Soil Water Reservoir

- Soil Texture
- Soil Structure
- Rootzone Depth
- Infiltrated Rainfall
  - Volume and seasonal distribution

Soil Texture

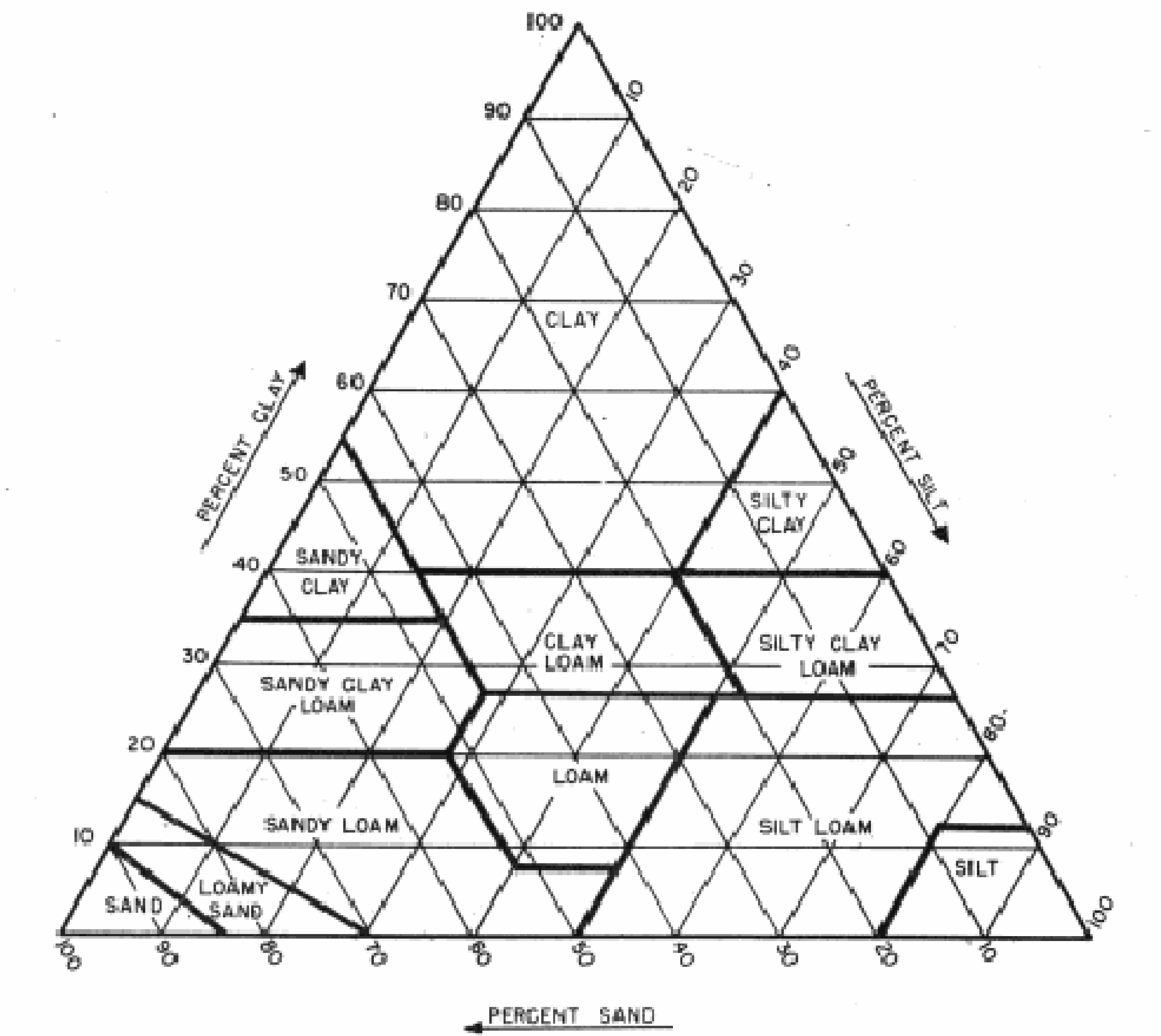
Relative proportions

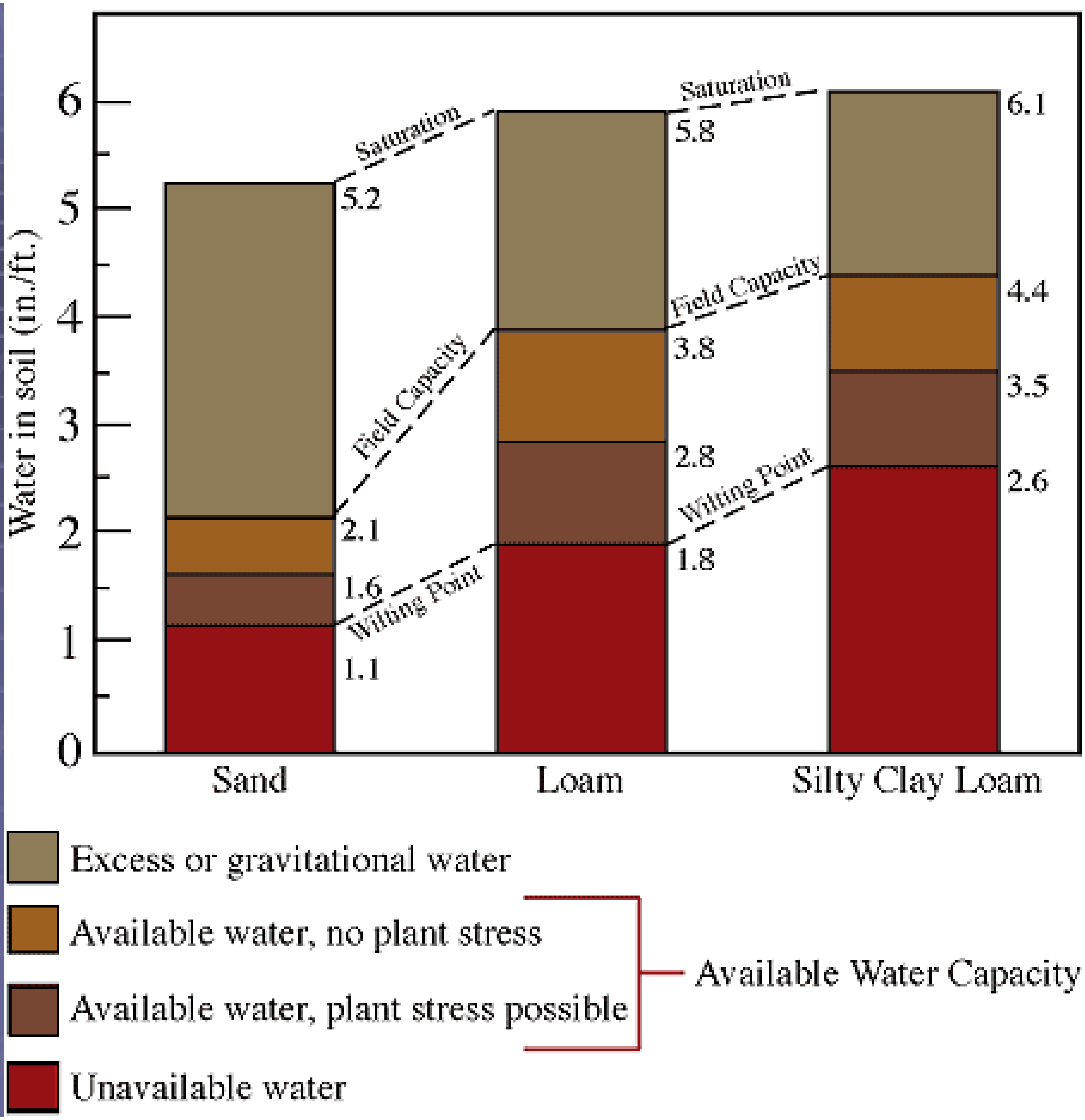
of

different particle sizes

Sand - Silt - Clay

Soil Texture

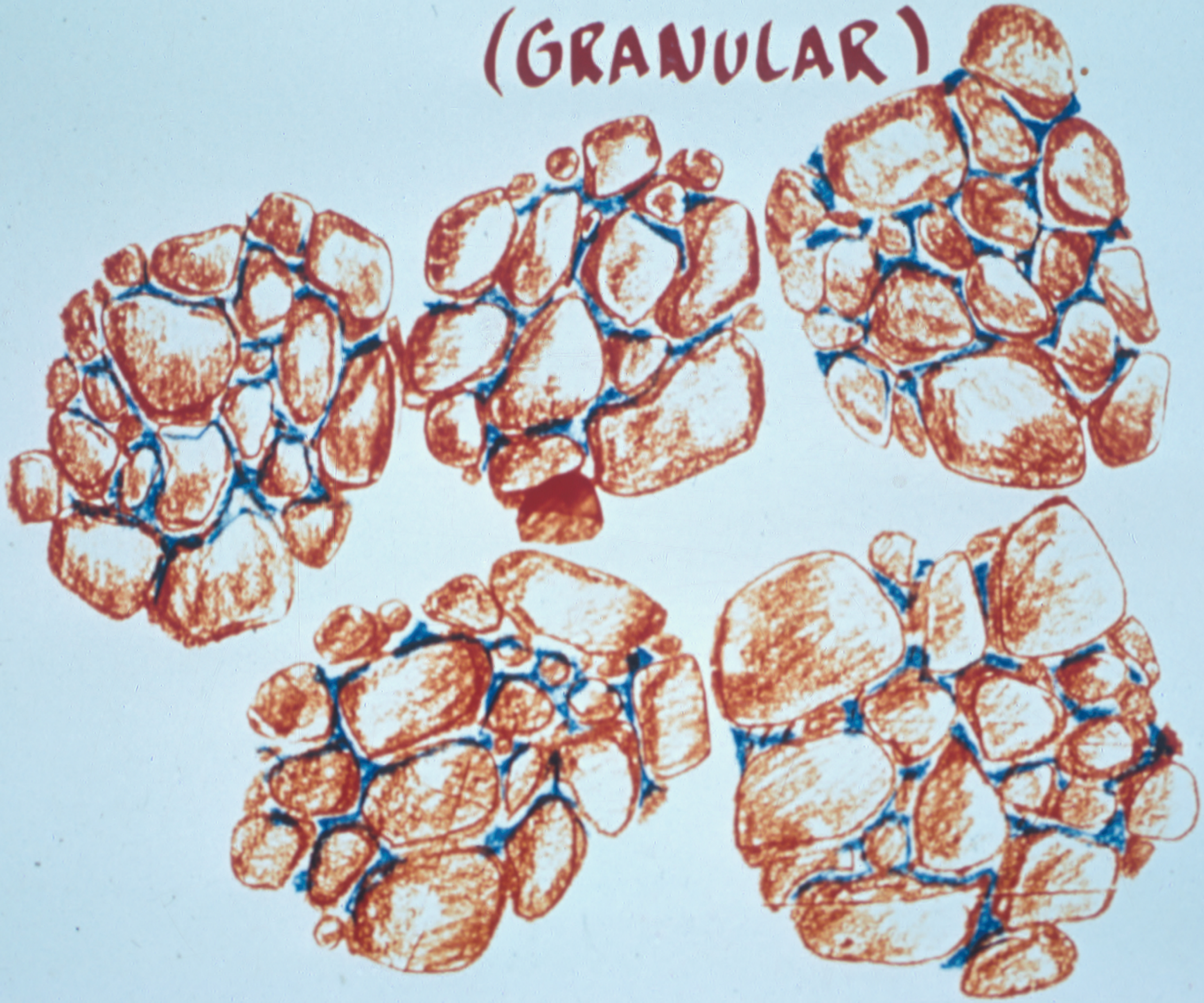




Water in soil (in./ft.)
0
1
2
3
4
5
6
Sand
Loam
Silty Clay Loam
Saturation
Saturation
Field Capacity
Field Capacity
Wilting Point
Wilting Point
5.2
2.1
1.6
1.1
5.8
3.8
2.8
1.8
6.1
4.4
3.5
2.6
Excess or gravitational water
Available water, no plant stress
Available water, plant stress possible
Unavailable water
Available Water Capacity

