survey should be in sufficient detail to locate and determine elevations or depressed areas and the best outlets.

3. Physical features of adjacent land should be obtained if they affect the drainage of the proposed area. Be sure to obtain the location and elevations of all ditch bottoms or drainageways, size of opening and flow line elevations of culverts and bridges, and any other similar information needed to plan the drainage system.

Other Field Information

Other field data should be gathered at the time of the design survey. Some of them are as follows:

1. The area to be drained should be delineated on an aerial photograph or other suitable map.

2. The drainage area should also be outlined if it is a factor that will affect design of the system.

3. Information should be gathered on crops to be grown and farm machinery likely to be used after drainage since they may affect the proposed design.

4. Soil borings are necessary unless the characteristics of the soil materials are known to a depth of at least one foot below the proposed depth of ditch for areas in need of surface drainage and to twice the depth of drain where subsurface drainage is needed.

5. Information on frequency and depth of flooding on the area to be drained is necessary. Drift marks of previous flooding often may be seen on trees, culverts, or fenceposts. Elevation and frequency of high water should be obtained if it will have a bearing on the ditch design.

SUBSURFACE DRAIN DESIGN PROCEDURE

1. Complete initial planning for system
    - Adequate outlet?
    - Wetland determination requested
    - Utilities located
    - Neighboring landowners
2. Complete topographic survey
3. Create contour map
4. Determine soil properties (county soil survey and on-site investigation)
5. Determine drainage coefficient to use (in/day)
6. Select drain spacing
7. Analyze contour map for drain layout alternatives then lay out and station mains and laterals on map
8. Plot profile of existing ground along main
9. Plot control points for main on profile
    - Low points of existing ground (use approx. 3' min. depth)
    - High points of existing ground (use approx 6'max. depth)
    - Outlet (need 1' freeboard)
    - Lateral depth, min. grade and cover (may need to plot a profile of key laterals to ensure adequate depth of cover)
    - Obstructions: buildings, utilities, bedrock, poor soils
    - Wetlands
10. Plot grade lines and calculate grades for mains
    - Round grades where possible
    - On profile sheet, note station and elevation of all final design grade changes

11. Determine main sizes and lengths starting at upstream end of main

    a) Determine beginning main size (often start with 6”).
    b) Determine capacity of this pipe.
    c) Determine flow area (in acres) of each lateral (lateral length x spacing).
    d) Determine flow contribution of each lateral.
    e) Accumulate flow contributions of each lateral until they exceed the capacity of the main. The area above this point is called a reach.
    f) Note accumulated flow and drainage area for this reach on the design chart.
    g) Note upstream and downstream stations of the reach on design chart.
    h) Select the main size for the next reach.
    i) Determine main capacity for this reach.
    j) Determine available capacity for main (main capacity less accumulated flow of upstream reaches).
    k) Continue the process with step 11c until the outlet is reached.

    Note: If a grade change occurs, consider this a reach change. Accumulate the flow at that station, perform step 11f and continue the process with step 11h.

12. Check to ensure outlet capacity is adequate to handle the total drainage system discharge.

*Modified document prepared by Bruce Atherton, Agricultural Engineer, USDA-NRCS Ankeny, Iowa
Adapted from material prepared by Paul W. Chester, Area Engineer, Findlay, Ohio

