Water Movement in Soils

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Columbia, Missouri

1) Soil Forming Factors
2) Primary Properties that affect Water Movement in Soils
3) Soil Water Concepts
4) Where to get additional information

Today's Talking Points

- **Parent Material**
- **Climate**
- **Topography**
- **Biological Activity**
- **Time**

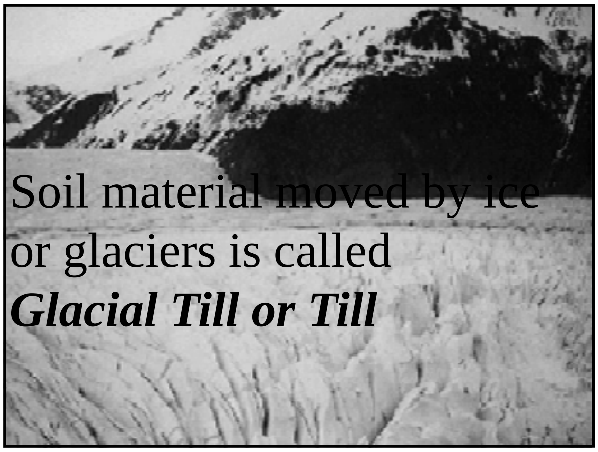
Soil Forming Factors

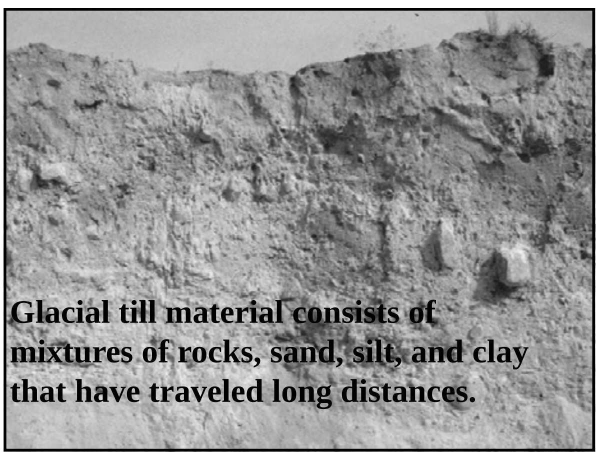
- Those that formed <u>in place</u> - residuum
- Those that have been <u>transported</u> - In Missouri: transported by Ice, Water, Wind and Gravity

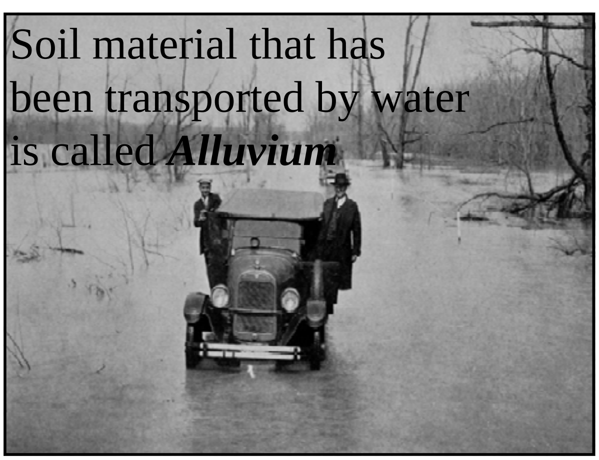
Two Categories of Parent Material

Soil that form <u>in place</u> from the weathering of the underlying rock or minerals is called

Residuum


Soil material moved by ice
or glaciers is called
Glacial Till or Till


**Glacial till material consists of
mixtures of rocks, sand, silt, and clay
that have traveled long distances.**


Soil material that has
been transported by water
is called ***Alluvium***

Slow velocity flooding produces clayey soils.

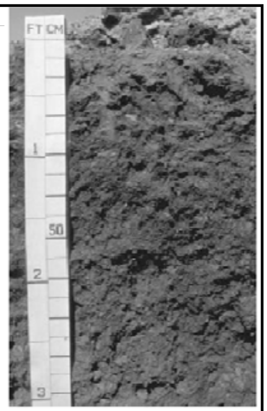


Figure 29.—Typical profile of Osage silty clay loam, 0 to 1 percent slopes, occasionally flooded.

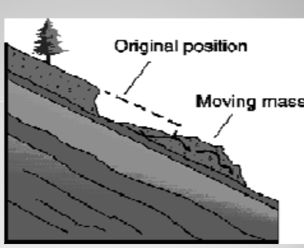
High velocity flooding produces loamy soils.

■ Wind deposited - the further from the source the loess gets thinner and has more clay (less silt)

■Thickest deposits are adjacent to the Missouri and Mississippi River flood plains.

Loess

Colluvium is material transported down slope by gravity.



Temperature and Moisture are major influences. In the US, we have permafrost in Alaska and very warm conditions in our southern states. With regard to moisture, we have both deserts and rain forests.

Climate

- The configuration of the land surface
  - Slope gradient
  - Slope shape

Topography

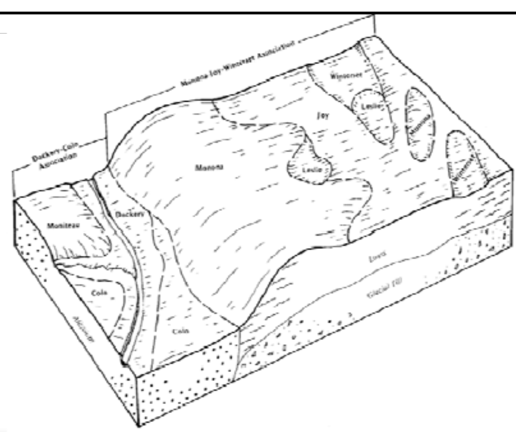
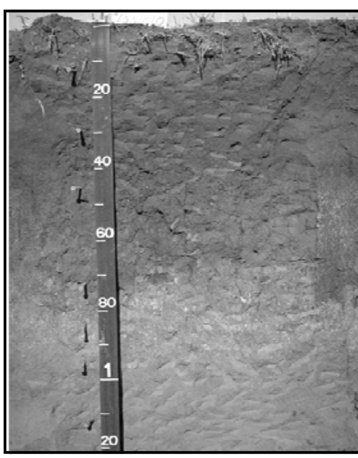


Figure 4.—Typical pattern of soils and parent material in the Monona-Joy-Winterset and Dockery-Colo associations.

- Plants
- Animals

Biota

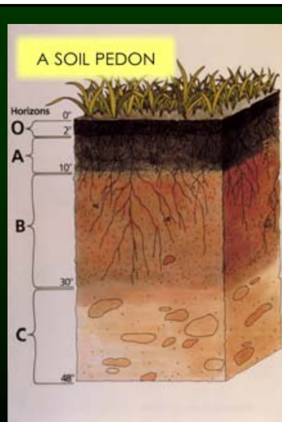


Makes thick dark

Surface Horizons

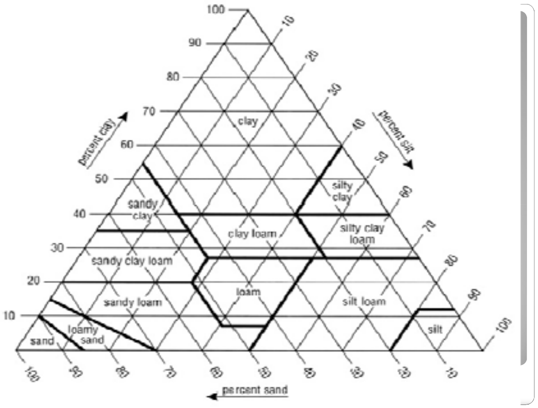
- Recent floods to “old” residuum

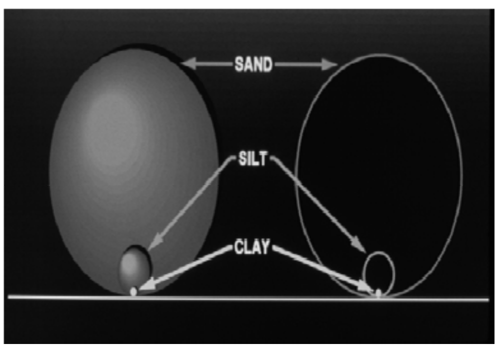
Time



1) Soil Texture – particle size distribution
2) Soil Structure
3) Organic Matter Content
4) Landform – hill slope profile

Primary Factors that influence Water Movement through the Soil





Particle Sizes

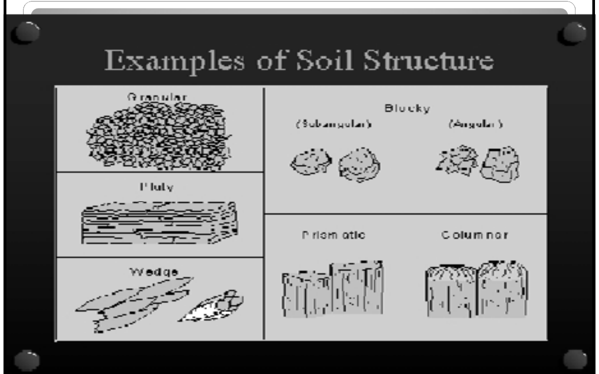
Sand: 2mm to .05mm

Silt: .05 mm to .002 mm

Clay: smaller than .002mm

- **Blocky or granular - surface layer, A horizons**
- **Platy or blocky - subsurface, E horizons if present**
- **Blocky and / or Prismatic - subsoil, B horizons (compound: prismatic parting to blocky)**
- **Massive or Single grained - substratum, C horizons**

Structure



- Soil Organic Matter Content higher levels:
  - Will increase the soils ability to store and give up water plants.
  - Will increase water movement rates through the soil.

Soil Organic Matter

- How we can describe shapes of the land surface.
- Slope shape and gradient are important considerations.

Landforms

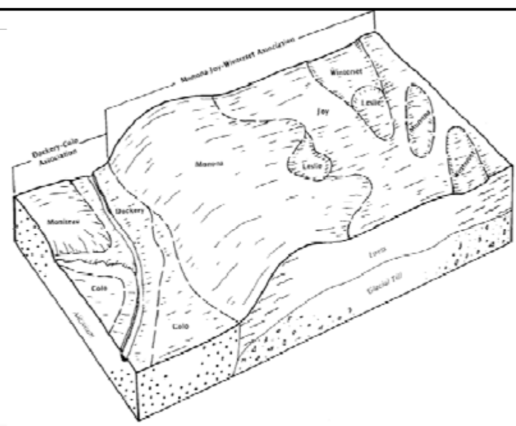


Figure 4.—Typical pattern of soils and parent material in the Monona-Joy-Winterset and Dockery-Colo associations.

- In soil science, permeability is defined qualitatively as the ease with which gases, liquids, or plant roots penetrate or pass though a soil mass or layer. It is measured in length with no time component.
- Saturated hydraulic conductivity is a quantitative measure of a saturated soil's ability to transmit water when subjected to a hydraulic gradient. It can be thought of as the ease with which pores of a saturated soil permit water movement. It is measured in both length and time.
- Permeability classes and most references to permeability have been removed from the *NSSH* and replaced with the saturated hydraulic conductivity classes of the 1993 *Soil Survey Manual*.