GOOD SOIL STRUCTURE

(GRANULAR)



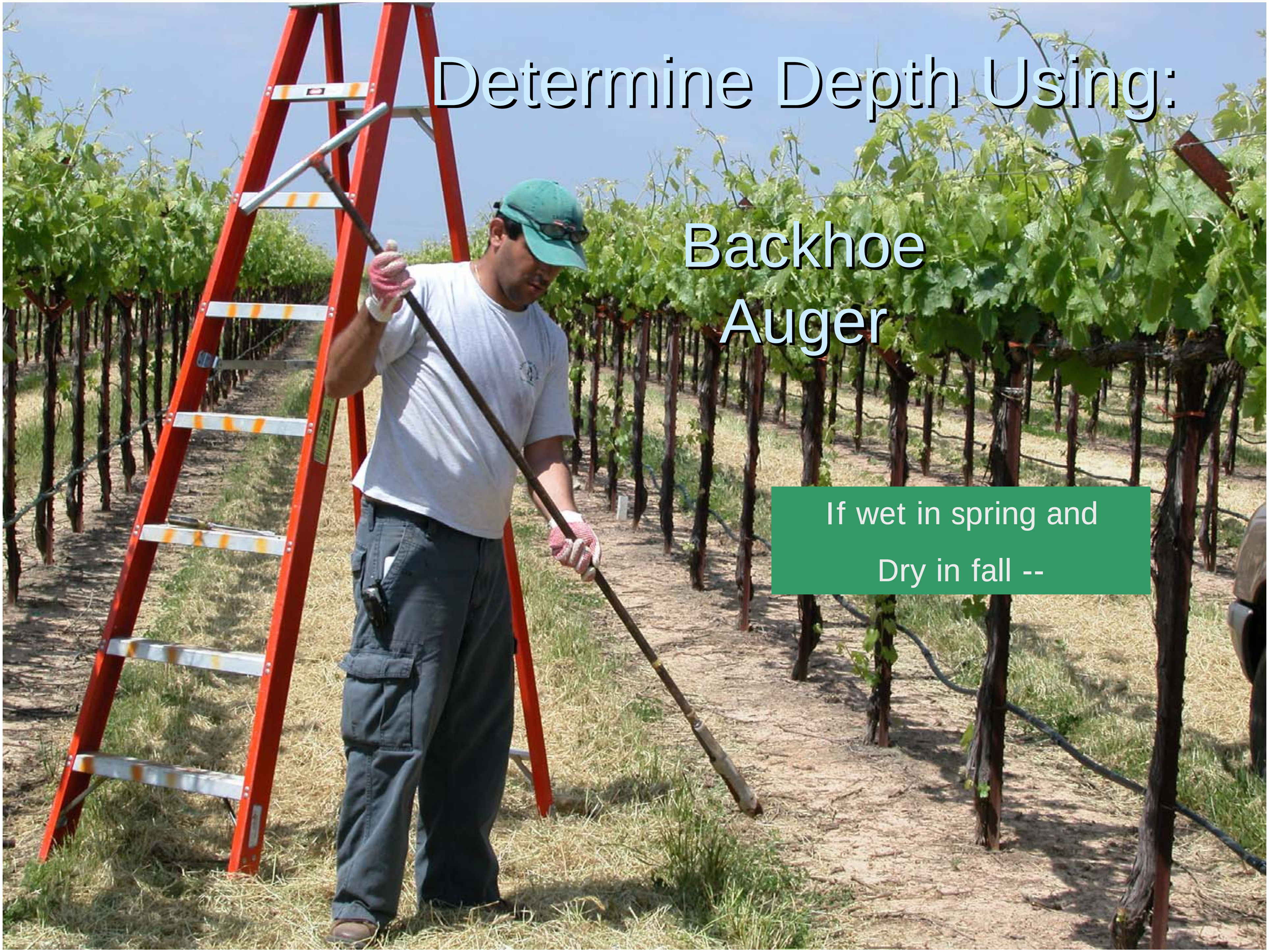
Rooting Depth Limitations

- Fine texture with poor internal drainage
- Dense, compact, or cemented subsoils
- Layered or stratified soil with abrupt change

- Rock
- Water table

Rootstocks

- Shallow rooting nature
  - 5C, 5BB, 1103


Determine Depth Using:
Backhoe
Auger
If wet in spring and
Dry in fall --

Rootzone Water Holding Capacity

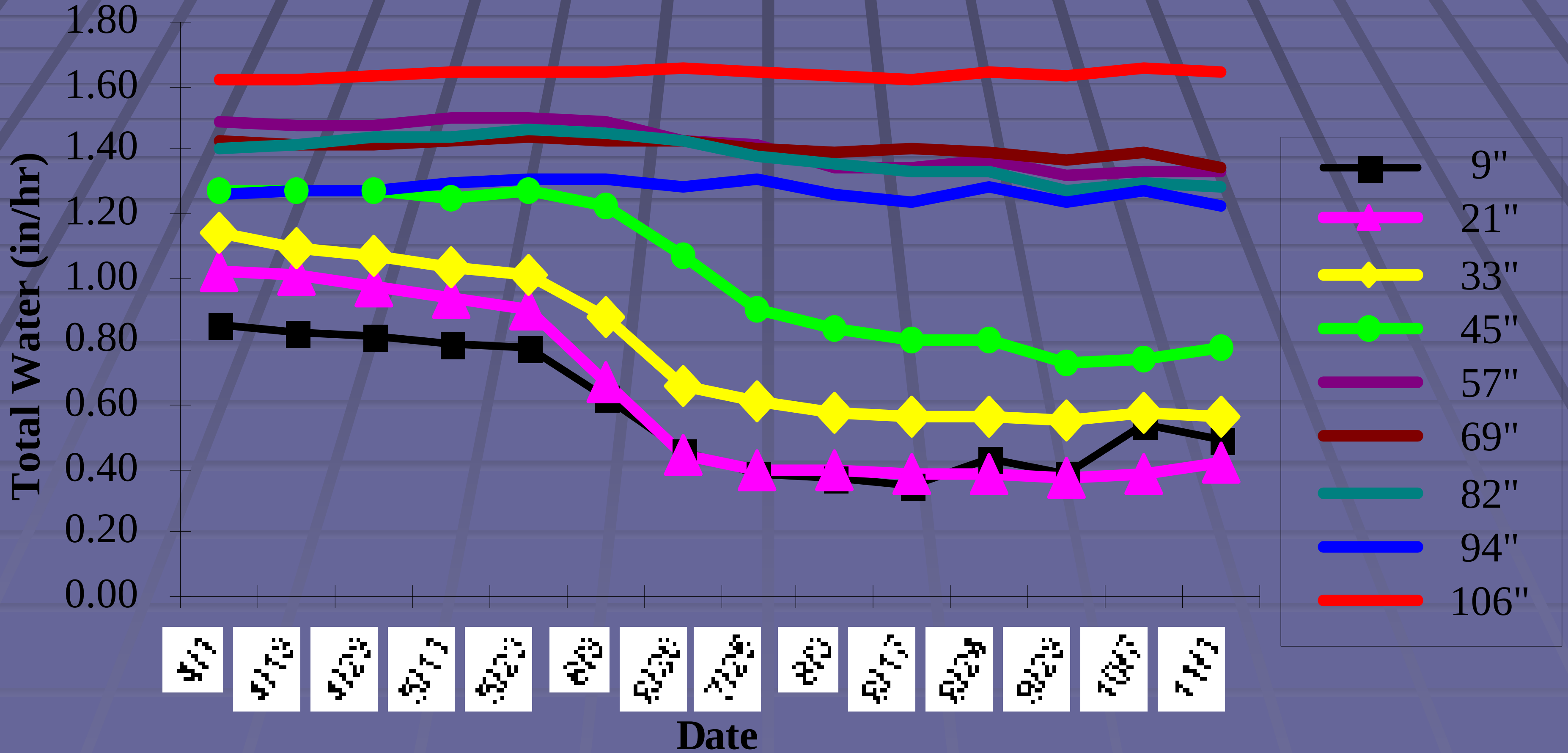
- Water holding capacity X Rootzone Depth

- Ex. Clay Loam = 1.6 in/ft Available water
- Rootzone Depth = 5 ft

- 1.6 X 5 = 8.0 inches of available water

Using Neutron Probe Data

Figure B-2. Winegrape non-irrigated in/ft by depth



Measuring Water Sources

- Soil moisture
- In-season Rainfall
- Irrigation Water

Volume Units

- Rainfall — inches/depth
- Crop Water Use — inches/depth
- Soil moisture — inches/depth