Drainage Design Reference

Area

1 acre = 43,560 square feet

Saturated Hydraulic Conductivity

1 micrometer per second = 1 µm/sec

1 µm/sec = 0.2834 feet per day

1 µm/sec = 0.1417 inch per hour

1 inch per hour = 7.0572 µm/sec

1 inch per hour = 2 feet per day

Pipe Flow

$Q = V \times A$ and $V = Q \div A$

Where: Q = Flow discharge rate, cubic feet per second

V = Flow velocity, feet per second

A = Cross Sectional Area, square feet

Required Drainage Capacity

$Q = 0.042 \times DC \times DA$

Where Q = Flow discharge rate, cubic feet per second

DC = Drainage Coefficient, inch/day

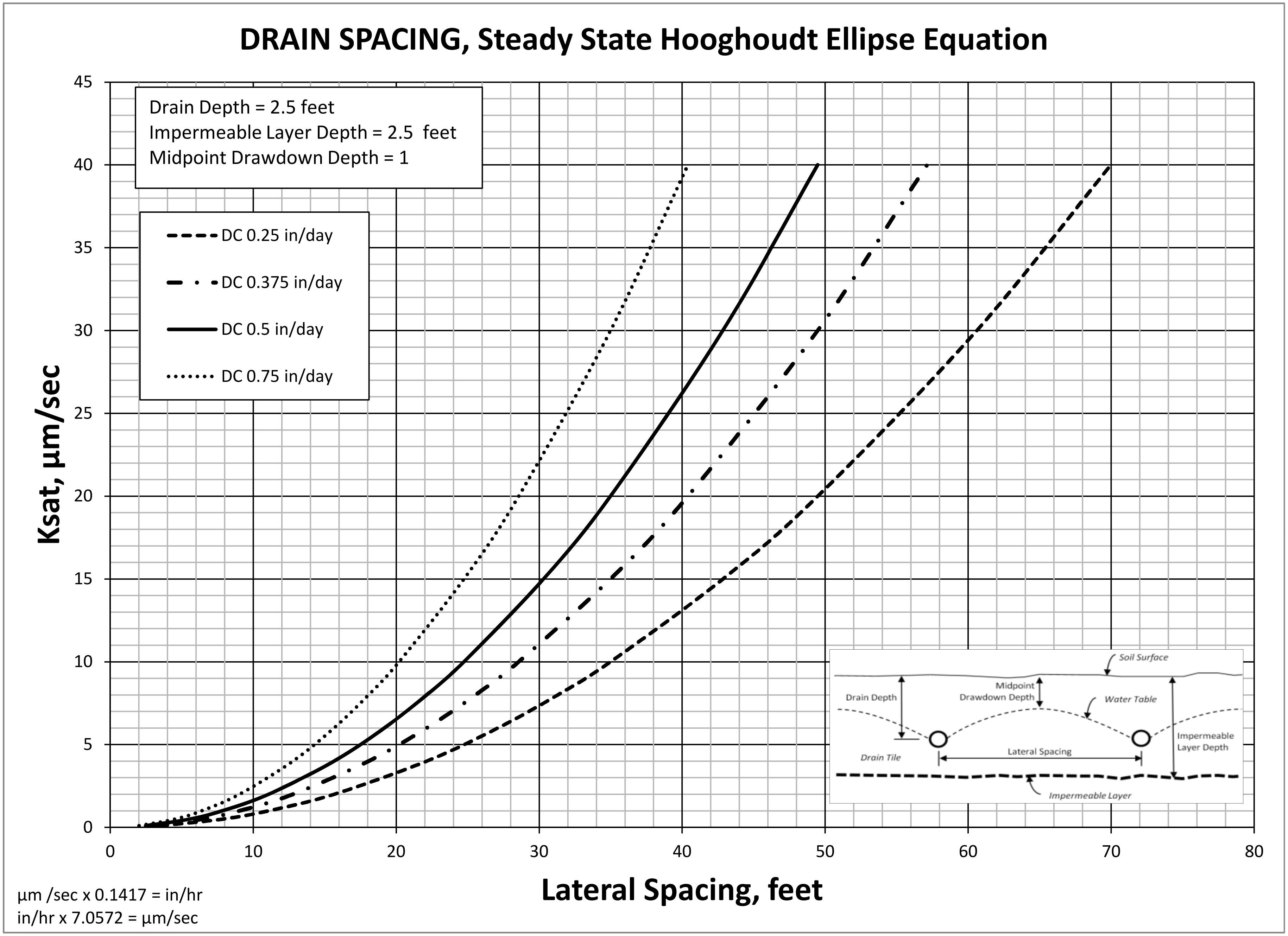
DA = Drained Area, acres

MAXIUM LATERAL LENGTH USING 3" DIAMETER CORRAGATED PLASTIC TILE

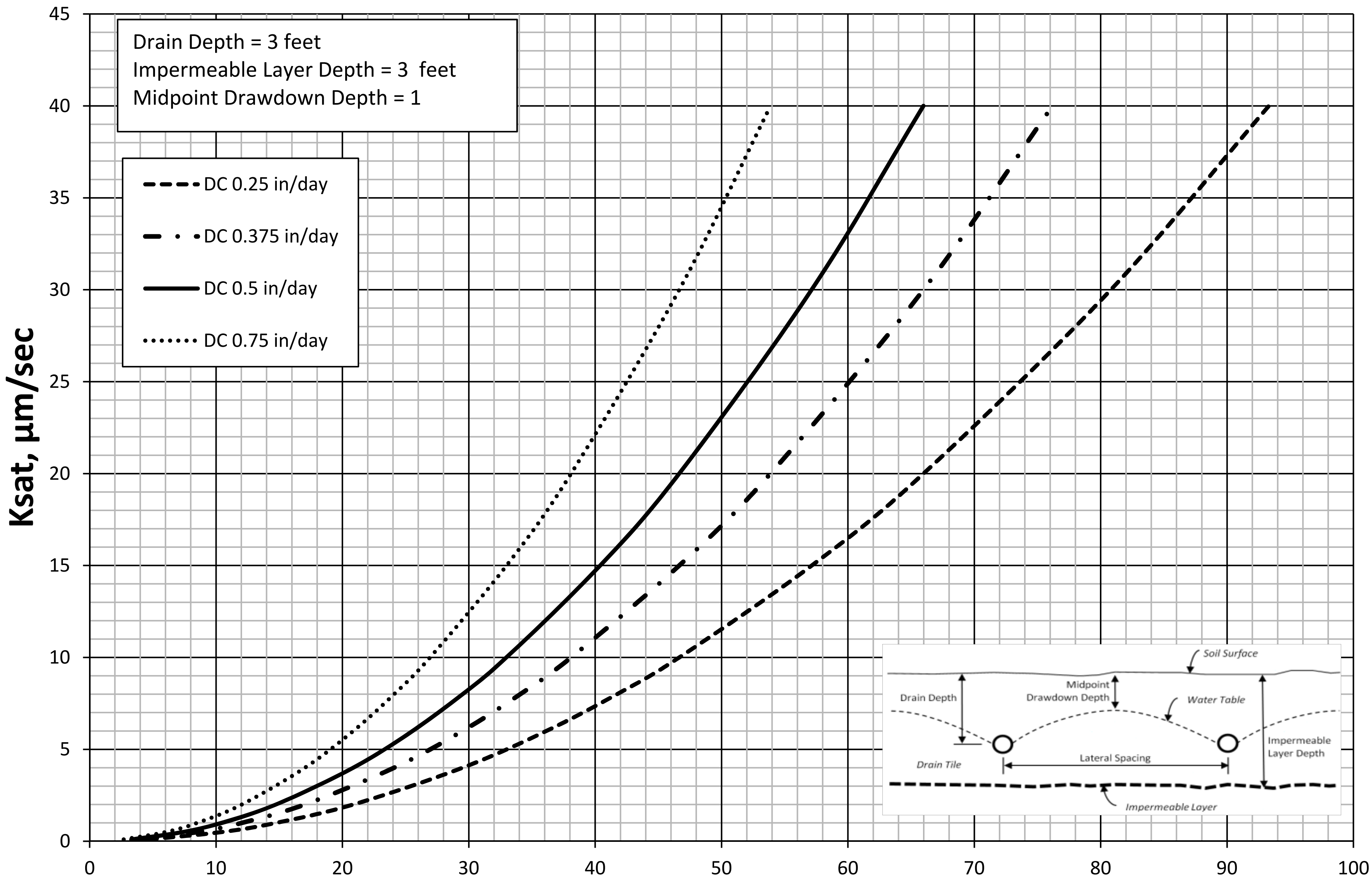
% Grade	DC	AREA	LATERAL SPACING (feet)									% Grade