Ksat
Saturated Hydraulic Conductivity

SATURATED HYDRAULIC CONDUCTIVITY - PERMEABILITY

K_{sat} Class		
705.00		100.00
	VERY HIGH	
100.00		14.17
	HIGH	
10.00		1.417
	MODERATELY HIGH	
1.00		0.1417
	MODERATELY LOW	
0.10		0.01417
	LOW	
0.01		#######
	VERY LOW	
0.00		0.00
µm/sec		in/hr

Permeability Class		
705.00		100.00
	VERY RAPID	
141.14		20.00
	RAPID	
42.34		6.00
	MODERATELY RAPID	
14.11		2.00
	MODERATE	
4.23		0.60
	MODERATELY SLOW	
1.41		0.20
	SLOW	
0.42		0.06
	VERY SLOW	
0.01		0.0015
	IMPERMEABLE	
0.00		0.00
µm/sec		in/hr

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

- Saturated hydraulic conductivity is the amount of water that would move vertically through a unit area of saturated soil in unit time under unit hydraulic gradient.
- If you find old permeability information, you can convert from *u*m/sec to in/hr by multiplying *u*m/sec by .1417

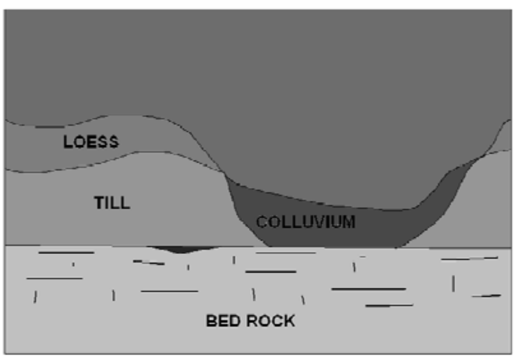
- Do you have an awareness of the factors of soil formation?
- How about the primary factors that influence water movement through soil?
- What is Saturated Hydraulic Conductivity?
- Ready to move on to Soil Water Concepts?

Quick Review

- Does water moves through all soils at the same rate?

- Soil horizons and restrictive features.
- Water tables.
- Interpretations: Hydraulic groups & Drainage classes.

Soil Water Concepts

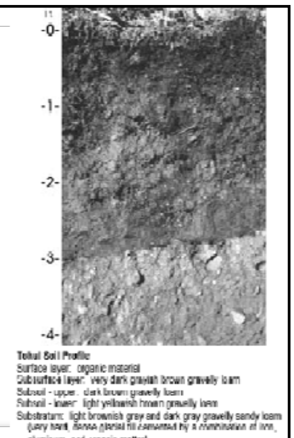


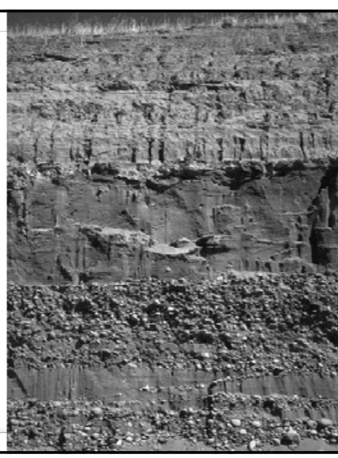
- clay pans
- abrupt texture change
- discontinuities
- bedrock

Soil Horizons and Restrictive Features

Clay Pan
Soils

Some have drastically different material underneath



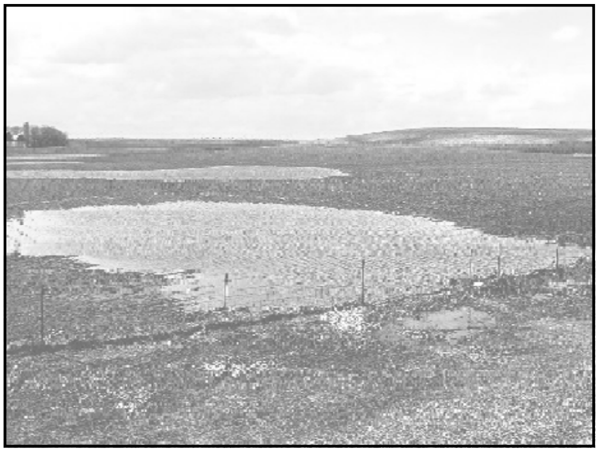


WATER TABLES

PERCHED (on something in the soil profile like)

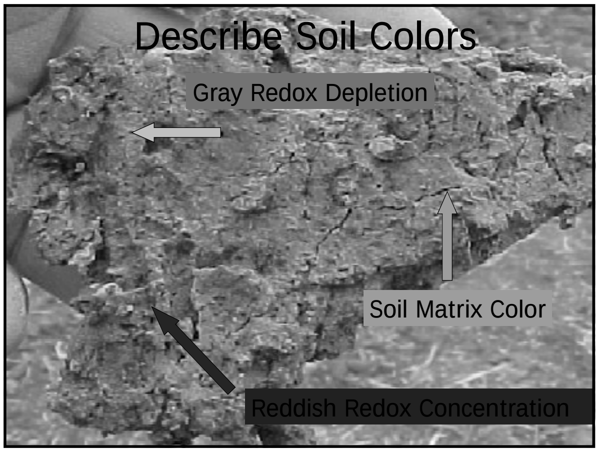
- fragipans
- clay pans
- abrupt texture change
- discontinuities
- bedrock

APPARENT (flood plains)
from the bottom up



Redoximorphic Features

The shapes and forms of bodies resulting from the **red**uction and **ox**idation of iron

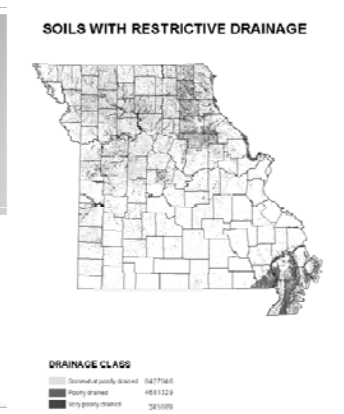


- **<u>Hydrologic Groups</u>**
- **(a) Definition**
- Hydrologic group is a group of soils having similar runoff potential under similar storm and cover conditions.

(b) Classes

- The soils in the United States are placed into four groups, A, B, C, and D, and three dual classes, A/D, B/D, and C/D. In the definitions of the classes, infiltration rate is the rate at which water enters the soil at the surface and is controlled by the surface conditions. Transmission rate is the rate at which water moves in the soil and is controlled by soil properties. Definitions of the classes are as follows:
- **A**. (Low runoff potential). The soils have a high infiltration rate even when thoroughly wetted. They chiefly consist of deep, well drained to excessively drained sands or gravels. They have a high rate of water transmission.
- **B**. The soils have a moderate infiltration rate when thoroughly wetted. They chiefly are moderately deep to deep, moderately well drained to well drained soils that have moderately fine to moderately coarse textures. They have a moderate rate of water transmission.
- **C**. The soils have a slow infiltration rate when thoroughly wetted. They chiefly have a layer that impedes downward movement of water or have moderately fine to fine texture. They have a slow rate of water transmission.
- **D**. (High runoff potential). The soils have a very slow infiltration rate when thoroughly wetted. They chiefly consist of clay soils that have a high swelling potential, soils that have a permanent high water table, soils that have a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. They have a very slow rate of water transmission.

- Dual hydrologic groups, A/D, B/D, and C/D, are given for certain wet soils that can be adequately drained. The first letter applies to the drained condition, the second to the undrained. Only soils that are rated D in their natural condition are assigned to dual classes. Soils may be assigned to dual groups if drainage is feasible and practical.



DRAINAGE CLASS

Definition.—"Drainage class" identifies the natural drainage condition of the soil. It refers to the frequency and duration of wet periods.

7 Drainage Classes used in MO

• Excessively Drained	>6′
• Somewhat Excessively Drained	>6′
• Well Drained	3.5 to 6′
• Moderately Well Drained	2-3.5′
• Somewhat Poorly Drained	1-2′
• Poorly Drained	0-1′
• Very Poorly Drained	+1′

Ksat vs. DRAINAGE

- Saturated hydraulic conductivity or Ksat
  Pertains to the amount of water that would move downward through a unit area of saturated in-place soil in unit time under unit hydraulic gradient.
- Natural Drainage Class
  Refers to the frequency and duration of wet periods similar to those under which the soil developed.

Soil Air Space & Water Movement

- Air space size
- Air space quantity
- Changes impact physical processes in the soil. Such as adhesion, cohesion, adsorption, and surface tension.

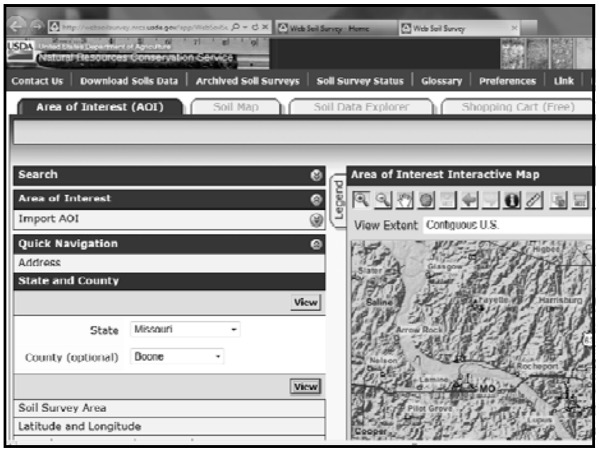
- Compaction breaks down the natural soil structure.
- Compaction changes the air space size and quantity.

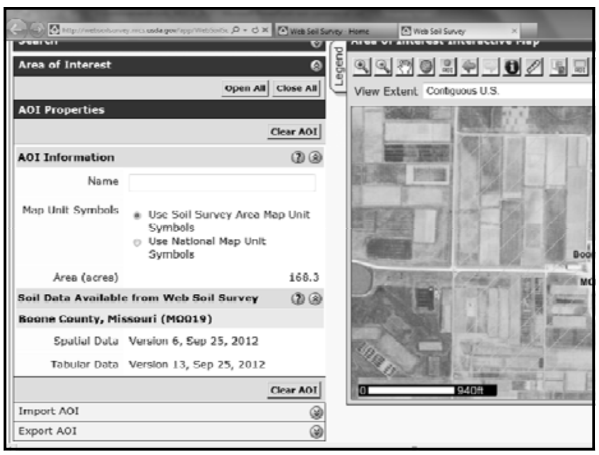
Soil Compaction

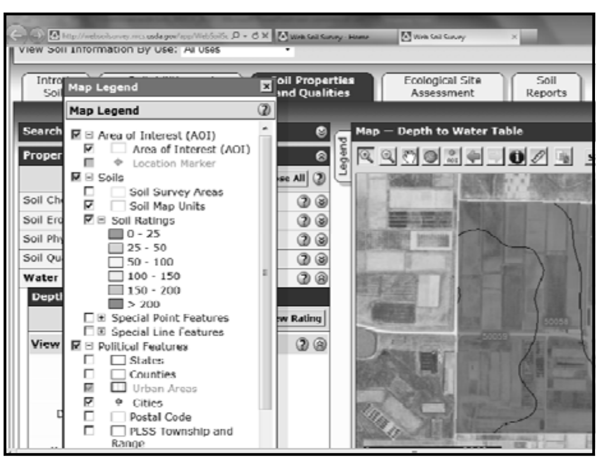
- Saturated flow (also called gravitational flow) occurs only under saturated conditions when the force of gravity is greater than forces holding water in the soil.