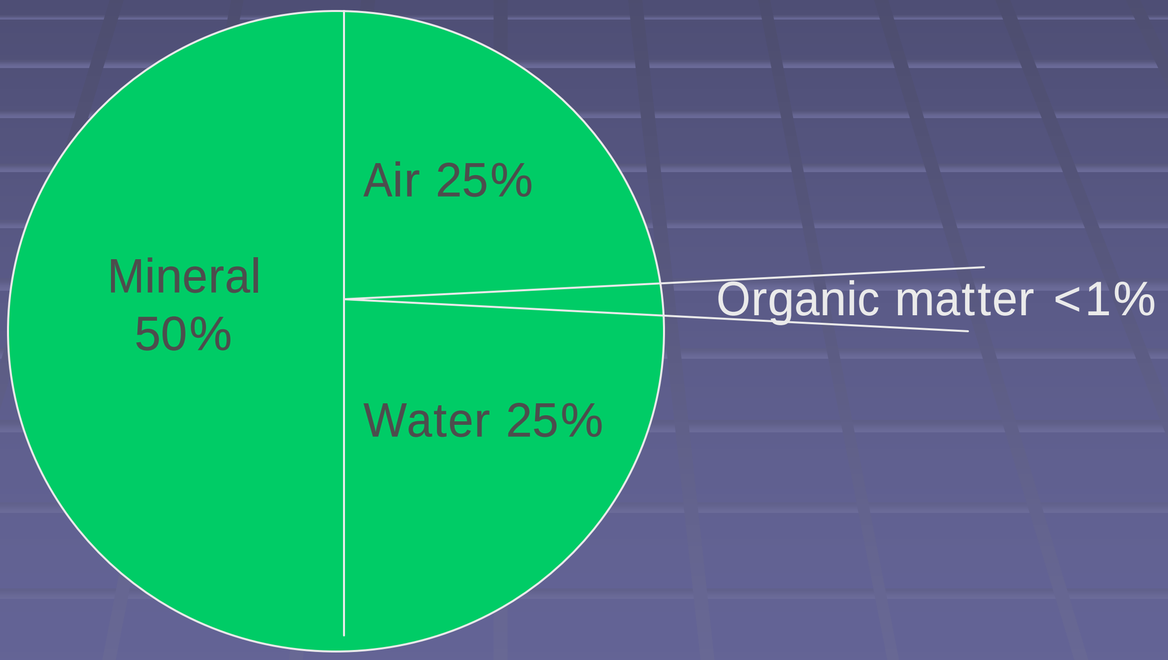
% = in / in

% x 12 inches = inches / foot soil

% x rootzone depth = inches water in rootzone

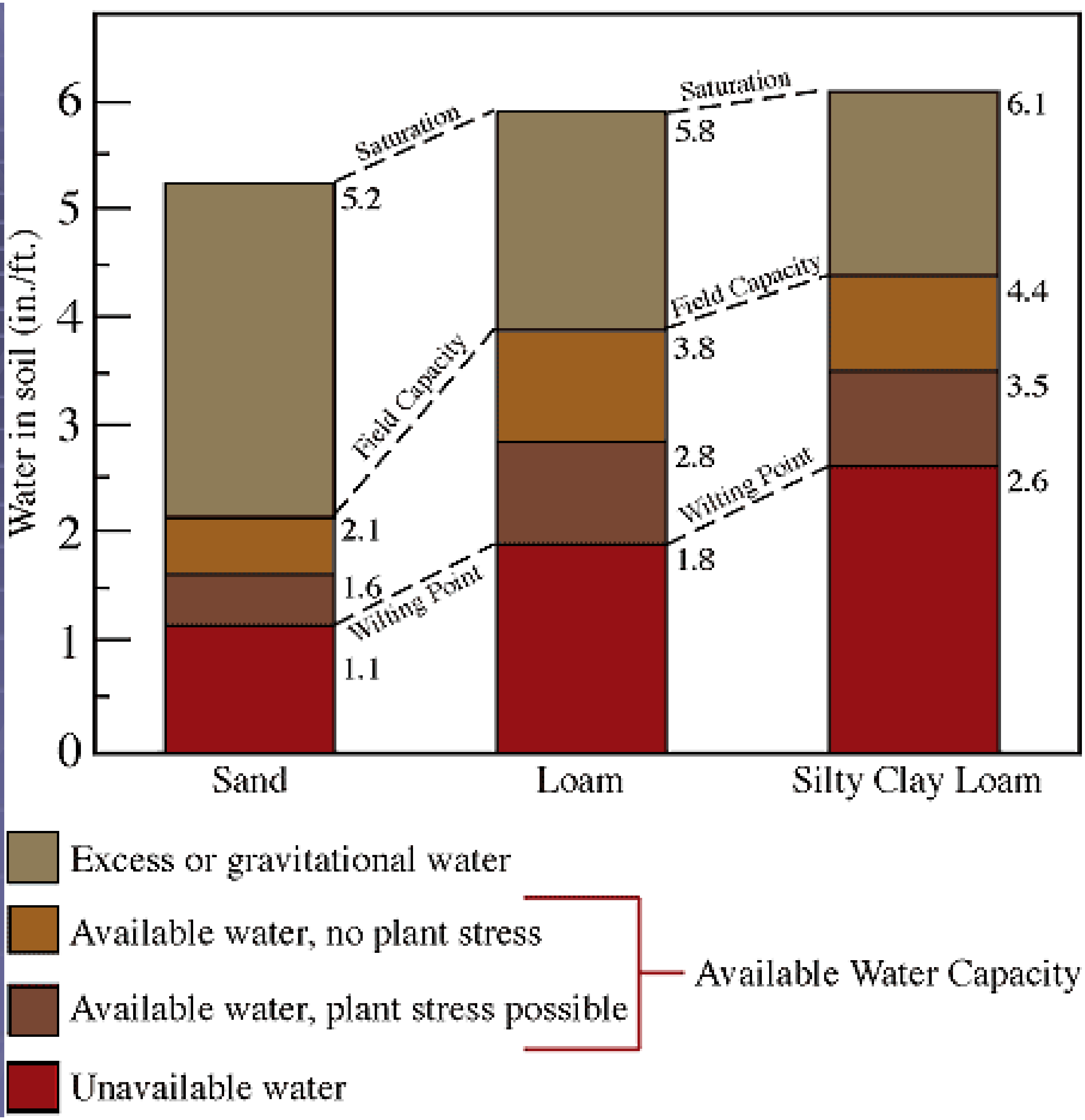
Soil Constituents by Volume

At field capacity



Available Soil Moisture

- Moisture contained in the soil which vines can remove
- All available moisture is not equally available



Water in soil (in./ft.)
0
1
2
3
4
5
6
Saturation
Saturation
Field Capacity
Field Capacity
Wilting Point
Wilting Point
5.2
2.1
1.6
1.1
5.8
3.8
2.8
1.8
6.1
4.4
3.5
2.6
Sand
Loam
Silty Clay Loam
Excess or gravitational water
Available water, no plant stress
Available water, plant stress possible
Unavailable water
Available Water Capacity

Available Soil Moisture

- Field Capacity – Perm wilt point

- Field Capacity
  - Upper limit when drainage ceases
- Permanent Wilting point
  - Lower limit when plants cannot extract moisture

Table C-1. Soil moisture content in inches of water per foot of soil at field capacity, 15 bars, and available soil moisture for various soil textures.

Soil Texture	Field Capacity	15 Bars	Available Moisture Content
Sand	1.2	0.5	0.7
Loamy Sand	1.9	0.8	1.1
Sandy Loam	2.5	1.1	1.4
Loam	3.2	1.4	1.8
Silt Loam	3.6	1.8	1.8
Sandy Clay Loam	3.5	2.2	1.3
Sandy Clay	3.4	1.8	1.6
Clay Loam	3.8	2.2	1.6
Silty Clay Loam	4.3	2.4	1.9
Silty Clay	4.8	2.4	2.4
Clay	4.8	2.6	2.2

Soil Water Measures

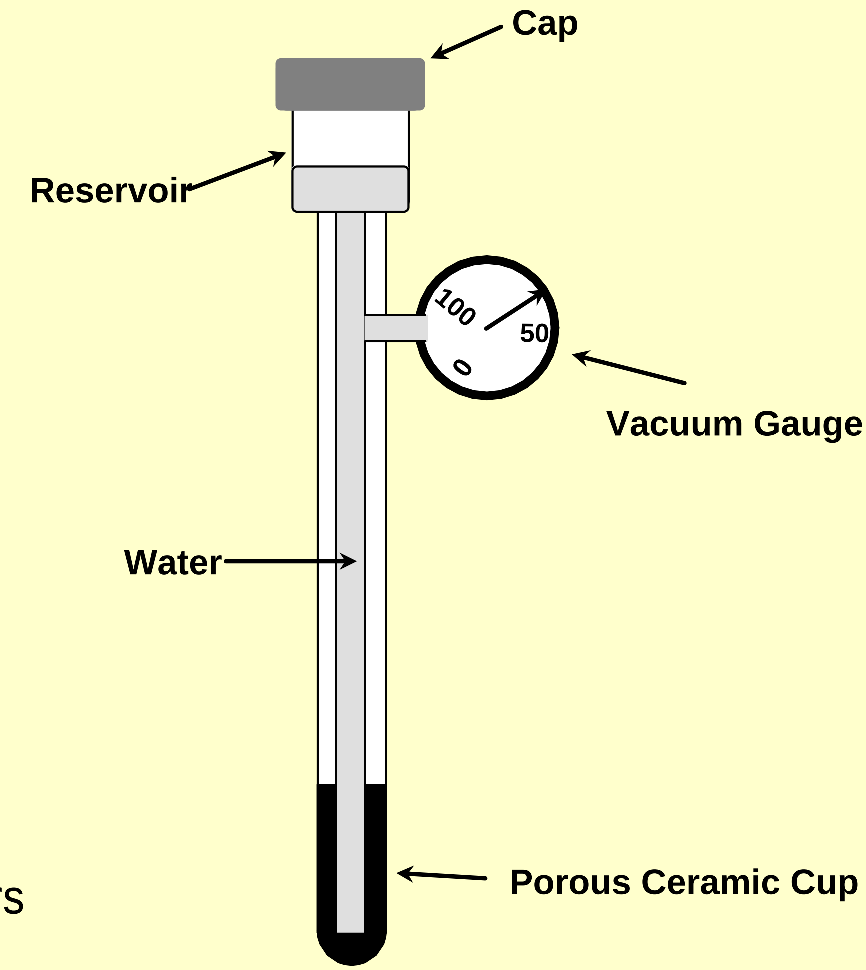
- Soil Water Content
  - Quantitative
    - Percent water by weight or volume