(3" CPT)	("/day)	(acre)	20	30	40	50	60	70	80	90	100	(3" CPT)
0.1	3/8	1.75	3,810	2,540	1,900	1,520	1,270	1,080	950	840	760	0.1
	1/2	1.30	2,830	1,880	1,410	1,130	940	800	700	620	560	
0.2	3/8	2.20	4,790	3,190	2,390	1,910	1,590	1,360	1,190	1,060	950	0.2
	1/2	1.65	3,590	2,390	1,790	1,430	1,190	1,020	890	790	710	
0.3	3/8	2.70	5,880	3,920	2,940	2,350	1,960	1,680	1,470	1,300	1,170	0.3
	1/2	2.00	4,350	2,900	2,170	1,740	1,450	1,240	1,080	960	870	
0.4	3/8	3.10	6,750	4,500	3,370	2,700	2,250	1,920	1,680	1,500	1,350	0.4
	1/2	2.30	5,000	3,330	2,500	2,000	1,660	1,430	1,250	1,110	1,000	
0.5	3/8	3.45	7,510	5,000	3,750	3,000	2,500	2,140	1,870	1,660	1,500	0.5
	1/2	2.60	5,660	3,770	2,830	2,260	1,880	1,610	1,410	1,250	1,130	
0.6	3/8	3.80	8,270	5,510	4,130	3,310	2,750	2,360	2,060	1,830	1,650	0.6
	1/2	2.85	6,200	4,130	3,100	2,480	2,060	1,770	1,550	1,370	1,240	