  Capillary flow occurs in unsaturated soil (also called unsaturated flow). Unbroken films of water spread through connected capillary pores.

Flow terminology


Contact Us
Download Soils Data
Archived Soil Surveys
Soil Survey Status
Glossary
Preferences
Link
Area of Interest (AOI)
Soil Map
Soil Data Explorer
Shopping Cart (Free)
Search
Area of Interest
Import AOI
Quick Navigation
Address
State and County
View
State
Missouri
County (optional)
Boone
View
Soil Survey Area
Latitude and Longitude
Legend
Area of Interest Interactive Map
View Extent
Contiguous U.S.


Area of Interest
Open All
Close All
AOI Properties
Clear AOI
AOI Information
Name
Map Unit Symbols
Use Soil Survey Area Map Unit Symbols
Use National Map Unit Symbols
Area (acres)
168.3
Soil Data Available from Web Soil Survey
Boone County, Missouri (MO019)
Spatial Data
Version 6, Sep 25, 2012
Tabular Data
Version 13, Sep 25, 2012
Clear AOI
Import AOI
Export AOI
Legend
View Extent
Contiguous U.S.
940ft


Soil Properties and Qualities
Ecological Site Assessment
Soil Reports
Map Legend
Map Legend
Area of Interest (AOI)
Area of Interest (AOI)
Location Marker
Soils
Soil Survey Areas
Soil Map Units
Soil Ratings
0 - 25
25 - 50
50 - 100
100 - 150
150 - 200
> 200
Special Point Features
Special Line Features
Political Features
States
Counties
Urban Areas
Cities
Postal Code
PLSS Township and Range
Map — Depth to Water Table
Legend

Report — Water Features

Boone County, Missouri							
Map unit symbol and soil name	Hydrologic group	Surface runoff	Month	Water table		Pondi	
				Upper limit	Lower limit	Surface depth	Duratio
				Ft	Ft	Ft	
50058—Mexico silt loam, 0 to 2 percent slopes							
Mexico	D	Very high	January	0.5-1.5	1.0-2.0	—	—
	D	Very high	February	0.5-1.5	1.0-2.0	—	—
	D	Very high	March	0.5-1.5	1.0-2.0	—	—
	D	Very high	April	0.5-1.5	1.0-2.0	—	—
	D	Very high	May	0.5-1.5	1.0-2.0	—	—
	D	Very high	November	0.5-1.5	1.0-2.0	—	—
	D	Very high	December	0.5-1.5	1.0-2.0	—	—
50059—Mexico silt loam, 1 to 4 percent slopes, eroded							
Mexico	D	Very high	January	0.5-1.5	1.0-2.0	—	—
	D	Very high	February	0.5-1.5	1.0-2.0	—	—
	D	Very high	March	0.5-1.5	1.0-2.0	—	—

Report — Physical Soil Properties

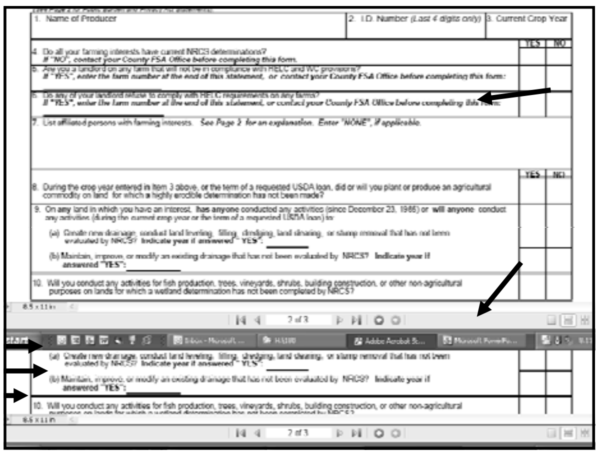
Boone County, Missouri							
Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Availa wat capa
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/I
50058—Mexico silt loam, 0 to 2 percent slopes							
Mexico	0-9	2- 5- 10	60-77-80	15-18-27	1.40-1.55	4.00-14.00	0.22-(
	9-15	5-10- 15	60-65-80	15-25-35	1.40-1.55	4.00-14.00	0.18-(
	15-34	1- 2- 5	30-39-50	40-59-60	1.25-1.45	0.01-0.42	0.08-(
	34-42	1- 2- 5	55-66-70	25-32-38	1.40-1.60	1.40-4.00	0.16-(
	42-80	4- 4- 10	40-66-70	24-30-45	1.40-1.60	1.40-4.00	0.16-(
50059—Mexico silt loam, 1 to 4 percent slopes, eroded							
Mexico	0-7	5- 9- 12	65-71-80	15-20-26	1.40-1.55	4.00-14.00	0.22-(
	7-12	5- 9- 12	55-61-	28-30-	1.45-	1.40-4.00	0.21-(

SUMMARY:

- PRIMARY CONTROL OF WATER MOVEMENT IN SOIL: --Soil Texture – particle size distribution; Soil Structure; Organic Matter Content, Landform – hill slope profile.
- Saturated flow (also called gravitational flow) occurs only under saturated conditions when the force of gravity is greater than forces holding water in the soil.
- The more accurate and site specific, the more effective the drainage system.
- Soils are inherently complicated; therefore so is soil water movement.

Wetland Determinations

- Food Security Act – USDA Program Participants.
- Clean Water Act – Applies to all.



1. Name of Producer | 2. I.D. Number (Last 4 digits only) | 3. Current Crop Year

	YES	NO
4. Do all your farming interests have current NRCS determinations? *If "NO", contact your County FSA Office before completing this form.*		
5. Are you a landlord on any farm that will not be in compliance with HELC and WC provisions? *If "YES", enter the farm number at the end of this statement, or contact your County FSA Office before completing this form:*		
6. Do any of your landlords refuse to comply with HELC requirements on any farms? *If "YES", enter the farm number at the end of this statement, or contact your County FSA Office before completing this form:*		

7. List affiliated persons with farming interests. *See Page 2 for an explanation. Enter "NONE", if applicable.*

	YES	NO
8. During the crop year entered in Item 3 above, or the term of a requested USDA loan, did or will you plant or produce an agricultural commodity on land for which a highly erodible determination has not been made?		
9. On **any** land in which you have an interest, **has anyone** conducted any activities (since December 23, 1985) or **will anyone** conduct any activities (during the current crop year or the term of a requested USDA loan) to:		
(a) Create new drainage, conduct land leveling, filling, dredging, land clearing, or stump removal that has not been evaluated by NRCS? **Indicate year if answered "YES":**		
(b) Maintain, improve, or modify an existing drainage that has not been evaluated by NRCS? **Indicate year if answered "YES":**		
10. Will you conduct any activities for fish production, trees, vineyards, shrubs, building construction, or other non-agricultural purposes on lands for which a wetland determination has not been completed by NRCS?		

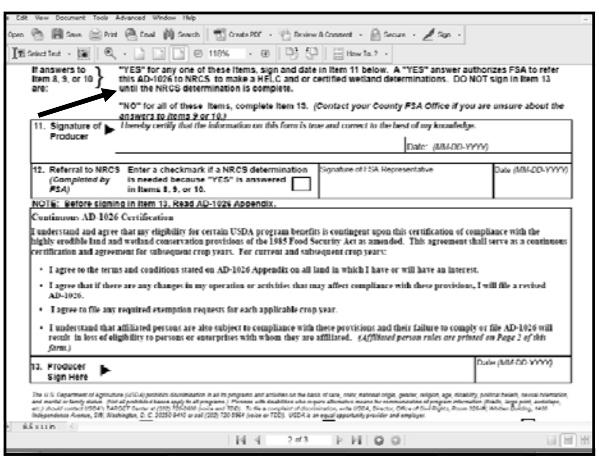
8.5 x 11 in   2 of 3

(a) Create new drainage, conduct land leveling, filling, dredging, land clearing, or stump removal that has not been evaluated by NRCS? **Indicate year if answered "YES":**

(b) Maintain, improve, or modify an existing drainage that has not been evaluated by NRCS? **Indicate year if answered "YES":**

10. Will you conduct any activities for fish production, trees, vineyards, shrubs, building construction, or other non-agricultural purposes on lands for which a wetland determination has not been completed by NRCS?

8.5 x 11 in   2 of 3



Edit View Document Tools Advanced Window Help

Open Save Print Email Search Create PDF Review & Comment Secure Sign

Select Text 110% How To ?

If answers to Item 8, 9, or 10 are: **"YES" for any one of these items, sign and date in Item 11 below. A "YES" answer authorizes FSA to refer this AD-1026 to NRCS to make a HELC and or certified wetland determinations. DO NOT sign in Item 13 until the NRCS determination is complete.**

"NO" for all of these items, complete Item 13. ***(Contact your County FSA Office if you are unsure about the answers to items 9 or 10.)***

11. Signature of Producer *I hereby certify that the information on this form is true and correct to the best of my knowledge.* Date: (MM-DD-YYYY)

12. Referral to NRCS ***(Completed by FSA)*** **Enter a checkmark if a NRCS determination is needed because "YES" is answered in Items 8, 9, or 10.** | Signature of FSA Representative | Date (MM-DD-YYYY)

NOTE: Before signing in Item 13, Read AD-1026 Appendix.