- Soil Moisture Status or Tension
  - Qualitative
    - Centibars of Tension

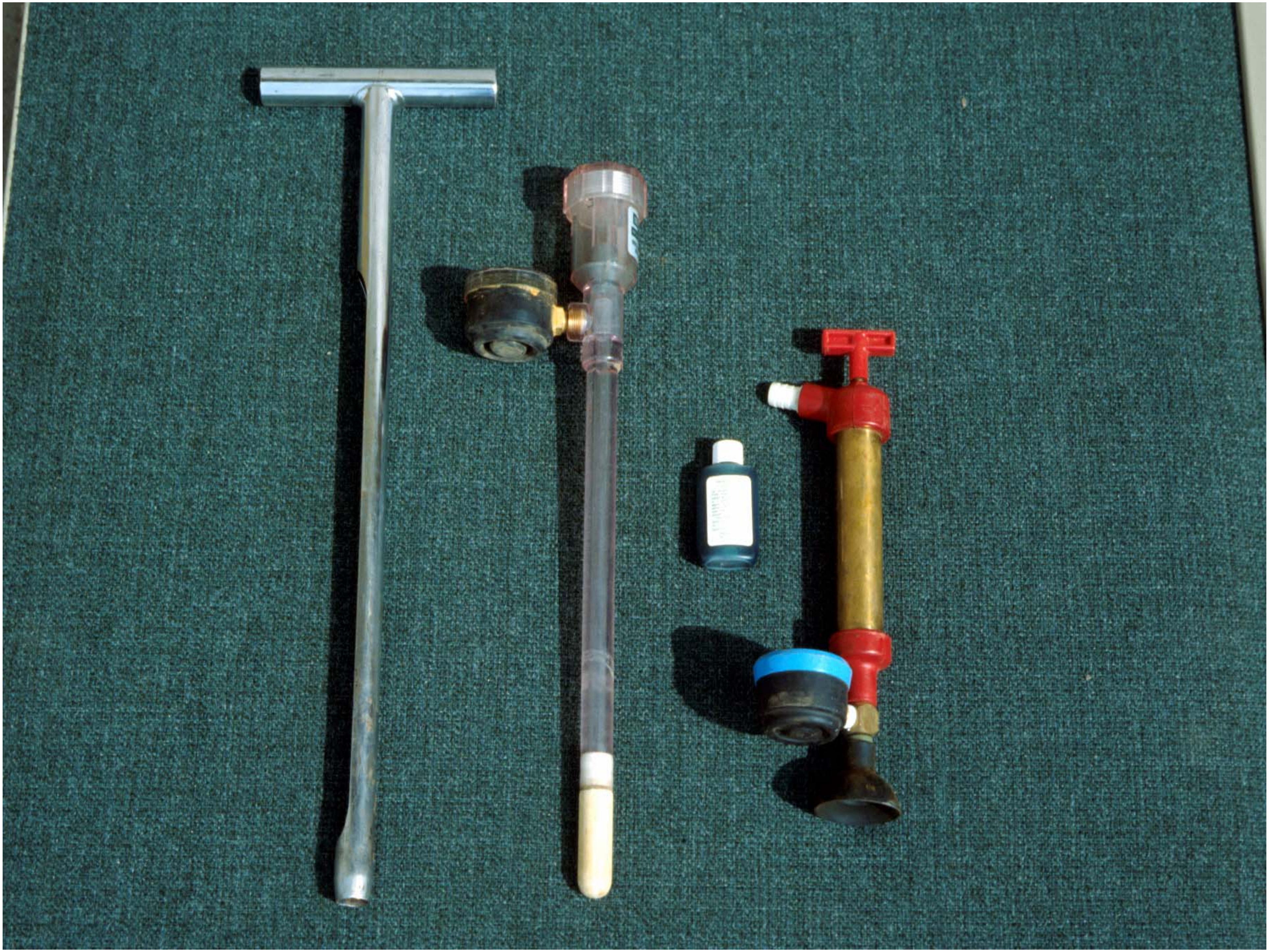
Moisture Status

- Tensiometers
- Gypsum Blocks

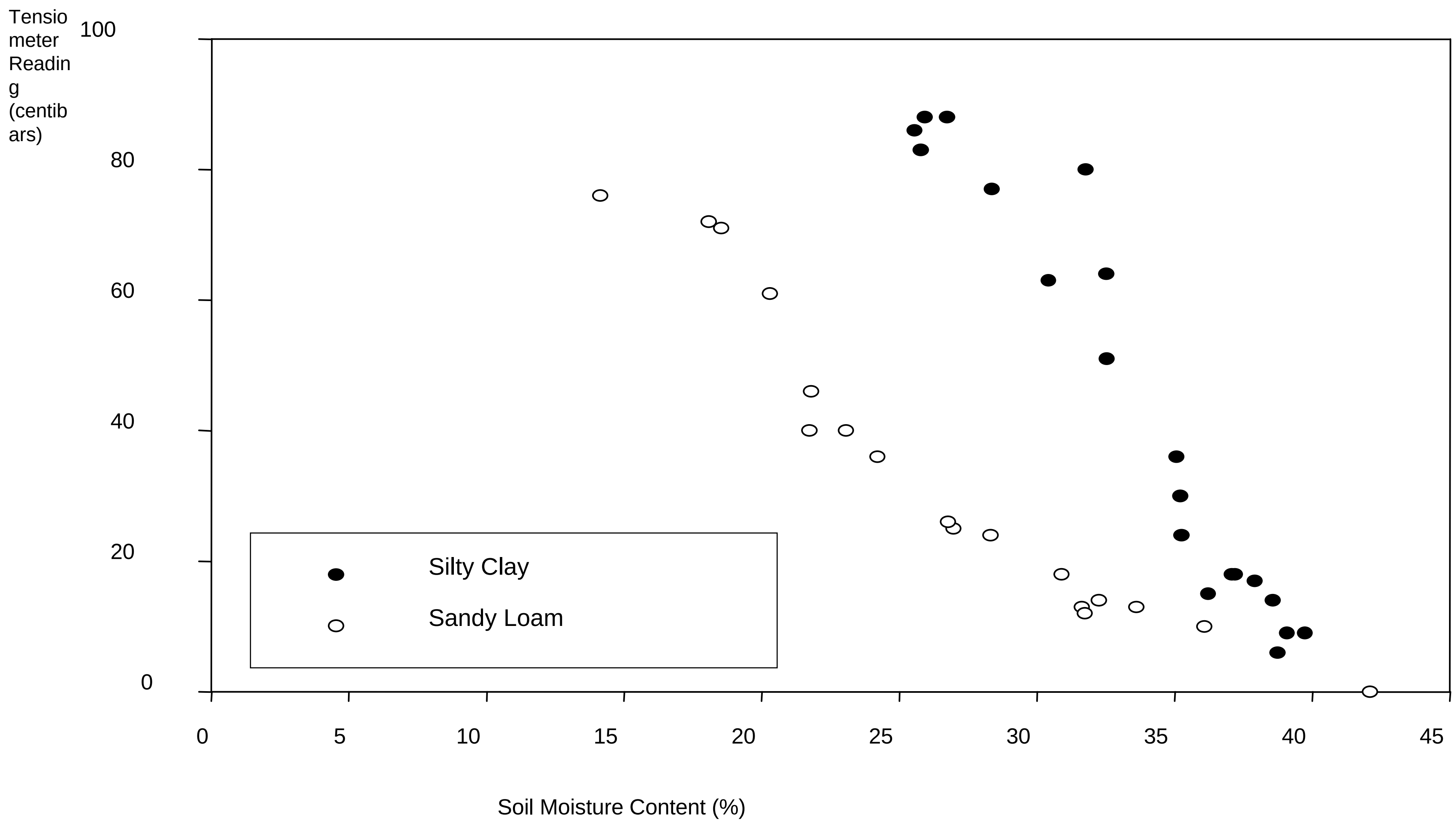
Tensiometer



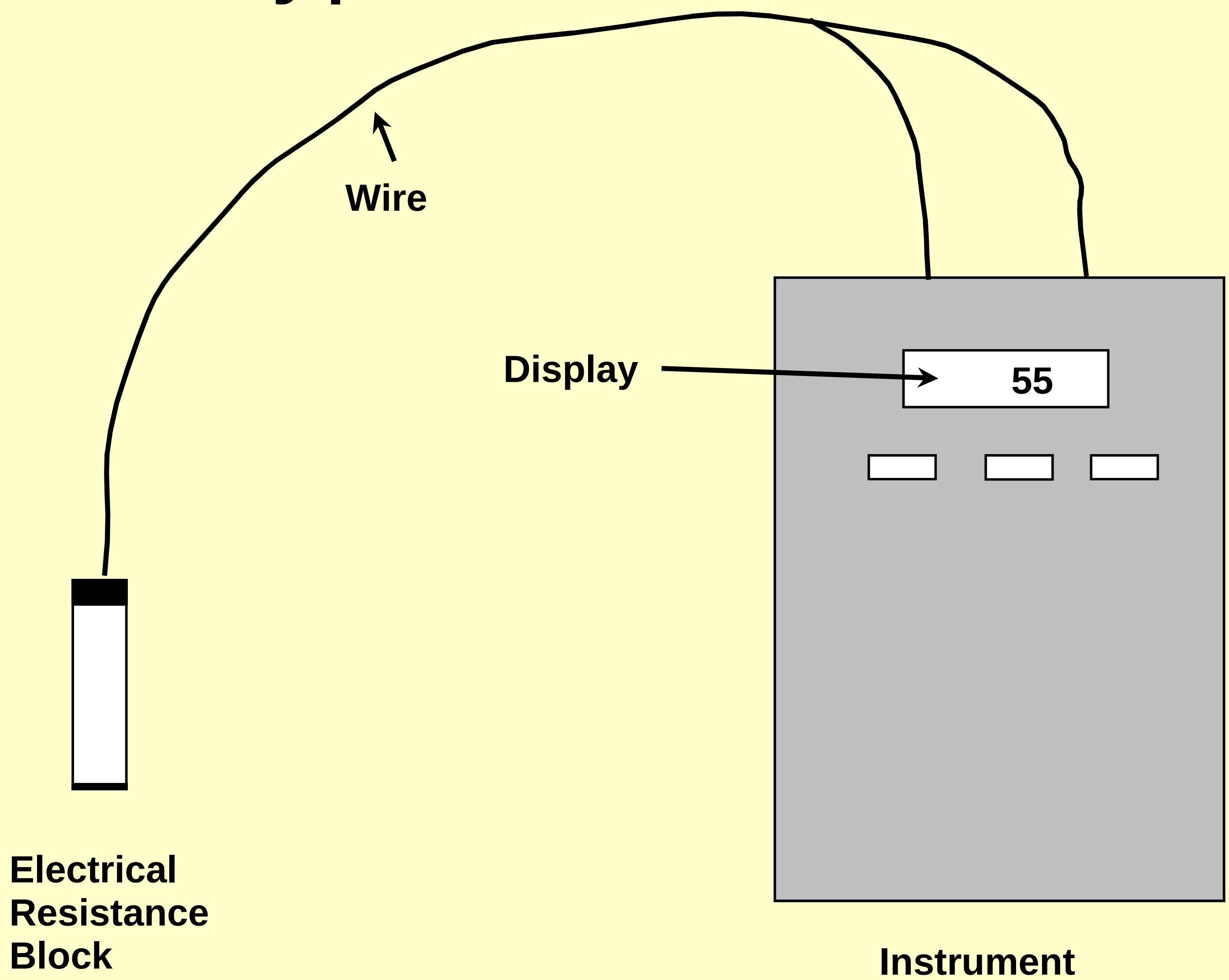
0 – 80 Centibars

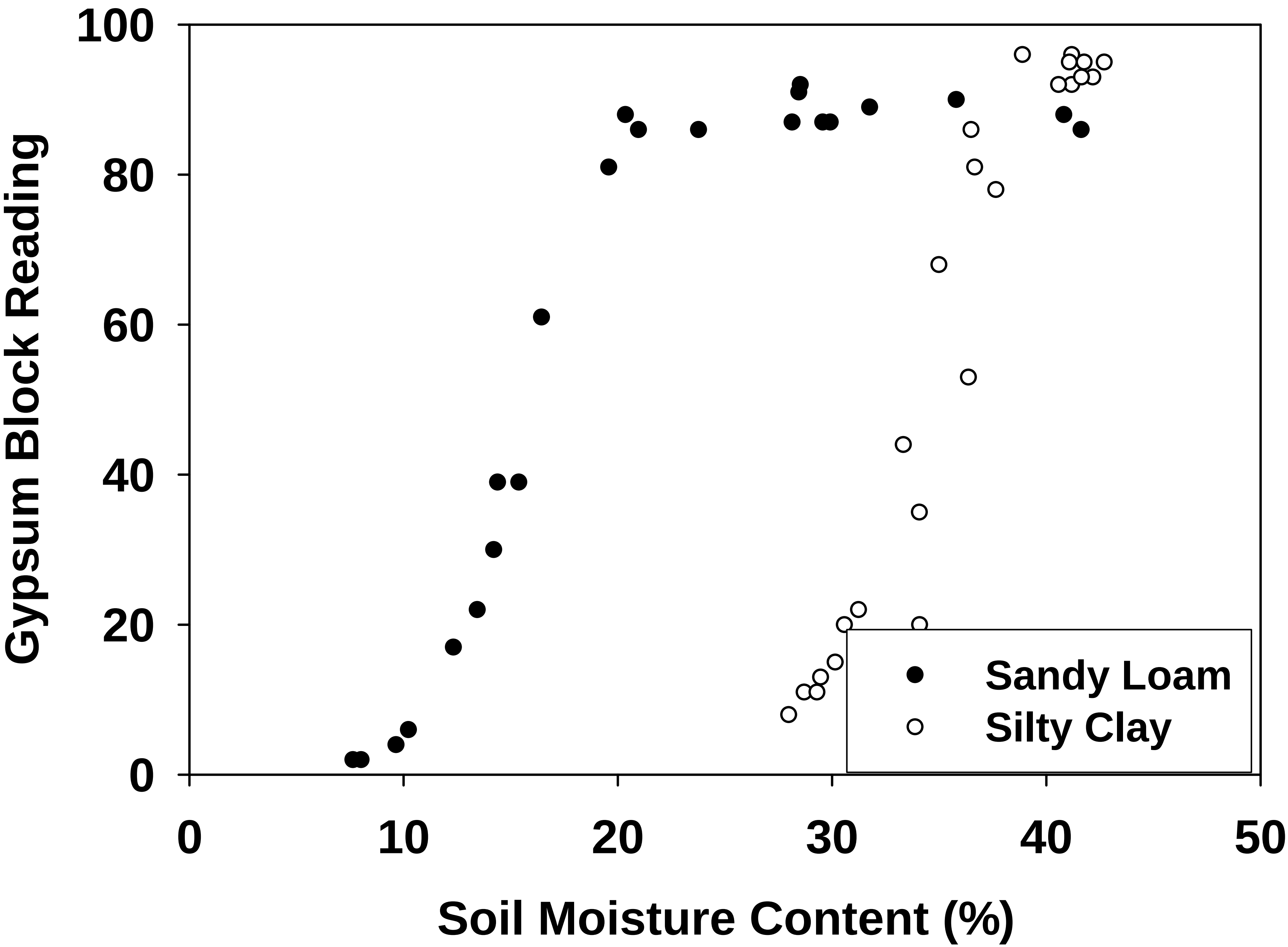


Tension versus soil moisture content for two soil textures.