MAXIUM LATERAL LENGTH USING 4" DIAMETER CORRAGATED PLASTIC TILE

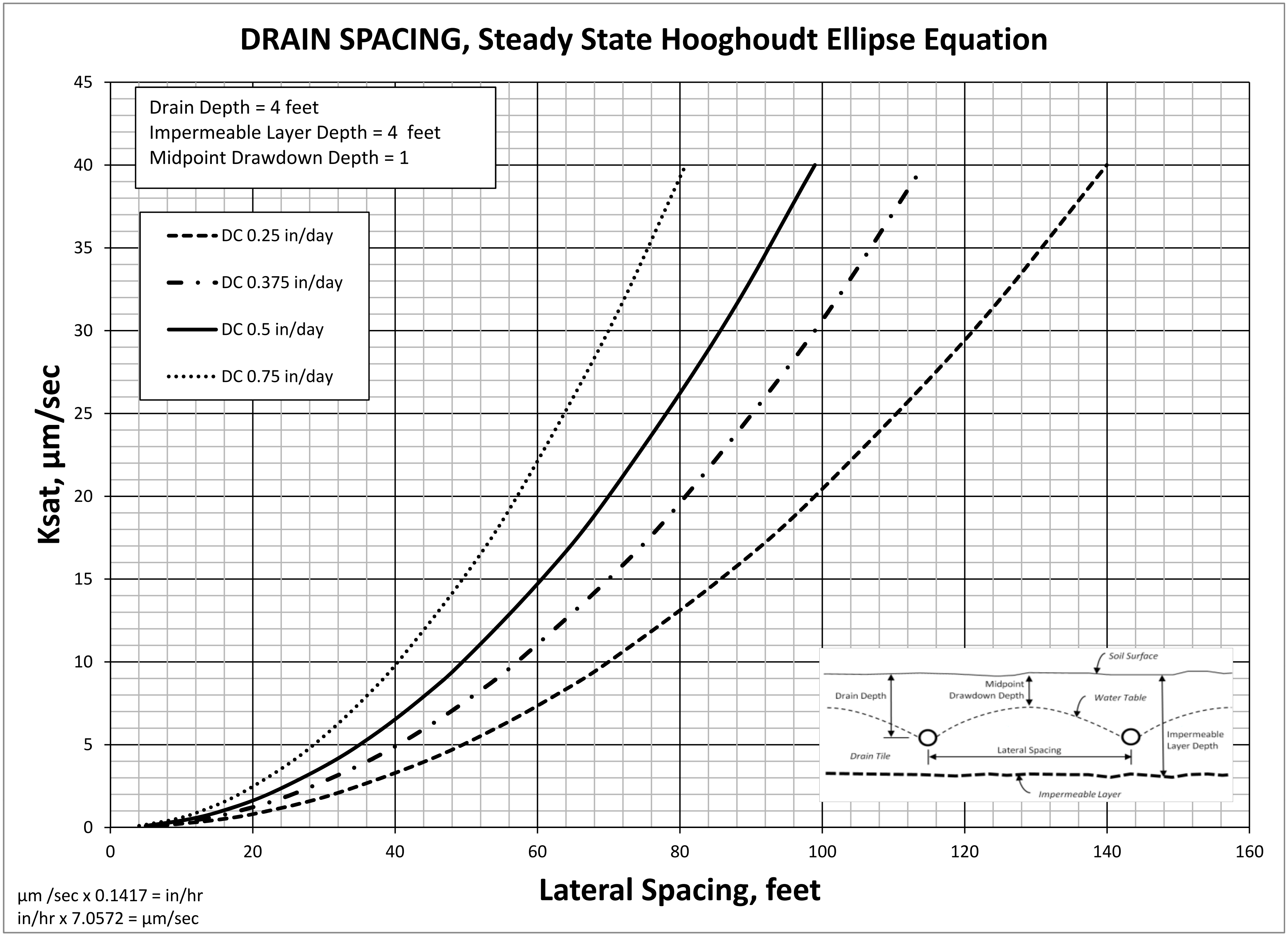
% Grade	DC	AREA	LATERAL SPACING (feet)									% Grade
(4" CPT)	("/day)	(acre)	20	30	40	50	60	70	80	90	100	(4" CPT)
0.05	3/8	2.35	5,110	3,410	2,550	2,040	1,700	1,460	1,270	1,130	1,020	0.05
	1/2	1.75	3,810	2,540	1,900	1,520	1,270	1,080	950	840	760	
0.1	3/8	3.35	7,290	4,860	3,640	2,910	2,430	2,080	1,820	1,620	1,450	0.1
	1/2	2.50	5,440	3,630	2,720	2,170	1,810	1,550	1,360	1,210	1,080	
0.2	3/8	4.75	10,340	6,890	5,170	4,130	3,440	2,950	2,580	2,290	2,060	0.2
	1/2	3.55	7,730	5,150	3,860	3,090	2,570	2,200	1,930	1,710	1,540	
0.3	3/8	5.80	12,630	8,420	6,310	5,050	4,210	3,600	3,150	2,800	2,520	0.3
	1/2	4.35	9,470	6,310	4,730	3,780	3,150	2,700	2,360	2,100	1,890	
0.4	3/8	6.65	14,480	9,650	7,240	5,790	4,820	4,130	3,620	3,210	2,890	0.4
	1/2	5.00	10,890	7,260	5,440	4,350	3,630	3,110	2,720	2,420	2,170	
0.5	3/8	7.50	16,330	10,890	8,160	6,530	5,440	4,660	4,080	3,630	3,260	0.5
	1/2	5.60	12,190	8,130	6,090	4,870	4,060	3,480	3,040	2,710	2,430	
0.6	3/8	8.10	17,640	11,760	8,820	7,050	5,880	5,040	4,410	3,920	3,520	0.6
	1/2	6.10	13,280	8,850	6,640	5,310	4,420	3,790	3,320	2,950	2,650	