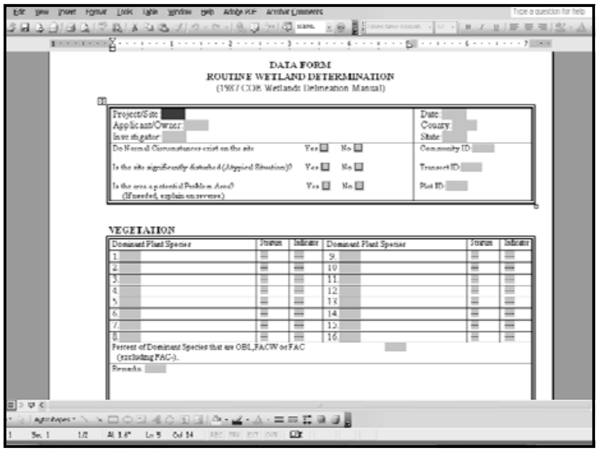
Continuous AD-1026 Certification

I understand and agree that my eligibility for certain USDA program benefits is contingent upon this certification of compliance with the highly erodible land and wetland conservation provisions of the 1985 Food Security Act as amended. This agreement shall serve as a continuous certification and agreement for subsequent crop years. For current and subsequent crop years:

- I agree to the terms and conditions stated on AD-1026 Appendix on all land in which I have or will have an interest.
- I agree that if there are any changes in my operation or activities that may affect compliance with these provisions, I will file a revised AD-1026.
- I agree to file any required exemption requests for each applicable crop year.
- I understand that affiliated persons are also subject to compliance with these provisions and their failure to comply or file AD-1026 will result in loss of eligibility to persons or enterprises with whom they are affiliated. *(Affiliated person rules are printed on Page 2 of this form.)*

13. Producer Sign Here | Date (MM-DD-YYYY)

8.5 x 11 in   2 of 3



DATA FORM
ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Delineation Manual)

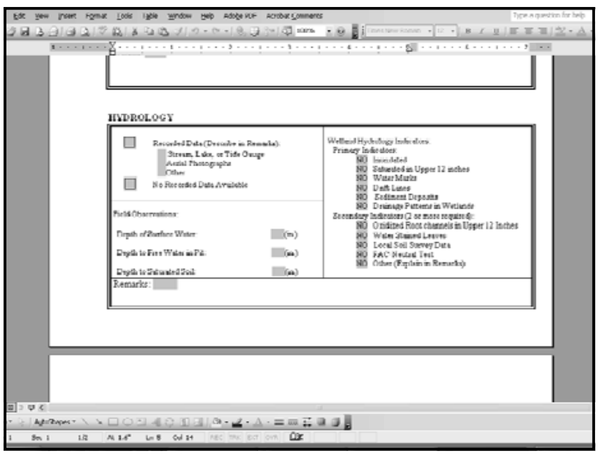
Project/Site:			Date:
Applicant/Owner:			County:
Investigator:			State:
Do Normal Circumstances exist on the site	Yes ☐	No ☐	Community ID:
Is the site significantly disturbed (Atypical Situation)?	Yes ☐	No ☐	Transect ID:
Is the area a potential Problem Area? (If needed, explain on reverse.)	Yes ☐	No ☐	Plot ID:

VEGETATION

Dominant Plant Species	Stratum	Indicator	Dominant Plant Species	Stratum	Indicator
1.			9.		
2.			10.		
3.			11.		
4.			12.		
5.			13.		
6.			14.		
7.			15.		
8.			16.		

Percent of Dominant Species that are OBL, FACW or FAC (excluding FAC-).

Remarks:



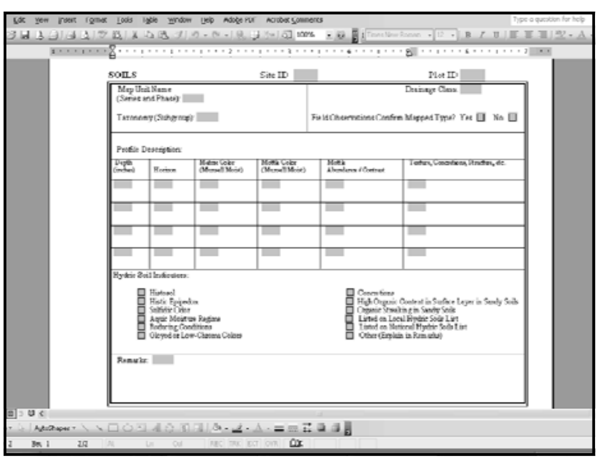
HYDROLOGY

☐ Recorded Data (Describe in Remarks):
Stream, Lake, or Tide Gauge
Aerial Photographs
Other
☐ No Recorded Data Available

Field Observations:
Depth of Surface Water: (in.)
Depth to Free Water in Pit: (in.)
Depth to Saturated Soil: (in.)

Wetland Hydrology Indicators:
Primary Indicators:
NO Inundated
NO Saturated in Upper 12 inches
NO Water Marks
NO Drift Lines
NO Sediment Deposits
NO Drainage Patterns in Wetlands
Secondary Indicators (2 or more required):
NO Oxidized Root channels in Upper 12 Inches
NO Water-Stained Leaves
NO Local Soil Survey Data
NO FAC-Neutral Test
NO Other (Explain in Remarks)

Remarks:



SOILS Site ID: Plot ID:

Map Unit Name (Series and Phase):
Drainage Class:
Taxonomy (Subgroup):
Field Observations Confirm Mapped Type? Yes ☐ No ☐

Profile Description:

Depth (inches)	Horizon	Matrix Color (Munsell Moist)	Mottle Color (Munsell Moist)	Mottle Abundance / Contrast	Texture, Concretions, Structure, etc.

Hydric Soil Indicators:

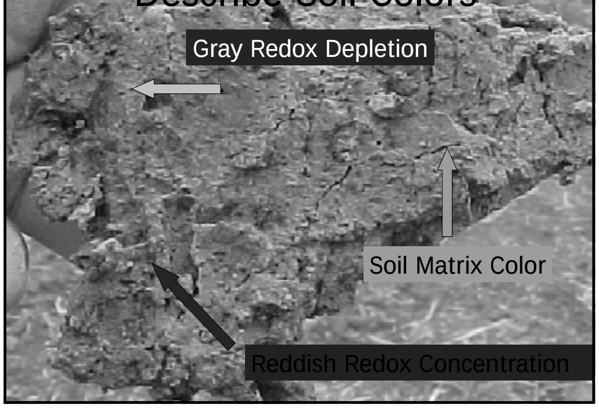
☐ Histosol
☐ Histic Epipedon
☐ Sulfidic Odor
☐ Aquic Moisture Regime
☐ Reducing Conditions
☐ Gleyed or Low-Chroma Colors
☐ Concretions
☐ High Organic Content in Surface Layer in Sandy Soils
☐ Organic Streaking in Sandy Soils
☐ Listed on Local Hydric Soils List
☐ Listed on National Hydric Soils List
☐ Other (Explain in Remarks)

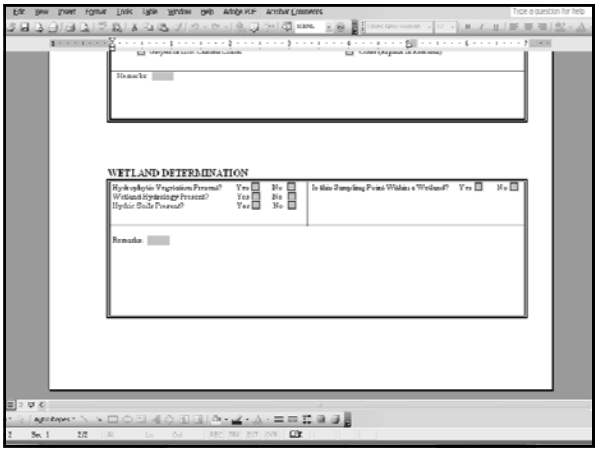
Remarks:

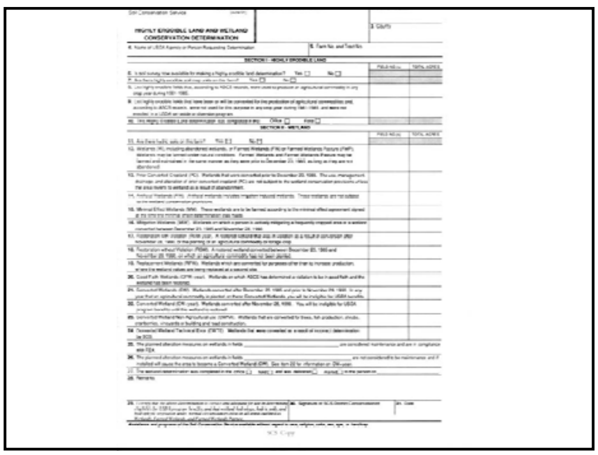
Redoximorphic Features

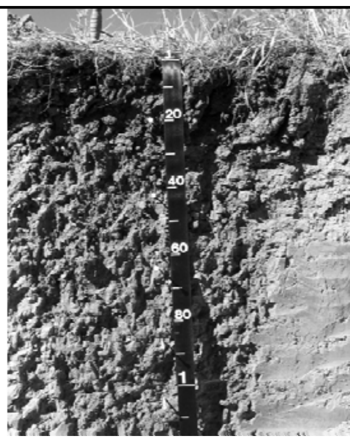
The shapes and forms of bodies resulting from the **red**uction and **ox**idation of iron

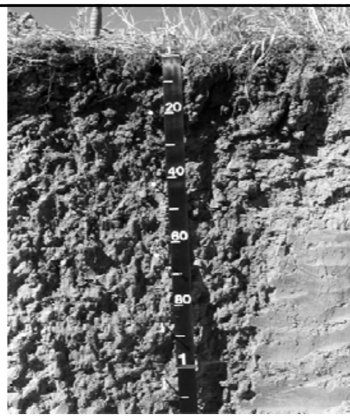
Describe Soil Colors




WETLAND DETERMINATION
Hydrophytic Vegetation Present? Yes No
Wetland Hydrology Present? Yes No
Hydric Soils Present? Yes No
Is this Sampling Point Within a Wetland? Yes No
Remarks:


HIGHLY ERODIBLE LAND AND WETLAND CONSERVATION DETERMINATION


20
40
60
80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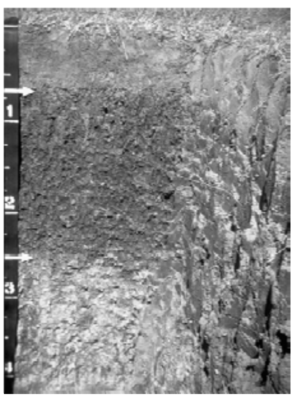
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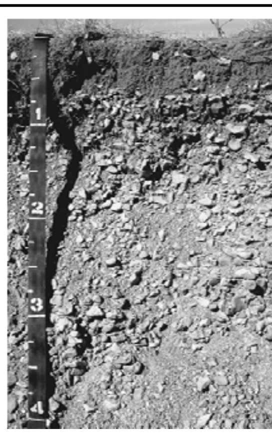
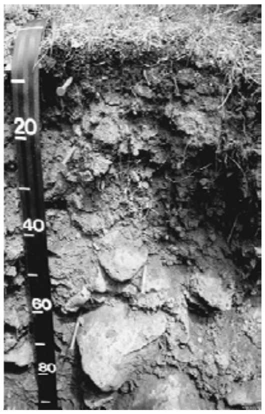

1
2
3
4


20
40
60
80

Appendix 14D Auger-hole Procedure for Hydraulic Conductivity

(1) Auger-hole method

The auger-hole method is the simplest and most accurate way to determine soil permeability (fig. 1). The measurements obtained using this method are a combination of vertical and lateral conductivity, however, under most conditions, the measurements represent the lateral value. The most limiting obstacle for using this method is the need for a water table within that part of the soil profile to be evaluated. This limitation requires more intensive planning. Tests must be made when a water table is available during the wet season. Obtaining accurate readings using this method requires a thorough knowledge of the procedure.