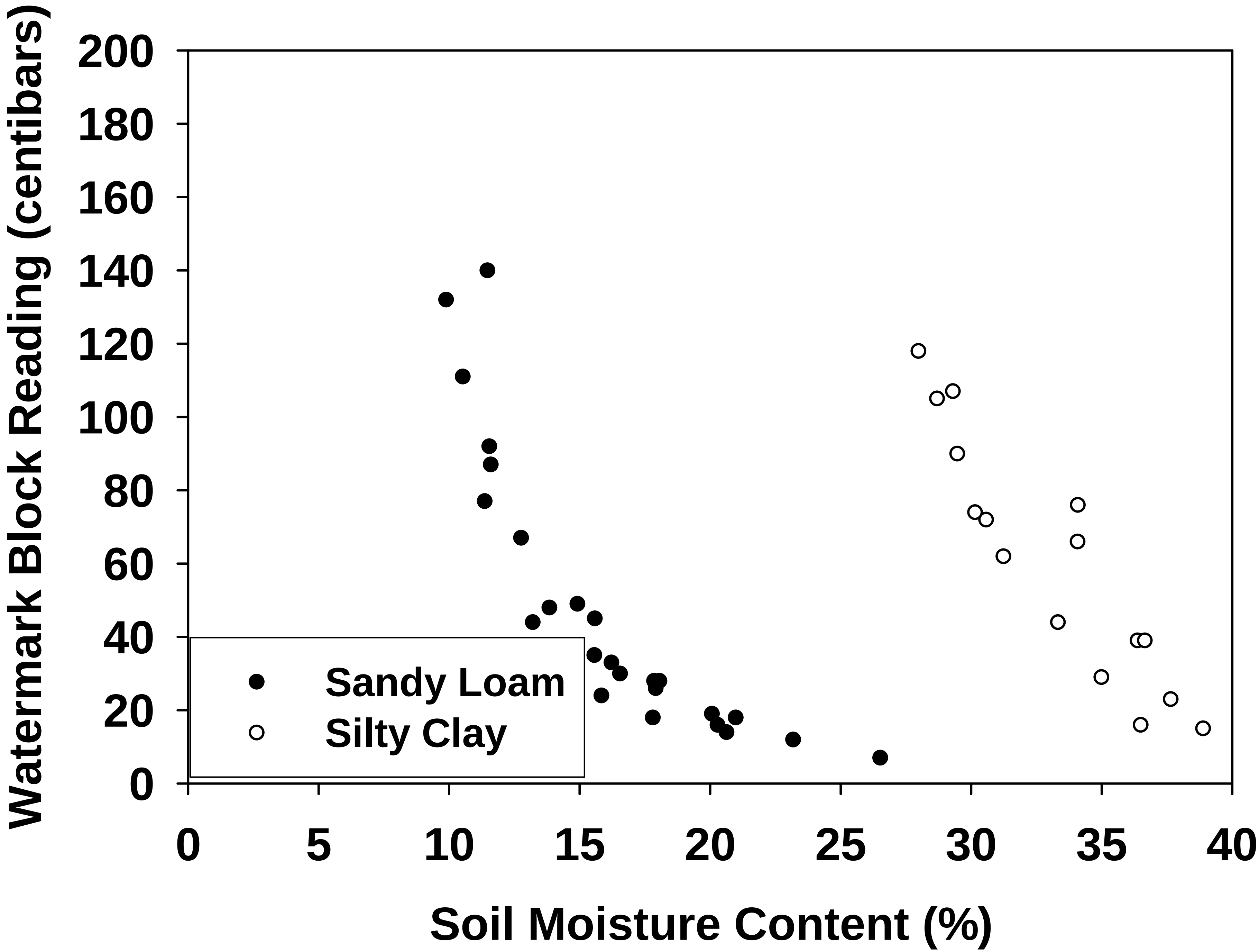
Gypsum Block





100
80
60
40
20
0
Gypsum Block Reading
0
10
20
30
40
50
Soil Moisture Content (%)
Sandy Loam
Silty Clay

Irrometer Watermark Sensor/Meter



Watermark Block Reading (centibars)
200
180
160
140
120
100
80
60
40
20
0
0
5
10
15
20
25
30
35
40
Soil Moisture Content (%)
Sandy Loam
Silty Clay

Soil Water Content
Direct / Indirect Methods

- Direct
  - Soil sampling by volume
    - Or--- by weight x soil bulk density

- Indirect

  any method which relates a “reading” to soil sampling moisture content

Indirect Methods

- **Soil Dielectric**

  Time Domain Reflectometry (TDR)

  Ground Penetrating Radar (GPR)

  Frequency Domain Reflectometry (FDR or capacitance)

- **Neutron Scatter**

Soil Dielectric

- The dielectric permittivity is a measure of the capacity of a non-conducting material to transmit electromagnetic waves or pulses.

- Dielectric Permittivity
  - Air = 1
  - soil minerals = 3 to 5

    (denser soils have higher apparent permittivities).
  - Water 81

Influencing Factors

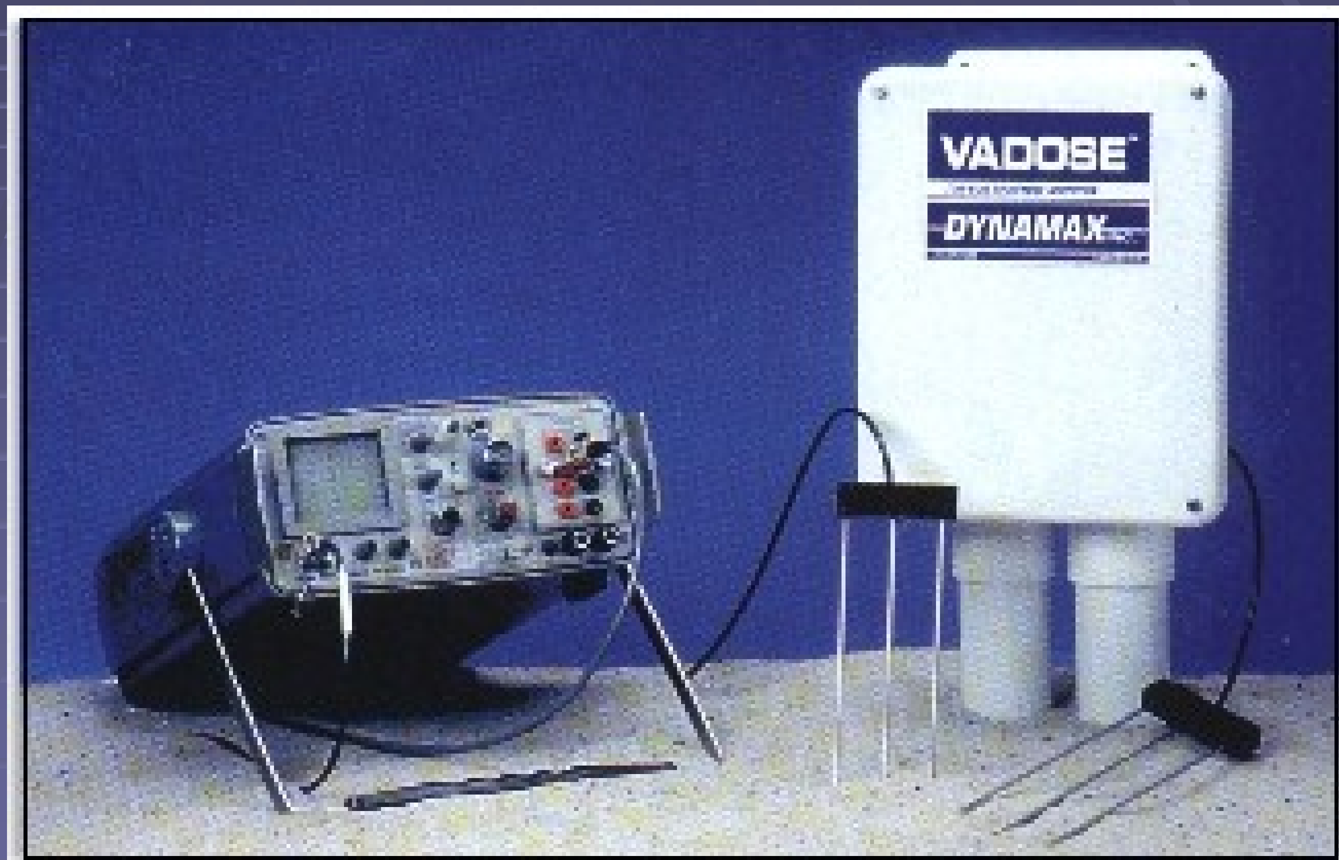
- Water Content
- Soil Temperature
- Soil Porosity and Bulk Density
- Minerals (clay)
- Measurement Frequency
- Air Gaps

Time Domain Reflectometry (TDR)

- Based on the propagation velocity of electromagnetic wave traveling along a probe placed in the soil (non conducting media)

- Water is the principal factor affecting a TDR signal (measurement a 1 Ghz)

TDR



TDR Advantages

- Precise
- Accurate
- Versatile packaging: from portable, self-contained units to modular systems capable of monitoring several probes and logging data
- Lack of radiation hazard associated with neutron probe
- Calibration requirements are minimal—in many cases soil-specific calibration is not needed

TDR Disadvantages

- Relatively expensive
- Small measuring volume
- Shallow measurements or buried probe
- Conductive soils may lead to inaccuracies
- Short cable lengths are necessary due signal attenuation

Water Content Reflectometer

Similar to TDR

- Lower frequency
- Wave storage electronics / software not necessary
- Uses data logger to store data
- More sensitive to Temp, Density, and Clay
- Calibration generally required

Cables up to 1000 ft

Less expensive

Ground Penetrating Radar (GPR)

- RF bursts are emitted and the reflected wave is captured and frequency measured
- Similar to TDR but the wave is not bound

GPR
(CNN) -- Grapes and geophysics

- Dry soil produces better red wine grapes;
- Moister soil makes white wine grapes thrive.

GPR

- Variations in soil texture (clay), crop cover, salinity, and irrigation practices result in large variability in soil moisture
- The depth of influence is a function of soil type, moisture content and GPR antenna frequency Limited to a few feet in dry clay soil– less in moist soil

GPR Advantages

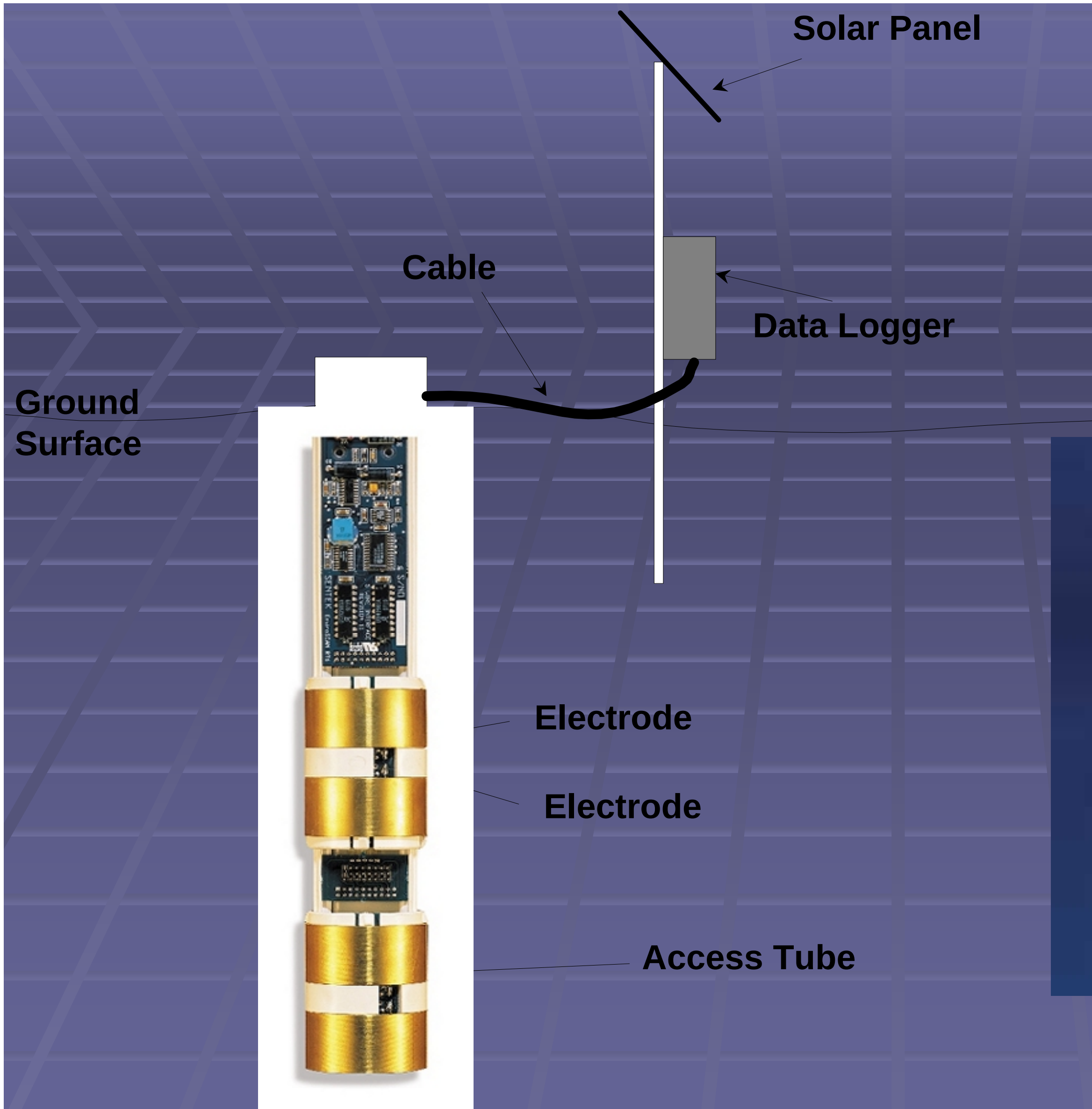
- Rapid
- Non-invasive
- Very high spatial data density
- Principles of operation almost identical to TDR but at a lower frequency