DRAIN SPACING, Steady State Hooghoudt Ellipse Equation
Drain Depth = 2.5 feet
Impermeable Layer Depth = 2.5 feet
Midpoint Drawdown Depth = 1
DC 0.25 in/day
DC 0.375 in/day
DC 0.5 in/day
DC 0.75 in/day
Ksat, µm/sec
0
5
10
15
20
25
30
35
40
45
0
10
20
30
40
50
60
70
80
Lateral Spacing, feet
Soil Surface
Drain Depth
Midpoint
Drawdown Depth
Water Table
Impermeable
Layer Depth
Drain Tile
Lateral Spacing
Impermeable Layer
µm /sec x 0.1417 = in/hr
in/hr x 7.0572 = µm/sec

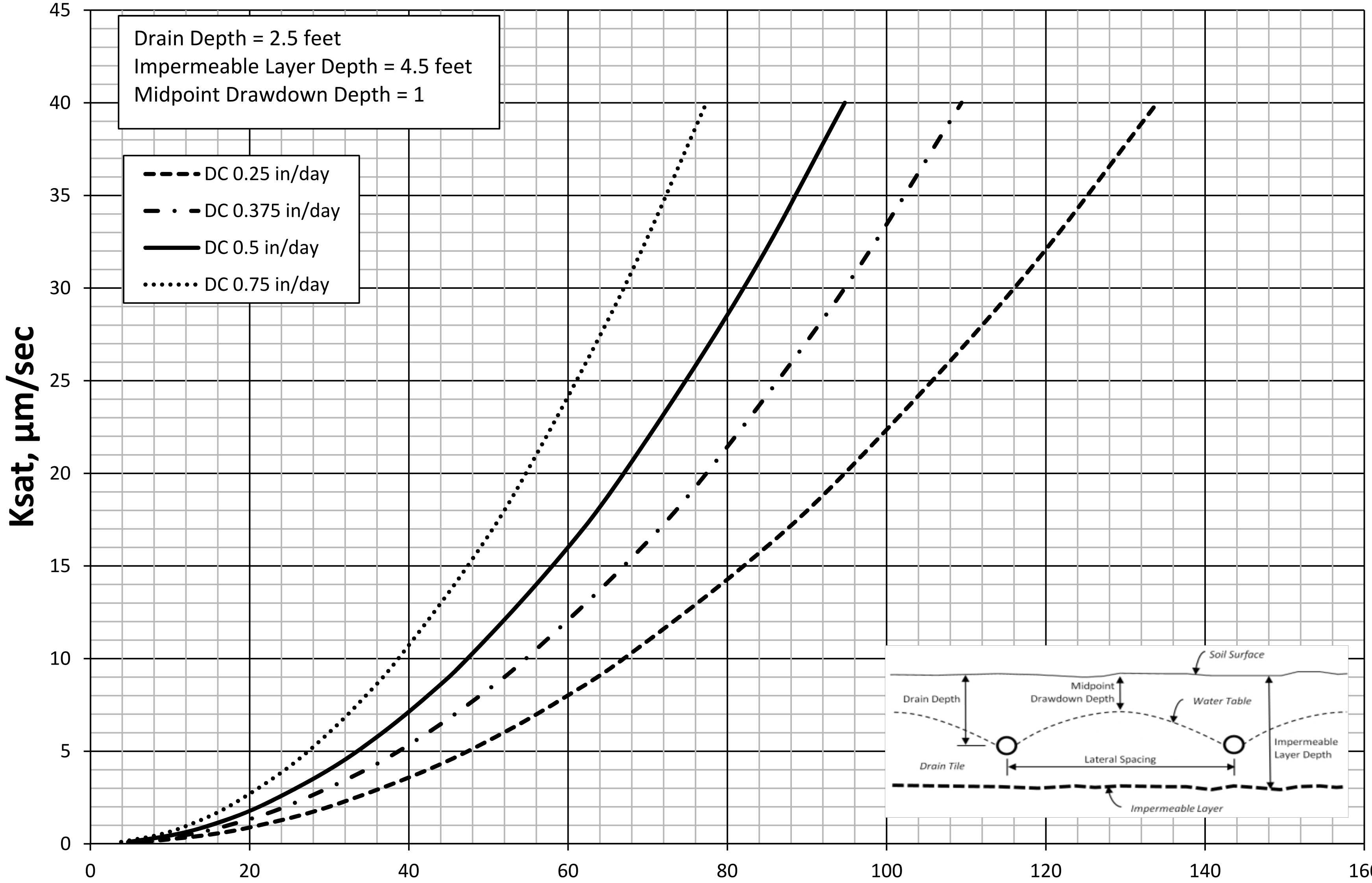
DRAIN SPACING, Steady State Hooghoudt Ellipse Equation