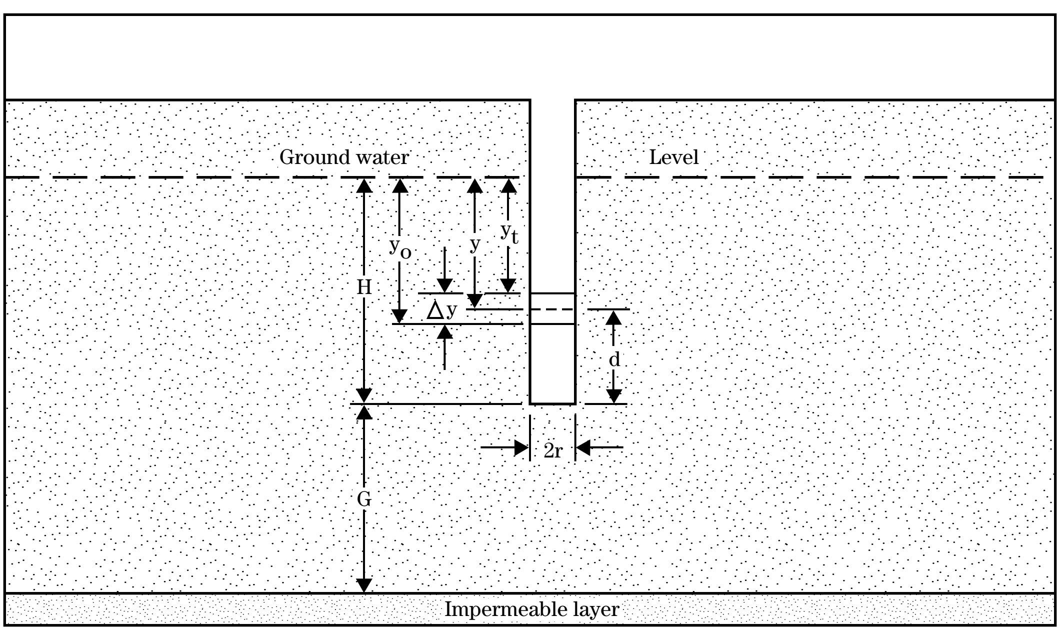
The principle of the auger-hole method is simple. A hole is bored to a certain distance below the water table. This should be to a depth about 1 foot below the average depth of drains. The depth of water in the hole should be about 5 to 10 times the diameter of the hole. The water level is lowered by pumping or bailing, and the rate at which the ground water flows back into the hole is measured. The hydraulic conductivity can then be computed by a formula that relates the geometry of the hole to the rate at which the water flows into it.

(i) Formulas for determination of hydraulic conductivity by auger-hole method—Determination of the hydraulic conductivity by the auger-hole method is affected by the location of the barrier or impermeable layer.

A barrier or impermeable layer is defined as a less permeable stratum, continuous over a major portion of the area and of such thickness as to provide a positive deterrent to the downward movement of ground water. The hydraulic conductivity of the barrier must be less than 10 percent of that of the overlying material if it is to be considered as a barrier. For the case where the impermeable layer coincides with the bottom of the hole, a formula for determining the hydraulic conductivity (K) has been developed by Van Bavel and Kirkham (1948).

$$K = \left(\frac{2220r}{SH}\right)\left(\frac{\Delta y}{\Delta t}\right) \qquad [1]$$

Figure 1 Symbols for auger-hole method of measuring hydraulic conductivity



where:

S = a function dependent on the geometry of the hole, the static depth of water, and the average depth of water during the test
K = hydraulic conductivity (in/hr)
H = depth of hole below the ground water table (in)
r = radius of auger hole (in)
y = distance between ground water level and the average level of water in the hole (in) for the time interval t (s)
Δy = rise of water (in) in auger hole during Δt
t = time interval (s)
G = depth of the impermeable layer below the bottom of the hole (in). Impermeable layer is defined as a layer that has the permeability of no more than a tenth of the permeability of the layers above.
d = average depth of water in auger hole during test (in)

A sample form for use in recording field observations and making the necessary computations is illustrated in figure 2. This includes a chart for determining the geometric function S for use in the formula for calculation of the hydraulic conductivity.

The more usual situation is where the bottom of the auger hole is some distance above the barrier. Formulas for computing the hydraulic conductivity in homogeneous soils by the auger-hole method have been developed for both cases (Ernst, 1950). These formulas (2 and 3) are converted to English units of measurement.

For the case where the impermeable layer is at the bottom of the auger-hole, G = 0:

$$K = \frac{15,000r^2}{(H+10r)\left(2-\frac{y}{H}\right)y}\frac{\Delta y}{\Delta t} \quad [2]$$

For the case where the impermeable layer is at a depth ≥ 0.5H below the bottom of the auger hole:

$$K = \frac{16,667r^2}{(H+20r)\left(2-\frac{y}{H}\right)y}\frac{\Delta y}{\Delta t} \quad [3]$$

The following conditions should be met to obtain acceptable accuracy from use of the auger-hole method:

$2r > 2\ 1/2$ and $< 5\ 1/2$ inches
$H > 10$ and < 80 inches
$y > 0.2\ H$
$G > H$
$y < 1/4\ y_o$

Charts have been prepared for solution of equation 3 for auger-holes of r = 1 1/2 and 2 inches. For the case where the impermeable layer is at the bottom of the auger hole, the hydraulic conductivity may be determined from these charts by multiplying the value obtained by a conversion factor f as indicated on figure 3.

Figure 2a Auger-hole method of measuring hydraulic conductivity—sheet 1 of 2

Field Measurement of Hydraulic Conductivity
Auger-Hole Method

For use only where bottom of hole coincides with barrier.

Soil Conservation District Dry River **Field Office** Salt Flat

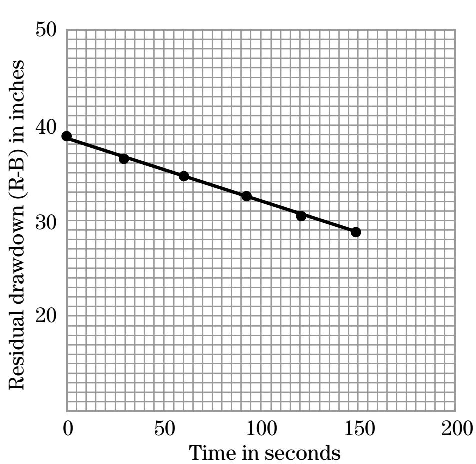
Cooperator Joe Doe - Farm No. 2 **Location** 1/2 Mi. E. Big Rock Jct.

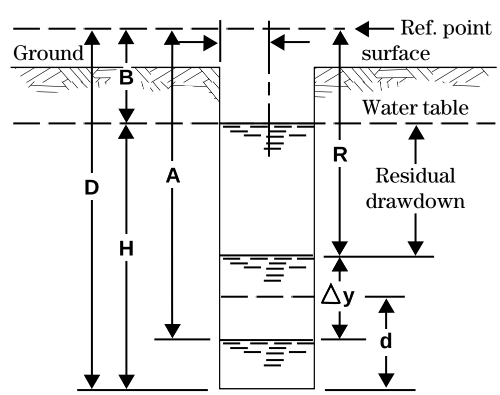
SCD Agreement No. 264 **Field No.** 4 **Farm No.** B-817

Technician Tom Jones **Date** 1 June 64

Boring No. 4 **Salinity (EC) Soil** — **Water** 5.6 **Estimated K** 1.0 in/hr

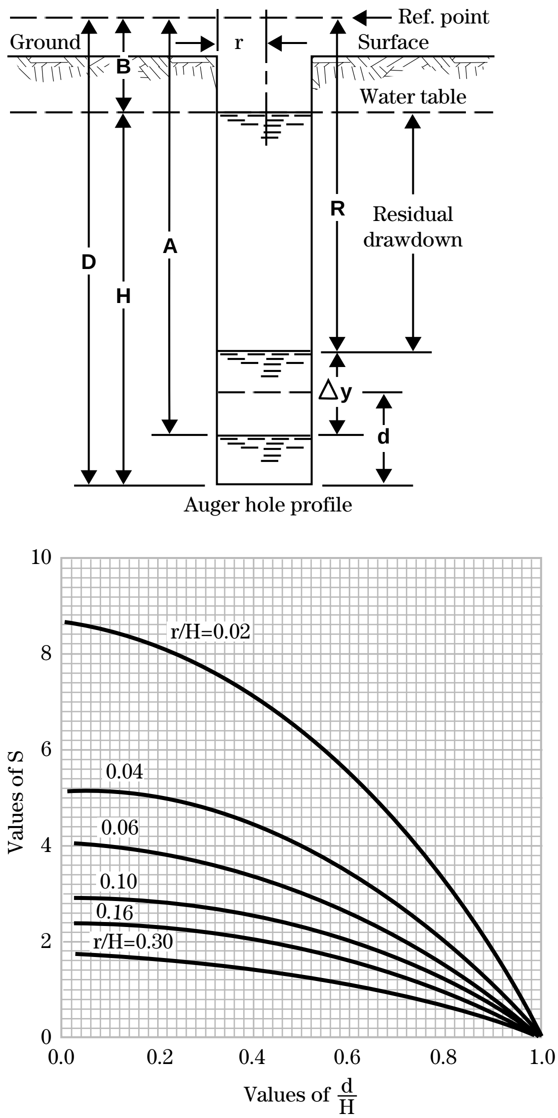
Start 10:03 Elapsed Time	Δt	Distance to water surface from reference point			Δy	Residual drawdown
		Before pumping	After pumping	During pumping		
		B	A	R	A-R	R-B
Seconds	Seconds	Inches	Inches	Inches	Inches	Inches
XX	XX	43	XX	XX	XX	XX
0.0	XX	XX	81.5		0.00	38.5
30				79.0		36.0
60				77.5		34.5
90				76.0		33.0
120				74.0		31.0
150	150			72.0	9.5	29.0





Auger hole profile

Figure 2a Auger-hole method of measuring hydraulic conductivity—sheet 2 of 2



Hole dia. *4"*
Hole depth *84" Ground to Ref.=11"*

D= *93"*
r= *2*
H= *50*
d= *16.2*
Δy= *9.5*
Δt= *150* seconds
r/H= *2* / *50* = *0.04*
d/H= *16.2* / *50* = *0.32*
S= *4.7*

$$K = 2220 \times \frac{2}{(4.7)(50)} \times \frac{9.5}{150}$$

K= *1.2 in/hr*

Figure 2b Auger-hole method of measuring hydraulic conductivity—sheet 1 of 2 (blank)

Field Measurement of Hydraulic Conductivity
Auger-Hole Method

For use only where bottom of hole coincides with barrier.