GPR Disadvantages

- Not well established—little work has been done to develop this method
- Depth of measurement is generally shallow and varies with soil type and moisture leading to uncertainty in zone of influence or measurement volume
- Relatively expensive

Frequency Domain/Capacitance

- A couple different methods are used however, they all use:
  - Electronic circuit in which the two plates, rods or rings use the soil between them as dielectric of a capacitor
- The change in the circuit output is related to the dielectric permittivity



Permanent/logging
Multi depth

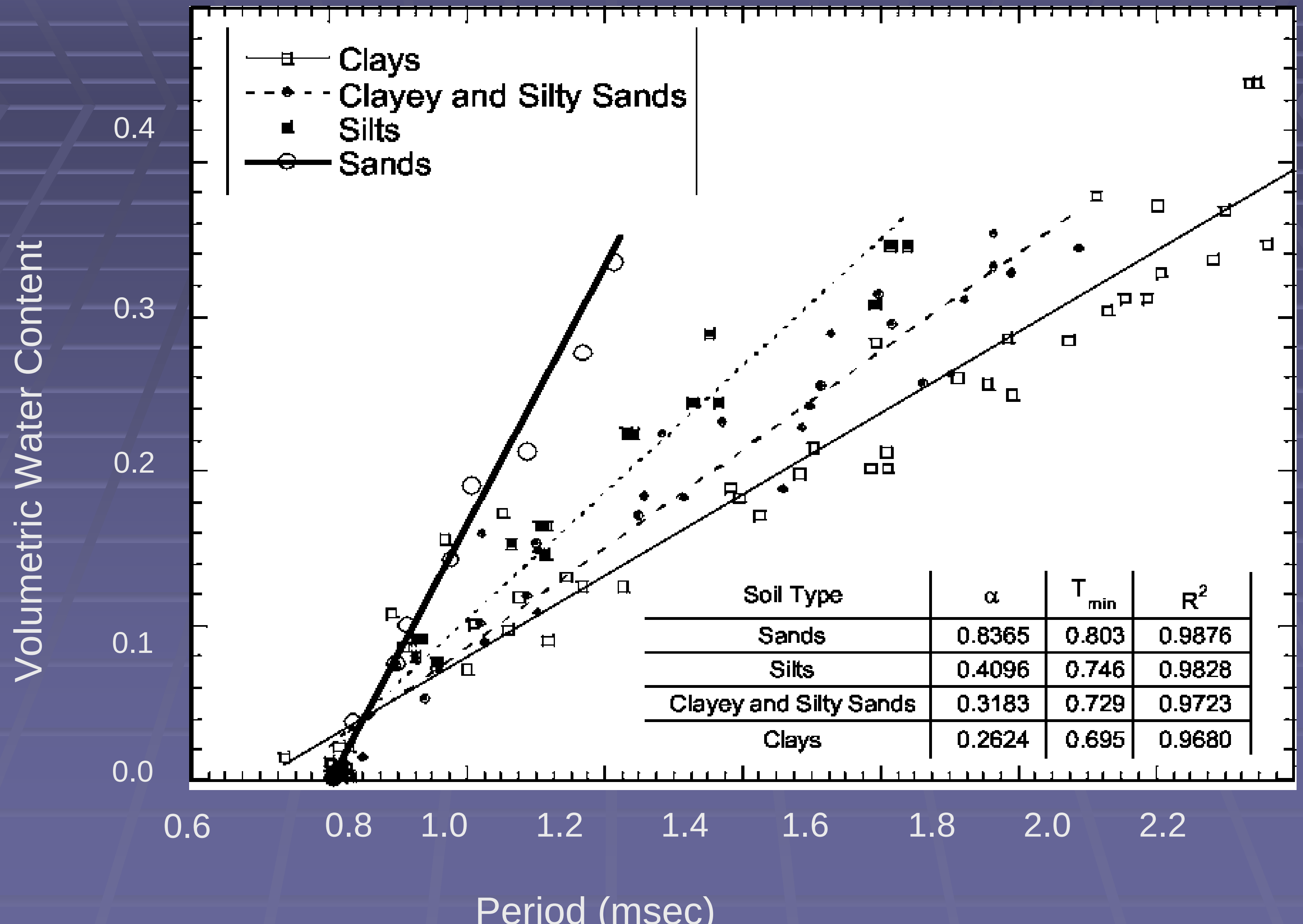
Portable

Single point measure

FDR

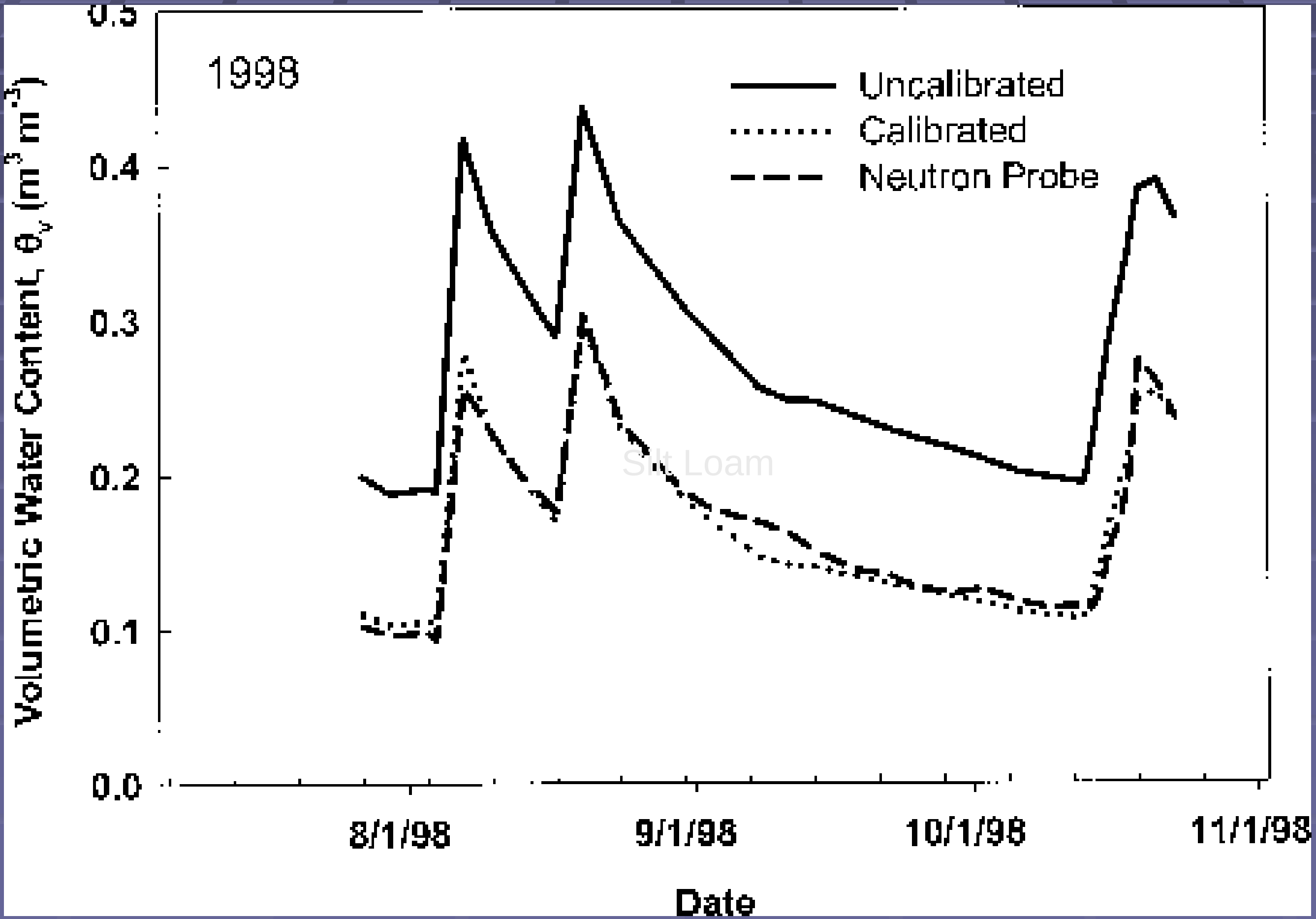
- Soil specific calibration curves are needed for soils that are highly conductive, have high organic content, or contain 2:1 clays