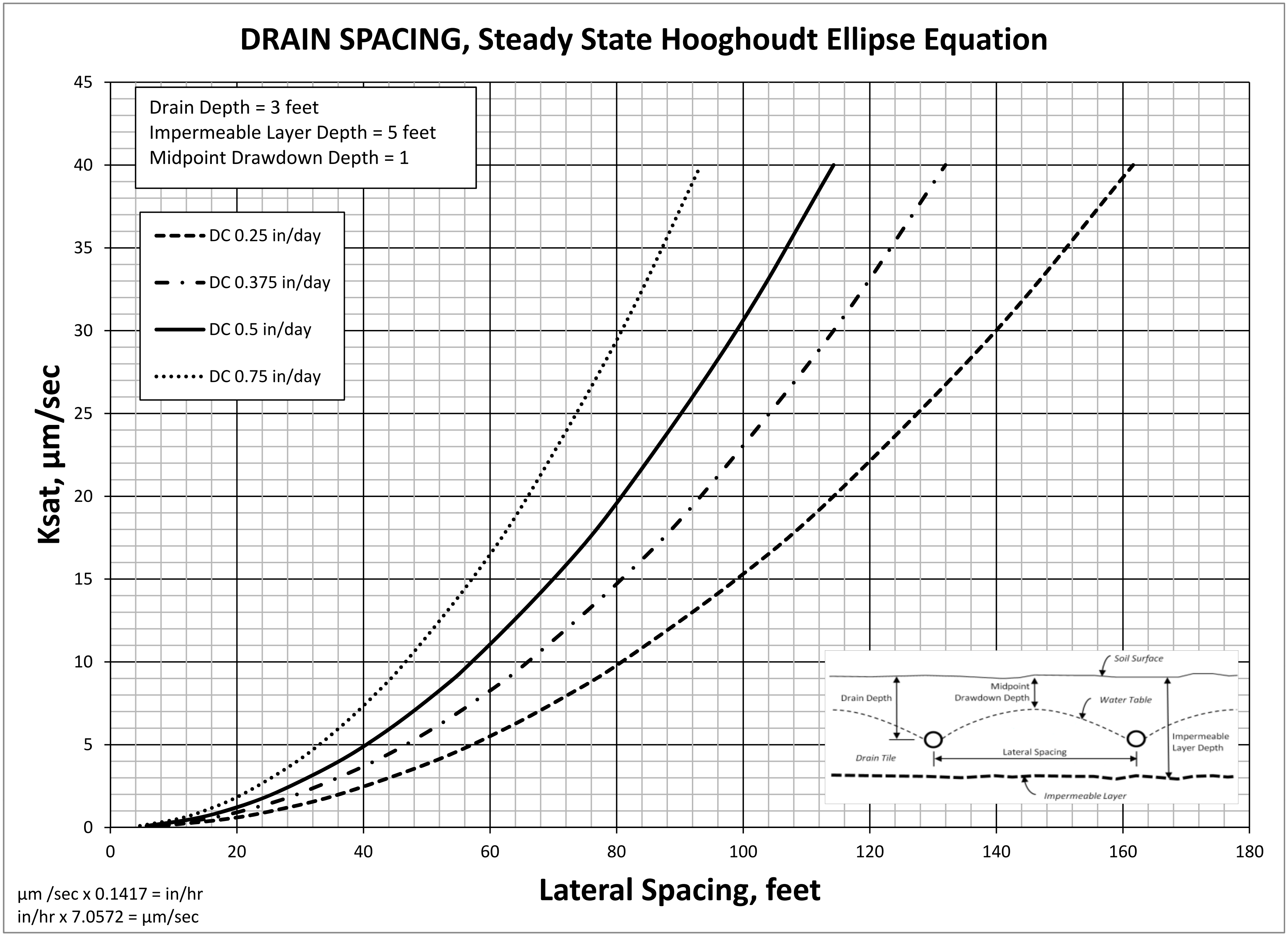
µm /sec x 0.1417 = in/hr
in/hr x 7.0572 = µm/sec