Soil Conservation District________________________ **Field Office**________________________

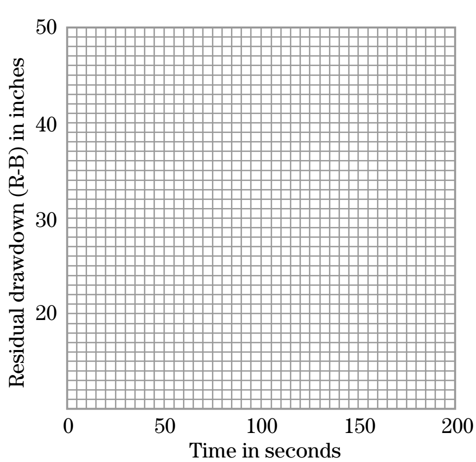
Cooperator________________________________ **Location**________________________

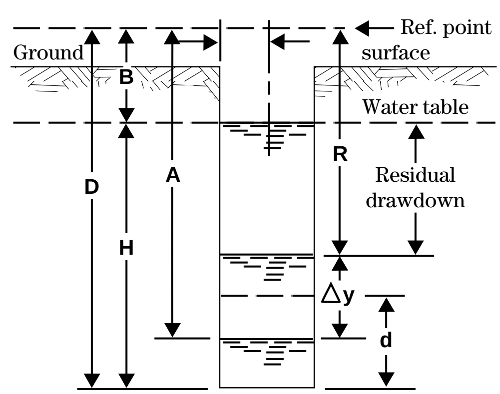
SCD Agreement No.______________**Field No.**__________ **Farm No.**____________________

Technician________________________________ **Date**________________________

Boring No.________ **Salinity (EC) Soil** ________ **Water**__________ **Estimated K**______________

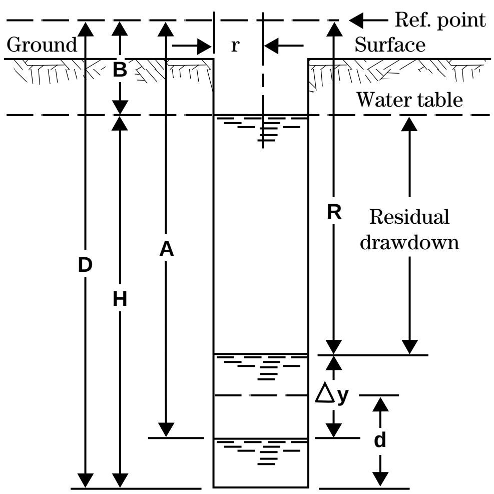
Start 10:03 / Elapsed Time	△t	Distance to water surface from reference point			△y	Residual drawdown
		Before pumping	After pumping	During pumping		
		B	A	R	A-R	R-B
Seconds	Seconds	Inches	Inches	Inches	Inches	Inches



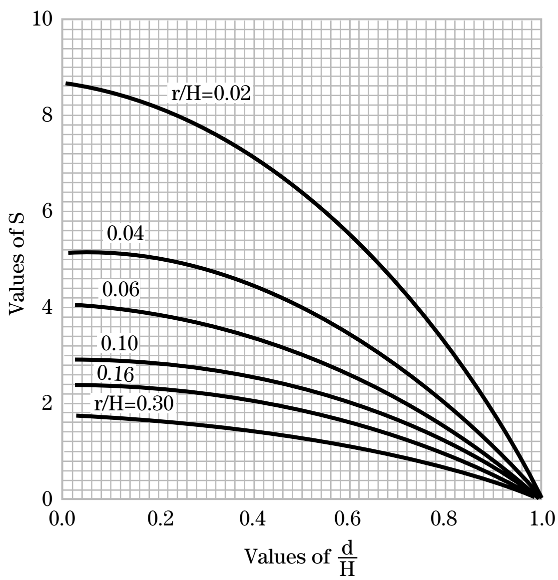


Auger hole profile

Figure 2b Auger-hole method of measuring hydraulic conductivity—sheet 2 of 2 (blank)



Auger hole profile



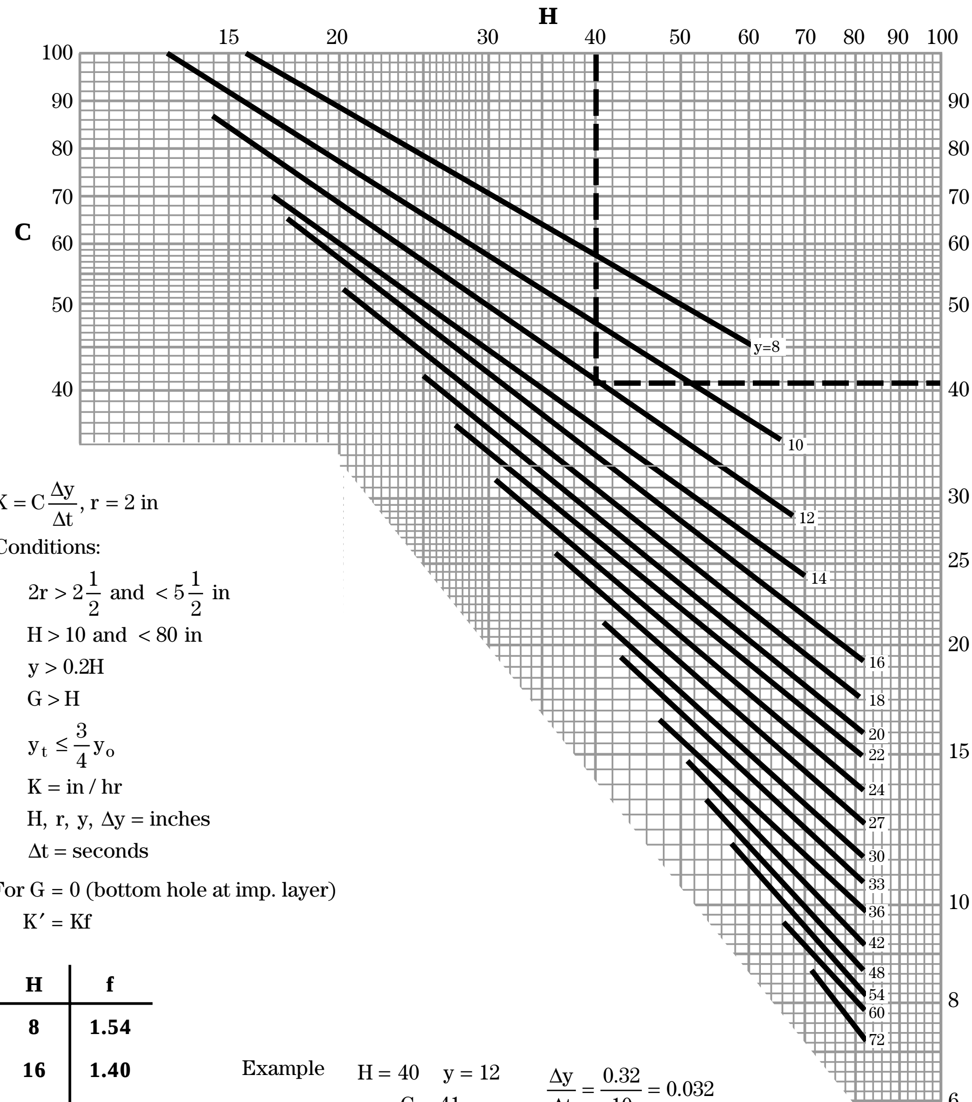
Hole dia. 4"
Hole depth 84" Ground to Ref.=11"

D= 93"
r= 2
H= 50
d= 16.2
Δy= 9.5
Δt= 150 seconds
r/H= 2 / 50 = 0.04
d/H= 16.2 / 50 = 0.32
S= 4.7

$$K = 2220 \times \frac{2}{(4.7)(50)} \times \frac{9.5}{150}$$

K= 1.2 in/hr

Figure 3 Hydraulic conductivity—auger-hole method using the Ernst Formula



$K = C\frac{\Delta y}{\Delta t}$, r = 2 in

Conditions:

- $2r > 2\frac{1}{2}$ and $< 5\frac{1}{2}$ in
- $H > 10$ and < 80 in
- $y > 0.2H$
- $G > H$
- $y_t \leq \frac{3}{4} y_o$
- K = in / hr
- H, r, y, Δy = inches
- Δt = seconds

For G = 0 (bottom hole at imp. layer)

$K' = Kf$

H	f
8	**1.54**
16	**1.40**
24	**1.31**
36	**1.22**
48	**1.16**
60	**1.13**
72	**1.10**

Example H = 40 y = 12 C = 41 $\frac{\Delta y}{\Delta t} = \frac{0.32}{10} = 0.032$

$K = 41 \times 0.032 = 1.31$ in/hr

REFERENCE From formula L.F. Ernst Groningen, The Netherlands

$$K = \frac{16,667r^2}{(H+20r)\left(2-\frac{y}{H}\right)y}\frac{\Delta y}{\Delta t}$$

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SOIL CONSERVATION SERVICE

ENGINEERING DIVISION-DRAINAGE SECTION

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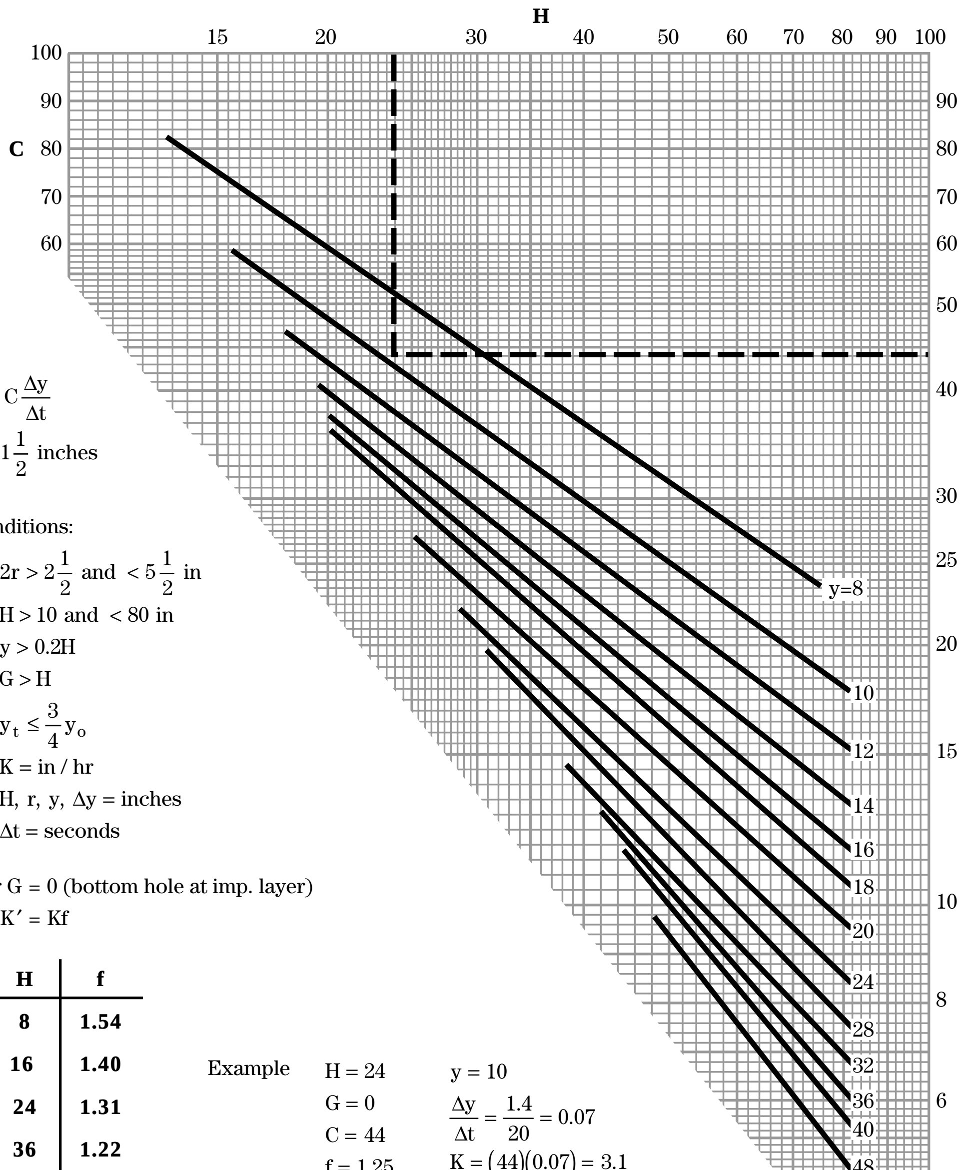
Figure 3 Hydraulic conductivity—auger-hole method by Ernst Formula—continued



$$K = C\frac{\Delta y}{\Delta t}$$

$$r = 1\frac{1}{2} \text{ inches}$$

Conditions:

- $2r > 2\frac{1}{2}$ and $< 5\frac{1}{2}$ in
- $H > 10$ and < 80 in
- $y > 0.2H$
- $G > H$
- $y_t \leq \frac{3}{4} y_o$
- $K = \text{in / hr}$
- $H, r, y, \Delta y = \text{inches}$
- $\Delta t = \text{seconds}$

For G = 0 (bottom hole at imp. layer)
$K' = Kf$

H	f
8	1.54
16	1.40
24	1.31
36	1.22
48	1.16
60	1.13
72	1.10

Example

$H = 24$
$G = 0$
$C = 44$
$f = 1.25$

$y = 10$
$\frac{\Delta y}{\Delta t} = \frac{1.4}{20} = 0.07$
$K = (44)(0.07) = 3.1$
$K' = (3.1)(1.25) = 3.9$ in/hr

REFERENCE From formula L.F. Ernst
Groningen, The Netherlands

$$K = \frac{16{,}667r^2}{(H+20r)\left(2-\frac{y}{H}\right)y}\frac{\Delta y}{\Delta t}$$

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(ii) Equipment for auger-hole method—The following equipment is required to test hydraulic conductivity:

- suitable auger
- pump or bail bucket to remove water from the hole
- watch with a second hand
- device for measuring the depth of water in the hole as it rises during recharge
- well screen may be necessary for use in unstable soils

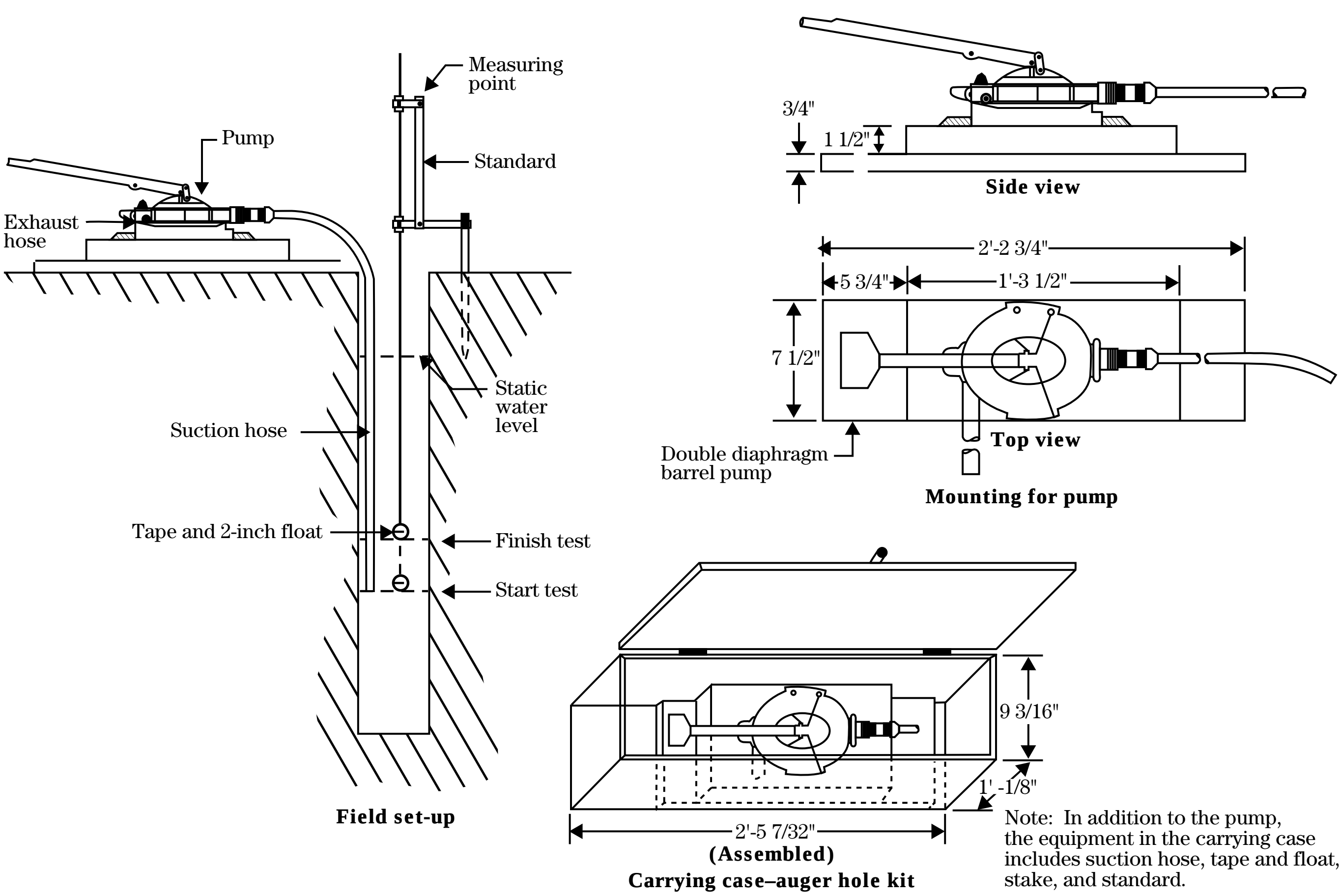
Many operators prefer a well made, light weight boat or stirrup pump that is easily disassembled for cleaning. A small, double diaphragm barrel pump has given good service. It can be mounted on a wooden frame for ease of handling and use.

For the depth measuring device, a light weight bamboo fishing rod marked in feet tenths and hundredths and that has a cork float works well. Other types of floats include a juice can with a standard soldered to one end to hold a light weight measuring rod.

A field kit for making the auger hole measurement of hydraulic conductivity is illustrated in figure 4. In addition to the items indicated in this figure, a watch and a soil auger are needed.

A perforated liner for the auger-hole is used in making the auger-hole measurement in fluid sands. This liner keeps the hole open and maintains the correct size. Several types of liners are used. Adequate slot openings or other perforations must be provided to allow free flow into the pipe.

Figure 4 Equipment for auger-hole method of measuring hydraulic conductivity



The openings in the screen should not restrict flow appreciably. The head loss through the screen should be negligible, and the velocity of flow through the openings should be small (0.3 foot per second or less) to prevent movement of fines into the hole. These criteria generally are met if the area of openings is 5 percent or more of the total screen area.

The Bureau of Reclamation uses 4-inch downspouting with 60 1/8- by 1-inch slots per foot of length. This works well in a variety of soils. A screen from the Netherlands is made from a punched brass sheet 2 millimeters thick with holes averaging about 0.5 millimeter in diameter. It is rolled into a tube 8 centimeters in diameter by 1 meter long. This screen works well because the sheet is rolled so that the direction in which the holes are punched is outward and the holes are variable in size. It has been used in many troublesome soils, and no clogging or failure to keep fines out of the hole has been reported.

Good judgment is needed in determining how far to drawdown the water level in the auger hole for the test. A minimum drawdown is necessary to physically satisfy theoretical criteria (refer to conditions given in fig. 3). Generally, a larger drawdown is made for slowly permeable soils than that for more permeable soils. A small drawdown for holes in sloughing soils may reduce the amount of sloughing. To prevent picking up sand in the pump, pumping should stop when the water level is within a few inches of the bottom of the hole.

Measurement of the rate of recovery of water in the auger hole should be completed before a fourth of the total amount of drawdown is recovered. Four or five readings should be taken at uniform short time intervals, and a plot of the readings made to determine a uniform rate of recovery to use in the formula. Plotting of time in seconds against the residual drawdown in inches indicates those readings at the beginning and end of the test that should be discarded and the proper values of t and y to use.