Soil Specific Calibration



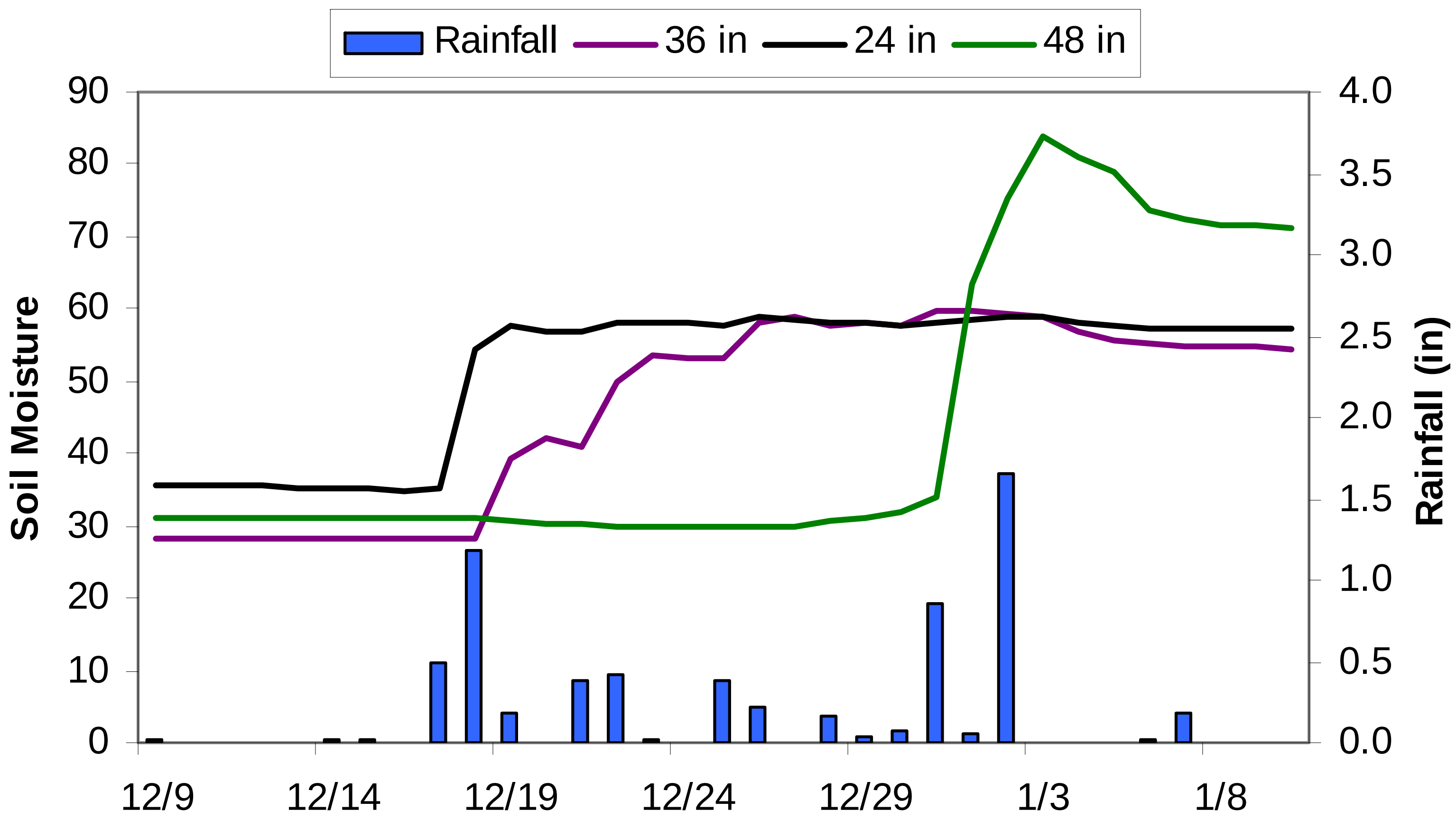
After Kim and Benson 2002

FDR

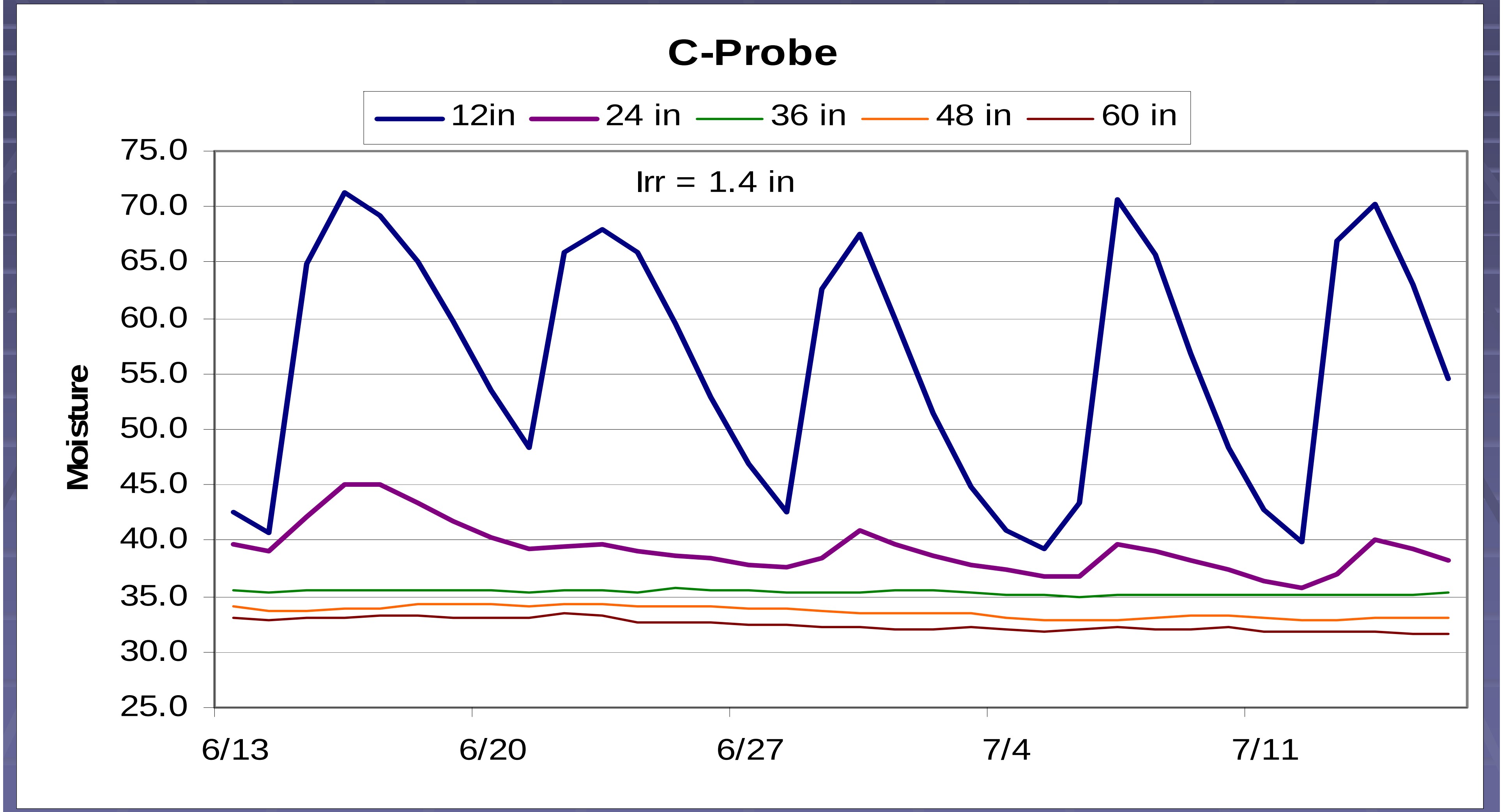


1998
Uncalibrated
Calibrated
Neutron Probe
Silt Loam
Volumetric Water Content, θ_v (m^3 m^{-3})
0.0
0.1
0.2
0.3
0.4
0.5
8/1/98
9/1/98
10/1/98
11/1/98
Date

C-Probe



Rainfall
36 in
24 in
48 in
Soil Moisture
Rainfall (in)
90
80
70
60
50
40
30
20
10
0
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
12/9
12/14
12/19
12/24
12/29
1/3
1/8



C-Probe
12in
24 in
36 in
48 in
60 in
Irr = 1.4 in
Moisture
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
30.0
25.0
6/13
6/20
6/27
7/4
7/11

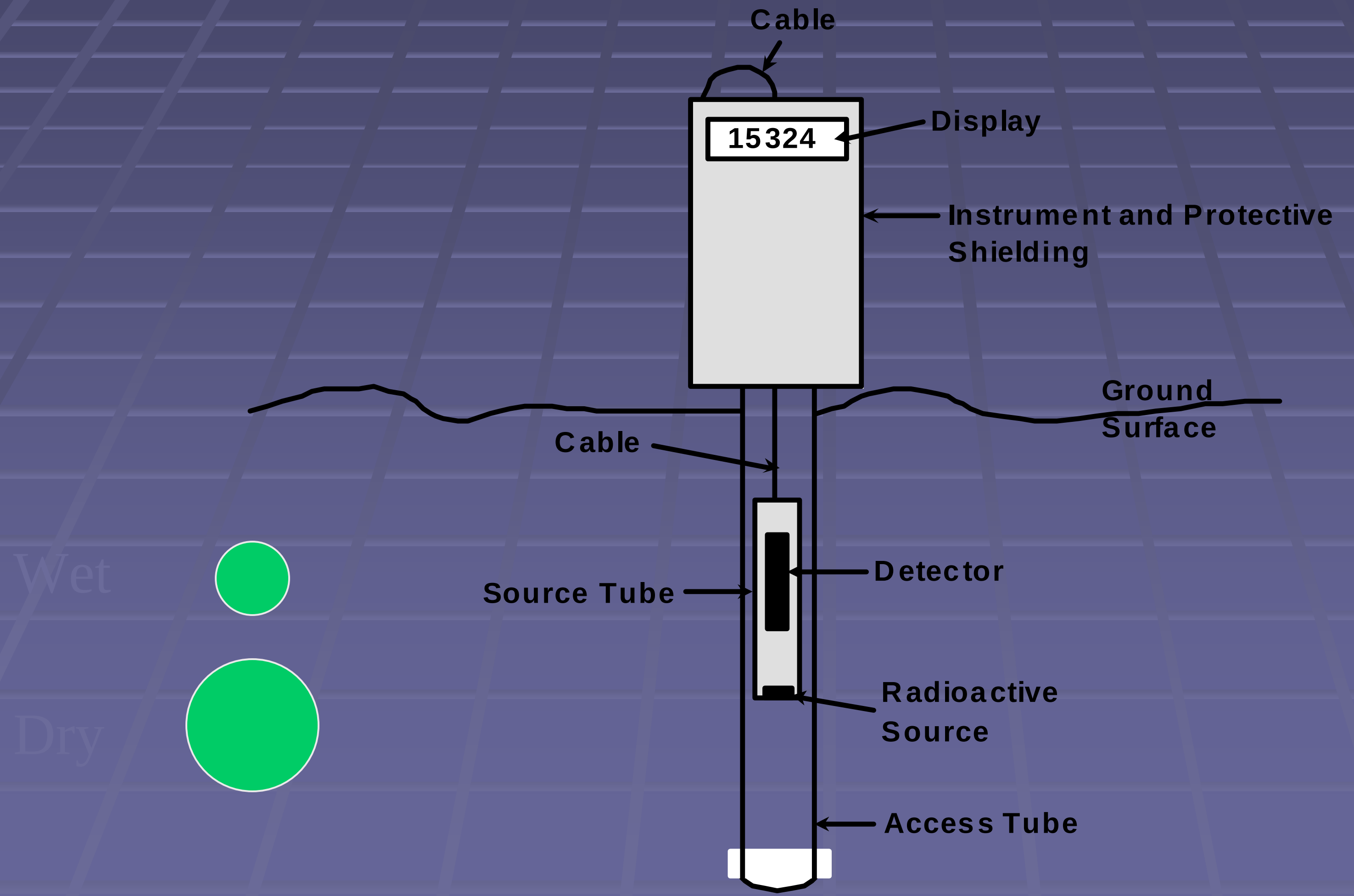
FDR Advantages

- Relatively inexpensive
  - low frequency standard circuitry
- No radiation hazard / hassles
- Fast response time
- Logging capable
- Portable