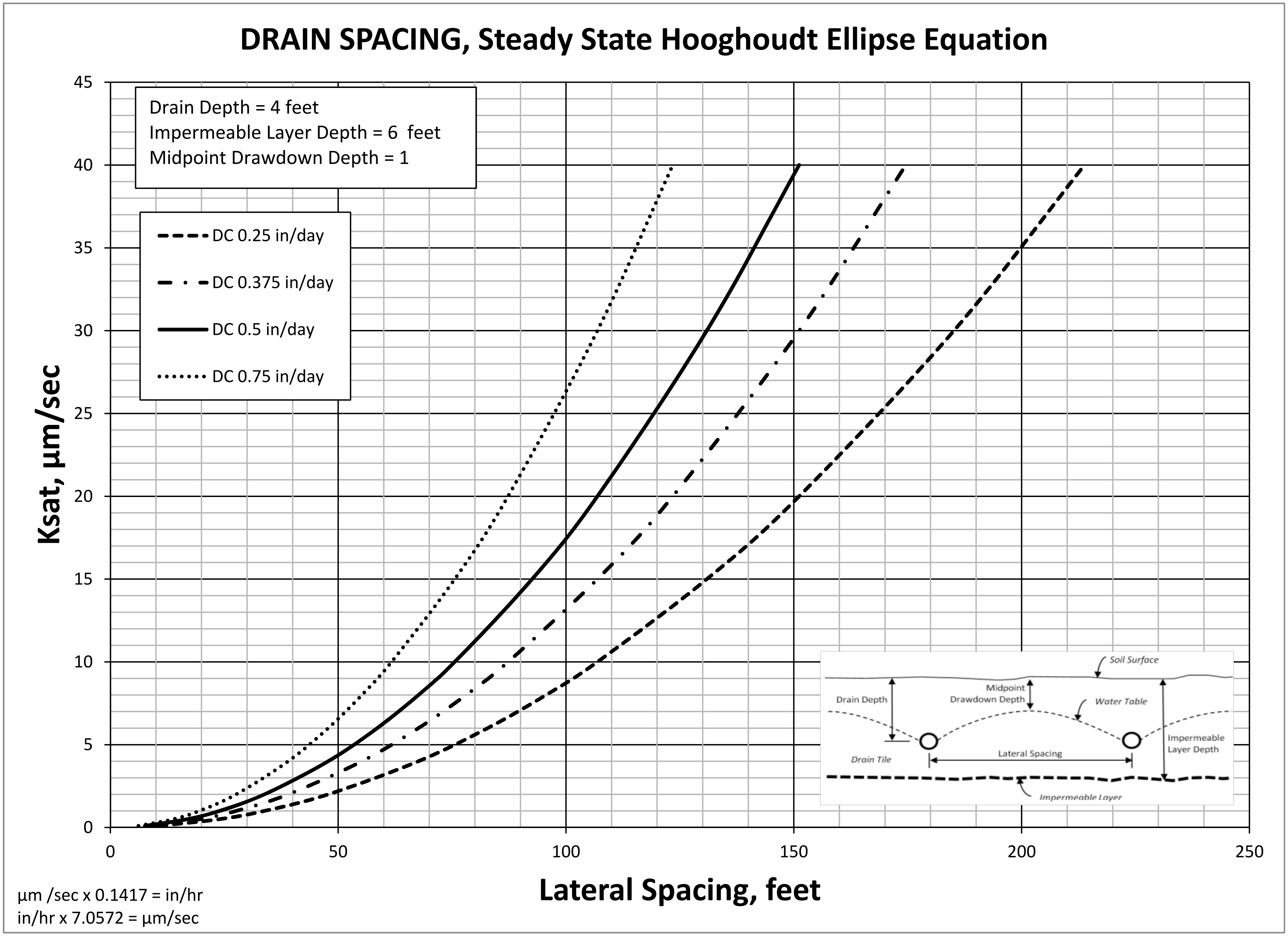

DRAIN SPACING, Steady State Hooghoudt Ellipse Equation
Drain Depth = 4 feet
Impermeable Layer Depth = 4 feet
Midpoint Drawdown Depth = 1
DC 0.25 in/day
DC 0.375 in/day
DC 0.5 in/day
DC 0.75 in/day
Ksat, µm/sec
Lateral Spacing, feet
0
5
10
15
20
25
30
35
40
45
0
20
40
60
80
100
120
140
160
Soil Surface
Drain Depth
Midpoint
Drawdown Depth
Water Table
Impermeable
Layer Depth
Drain Tile
Lateral Spacing
Impermeable Layer
µm /sec x 0.1417 = in/hr
in/hr x 7.0572 = µm/sec

DRAIN SPACING, Steady State Hooghoudt Ellipse Equation



µm /sec x 0.1417 = in/hr
in/hr x 7.0572 = µm/sec


DRAIN SPACING, Steady State Hooghoudt Ellipse Equation
Drain Depth = 3 feet
Impermeable Layer Depth = 5 feet
Midpoint Drawdown Depth = 1
DC 0.25 in/day
DC 0.375 in/day
DC 0.5 in/day
DC 0.75 in/day
Ksat, µm/sec
Lateral Spacing, feet
0
5
10
15
20
25
30
35
40
45
0
20
40
60
80
100
120
140
160
180
Soil Surface
Drain Depth
Midpoint
Drawdown Depth
Water Table
Impermeable
Layer Depth
Drain Tile
Lateral Spacing
Impermeable Layer
µm /sec x 0.1417 = in/hr
in/hr x 7.0572 = µm/sec


DRAIN SPACING, Steady State Hooghoudt Ellipse Equation
Drain Depth = 4 feet
Impermeable Layer Depth = 6 feet
Midpoint Drawdown Depth = 1
DC 0.25 in/day
DC 0.375 in/day
DC 0.5 in/day
DC 0.75 in/day
Ksat, µm/sec
Lateral Spacing, feet
0
5
10
15
20
25
30
35
40
45
0
50
100
150
200
250
Soil Surface
Drain Depth
Midpoint
Drawdown Depth
Water Table
Impermeable
Layer Depth
Lateral Spacing
Drain Tile
Impermeable Layer
µm /sec x 0.1417 = in/hr
in/hr x 7.0572 = µm/sec