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

SATURATED HYDRAULIC CONDUCTIVITY - PERMEABILITY

K_{sat} Class

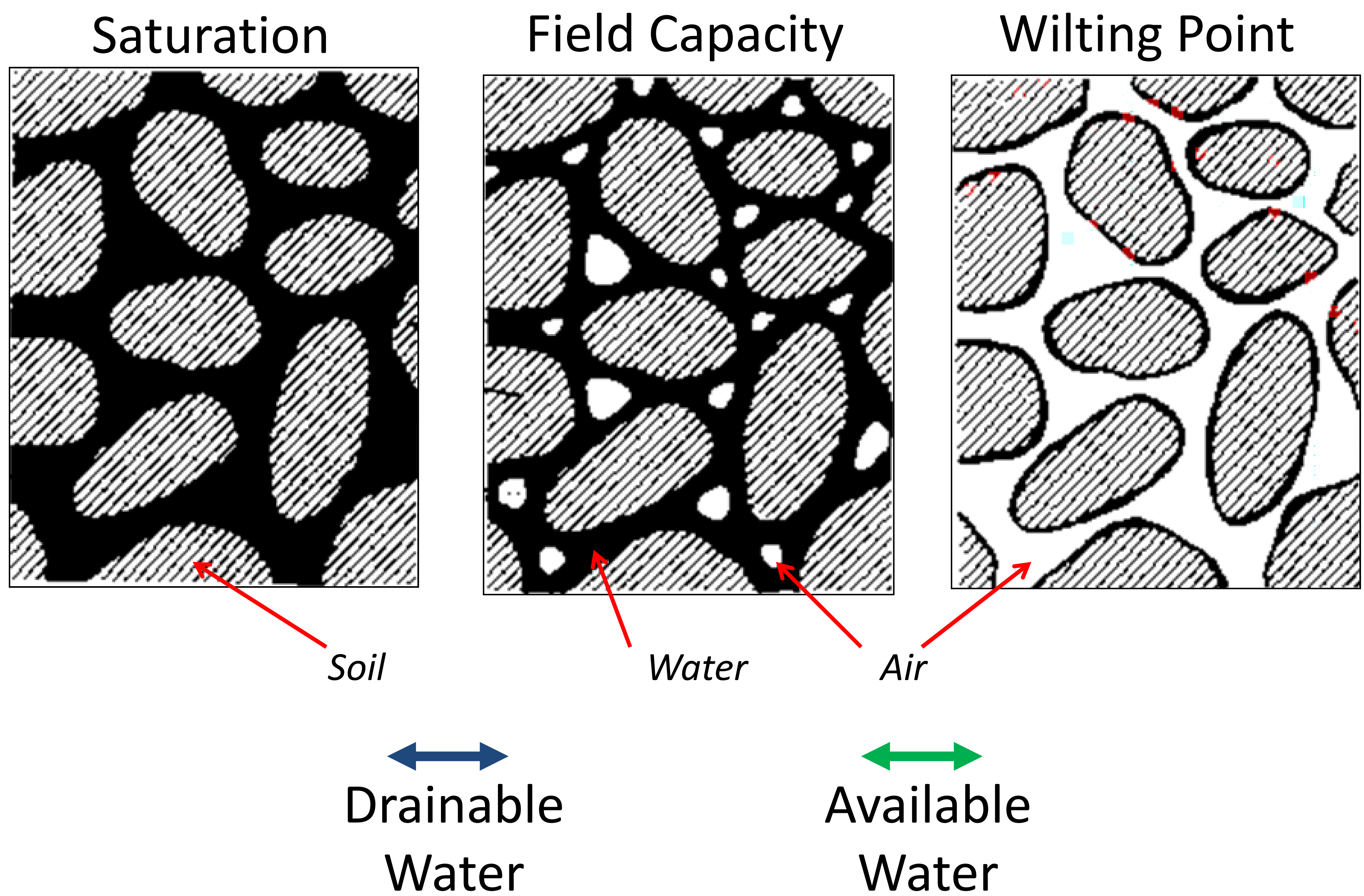
μm/sec	Class	in/hr
705.00		100.00
	VERY HIGH	
100.00		14.17
	HIGH	
10.00		1.417
	MODERATELY HIGH	
1.00		0.1417
	MODERATELY LOW	
0.10		0.01417
	LOW	
0.01		0.001417
	VERY LOW	
0.00		0.00
μm/sec		**in/hr**

Permeability Class

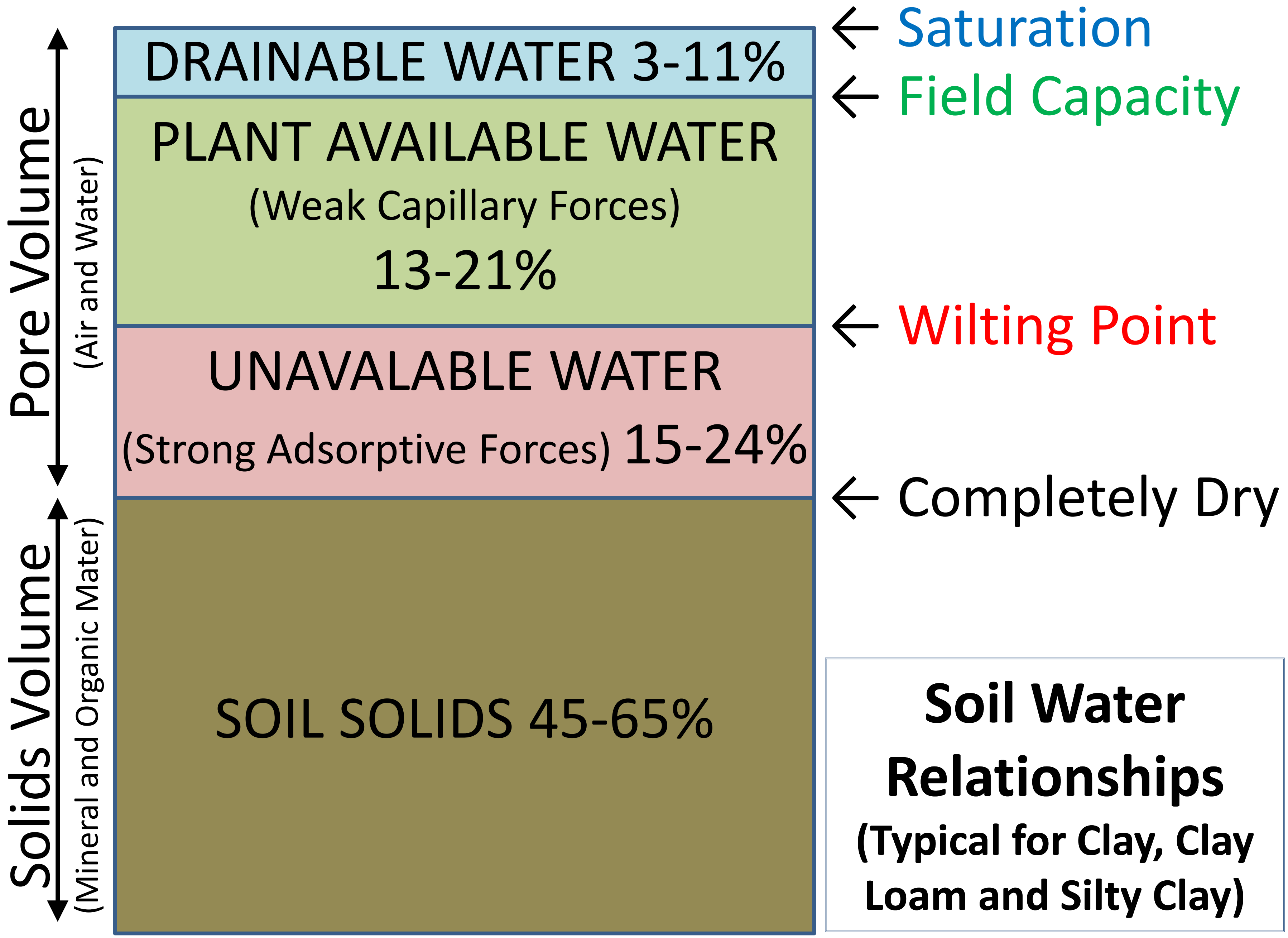
μm/sec	Class	in/hr
705.00		100.00
	VERY RAPID	
141.14		20.00
	RAPID	
42.34		6.00
	MODERATELY RAPID	
14.11		2.00
	MODERATE	
4.23		0.60
	MODERATELY SLOW	
1.41		0.20
	SLOW	
0.42		0.06
	VERY SLOW	
0.01		0.0015
	IMPERMEABLE	
0.00		0.00
μm/sec		**in/hr**

μm/sec x 0.1417 = in/hr	***in/hr x 7.0572 = μm/sec***
μm/sec x 0.2834 = ft/day	***in/hr x 2 = ft/day***

Soil Water


Saturation
Field Capacity
Wilting Point
Soil
Water
Air
Drainable Water
Available Water

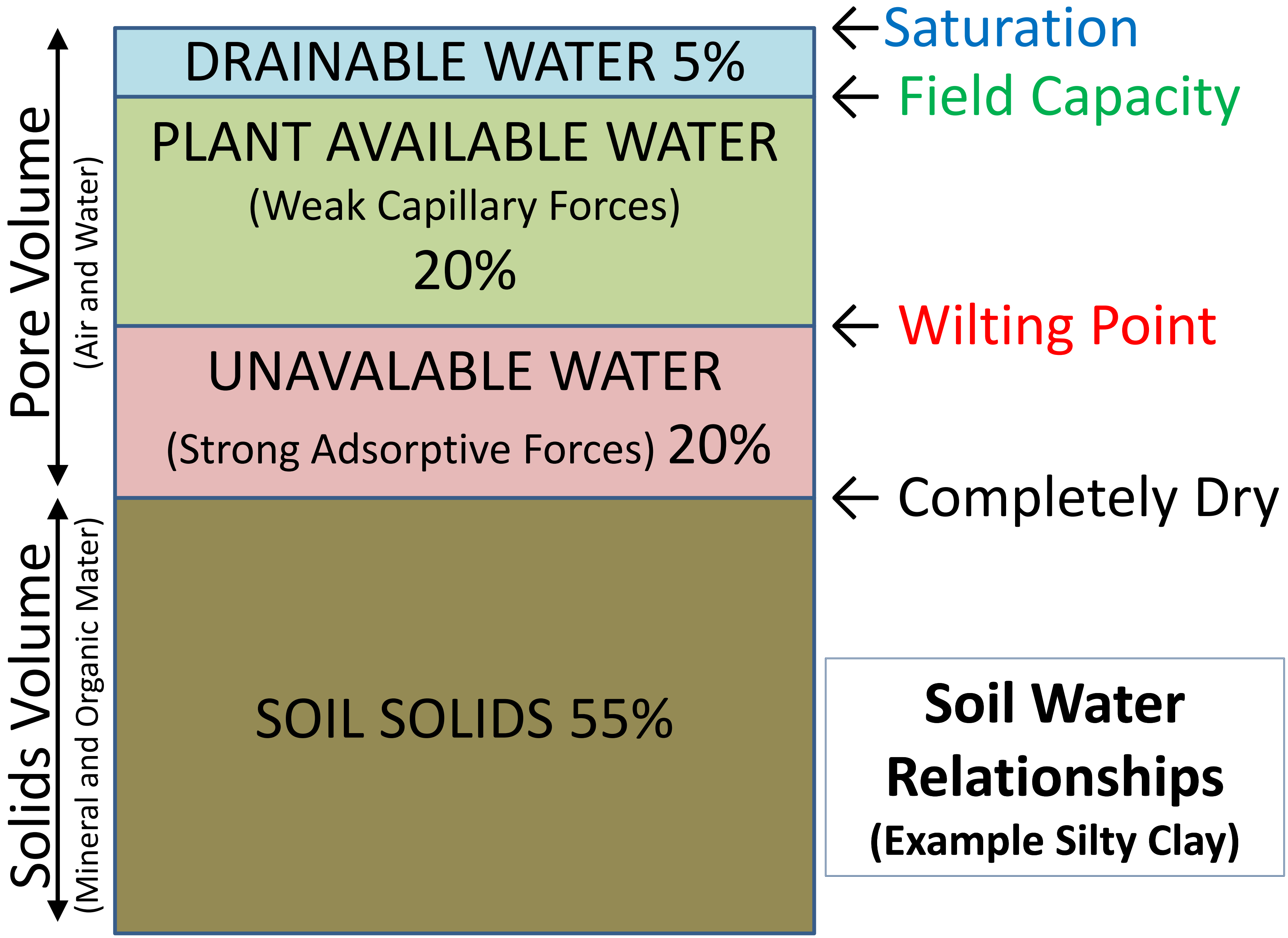
Soil Water Relationships
(Typical for Clay, Clay Loam and Silty Clay)



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	7-20	18-35

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



Soil Water Relationships
(Example Silty Clay)

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