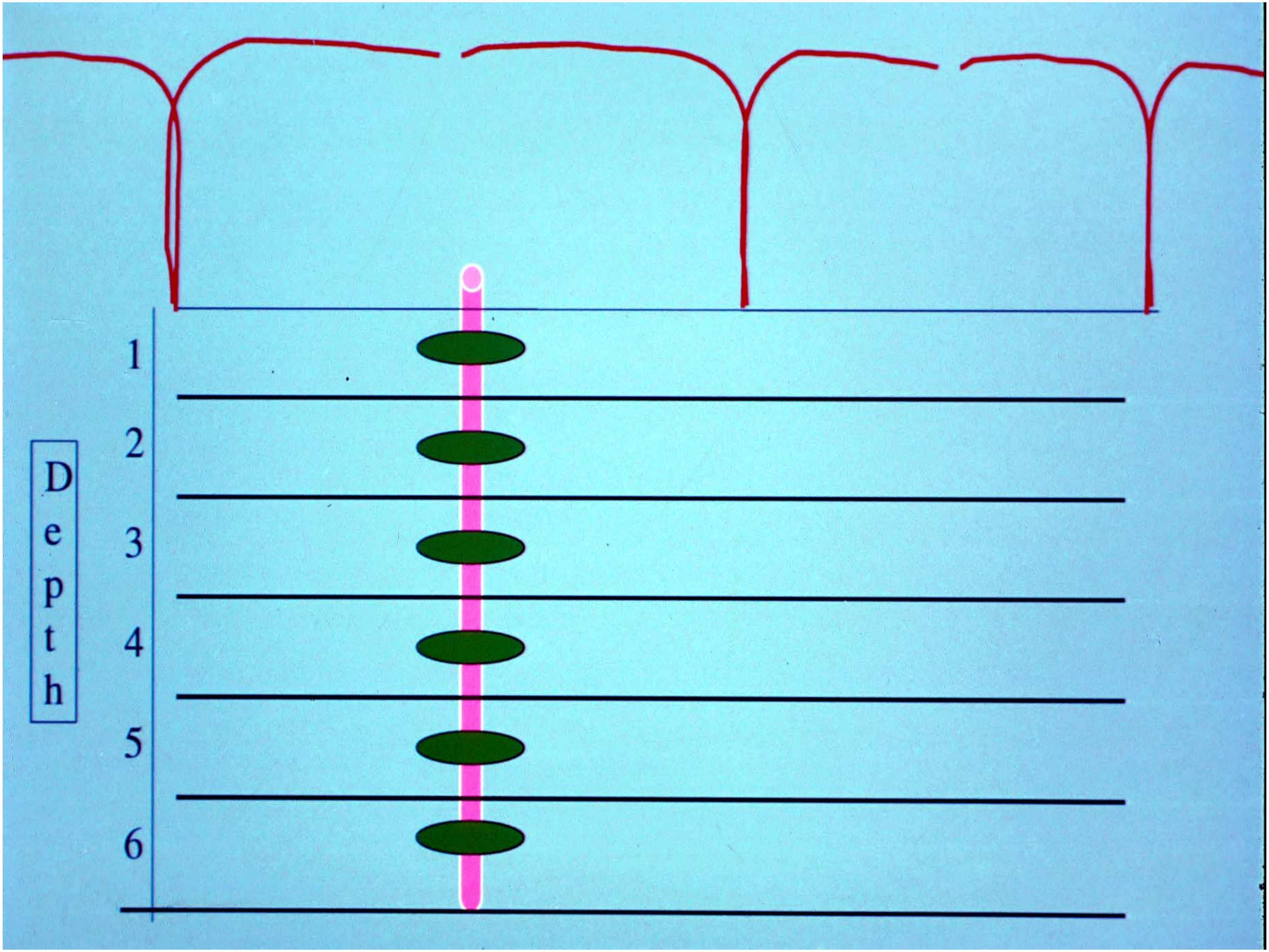
FDR Disadvantages

- Small measurement volume sensitive to small-scale soil variations (most in 5mm)
- Sensitivity to installation similar to TDR
- Site specific calibration is necessary for accurate soil volumetric water content
- Tends to have larger sensitivity to salinity, temperature, bulk density, clay content and air gaps than TDR

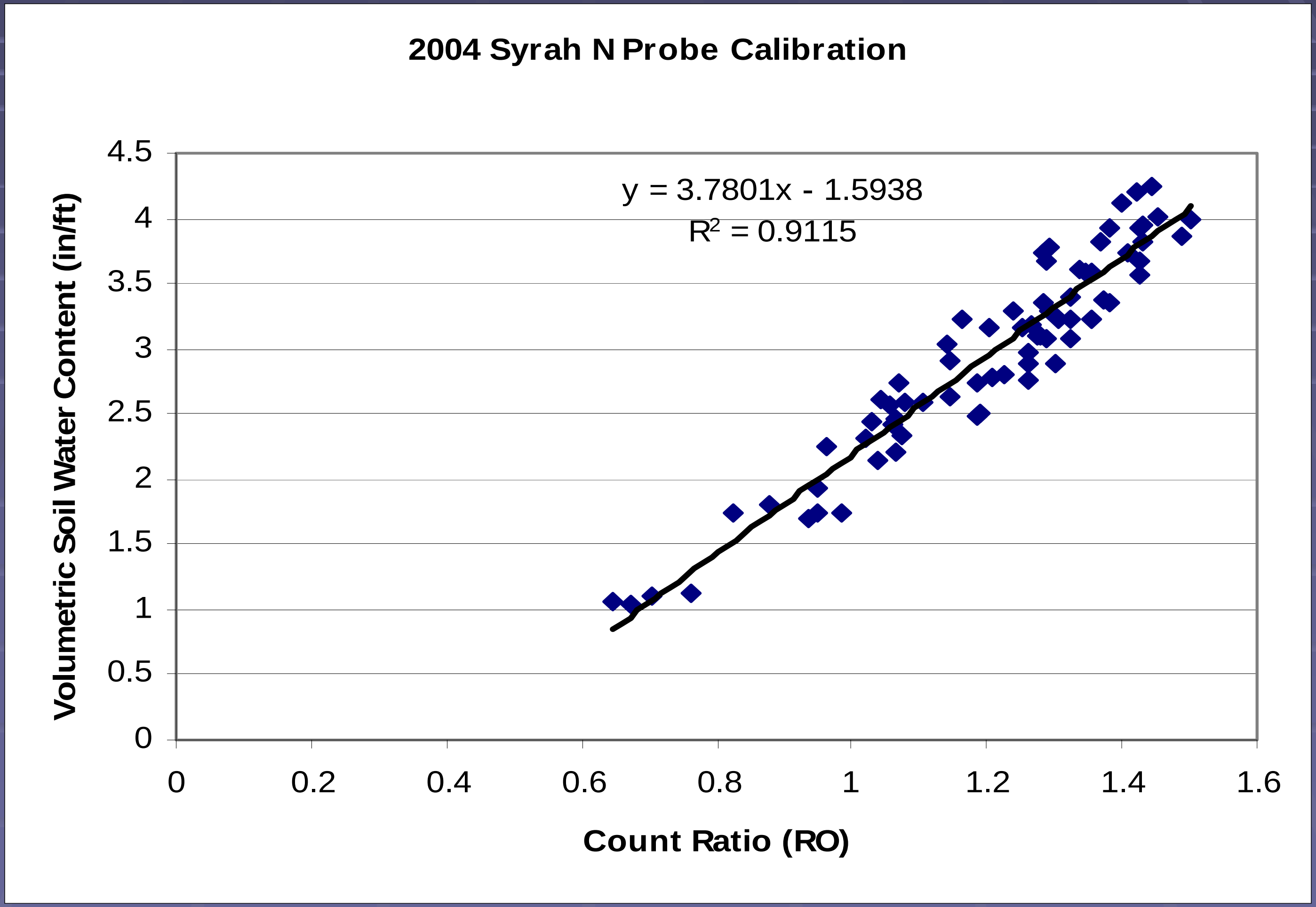
Neutron Scatter / Probe




CPN
U.C.BERKELEY
MODEL 503


1
2
3
4
5
6
Depth

NP Field Calibration



Calibration

- Down-hole samplers are pushed into the soil at the bottom of an augered hole to take fixed volumetric (60 cc) samples
- Device readings are taken at the same depths immediately after sampling
- Samples are oven dried
- Percent water content vs reading

NP Advantages

- Large measurement volume produces high precision
- Works well in stony soils and expansive clays
- Very accurate, when calibrated
- Air gaps and soil disturbance during access tube installation has minimal effects
- Multiple point measurements

NP Disadvantages

- Costly
- Cannot be automated because radioactive source may not be left unattended
- Cost of regulation and licensing of a radioactive source/ and disposal cost
- Surface measurements inaccurate < 9 in
- Heavy awkward device
- Time required for reading

Soil and Water Holding / Supplying Variability

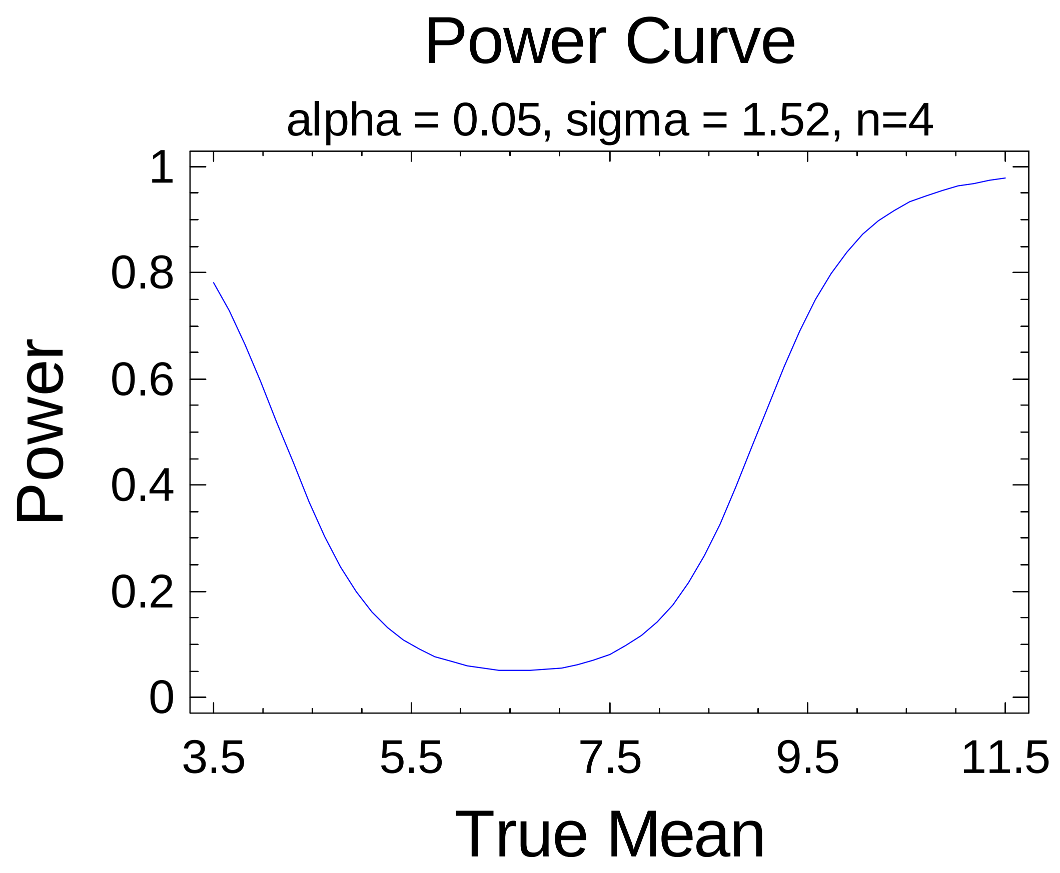
- Variability within the vines root zone and on a field scale is the largest error when trying to approximate the mean soil moisture
- Soil Variability
  - Texture
  - Density
  - Root limiting conditions
  - Vine water extraction

Solution to Variability

- More measurement points
  - Based on:
    - Level of confidence needed ie. 95%
    - Variability that exists
    - Mean Value expected

Number of Sites

Mean = 6.59
Sdev = 1.52



Data Handling / Telemetry

- Wide range available
  - Direct hand held "pod" collection
  - Cell phone modem to

    data processing to

    internet acc

Summary

- Volumetric Water Content
    - Dielectric Methods
    - Nuclear Methods
- All require field calibration if volumetric required
- Dielectric
    - Can be automated / unattended / transmitted
    - Generally inexpensive
    - Need a number of sites/depths to characterize the rootzone and field

Looking Ahead

- Increased use of devices which can log transmit and allow automatic data processing. --- Dielectric methods
- The Neutron Probe is the standard and will be slow to replace by virtue of its advantages

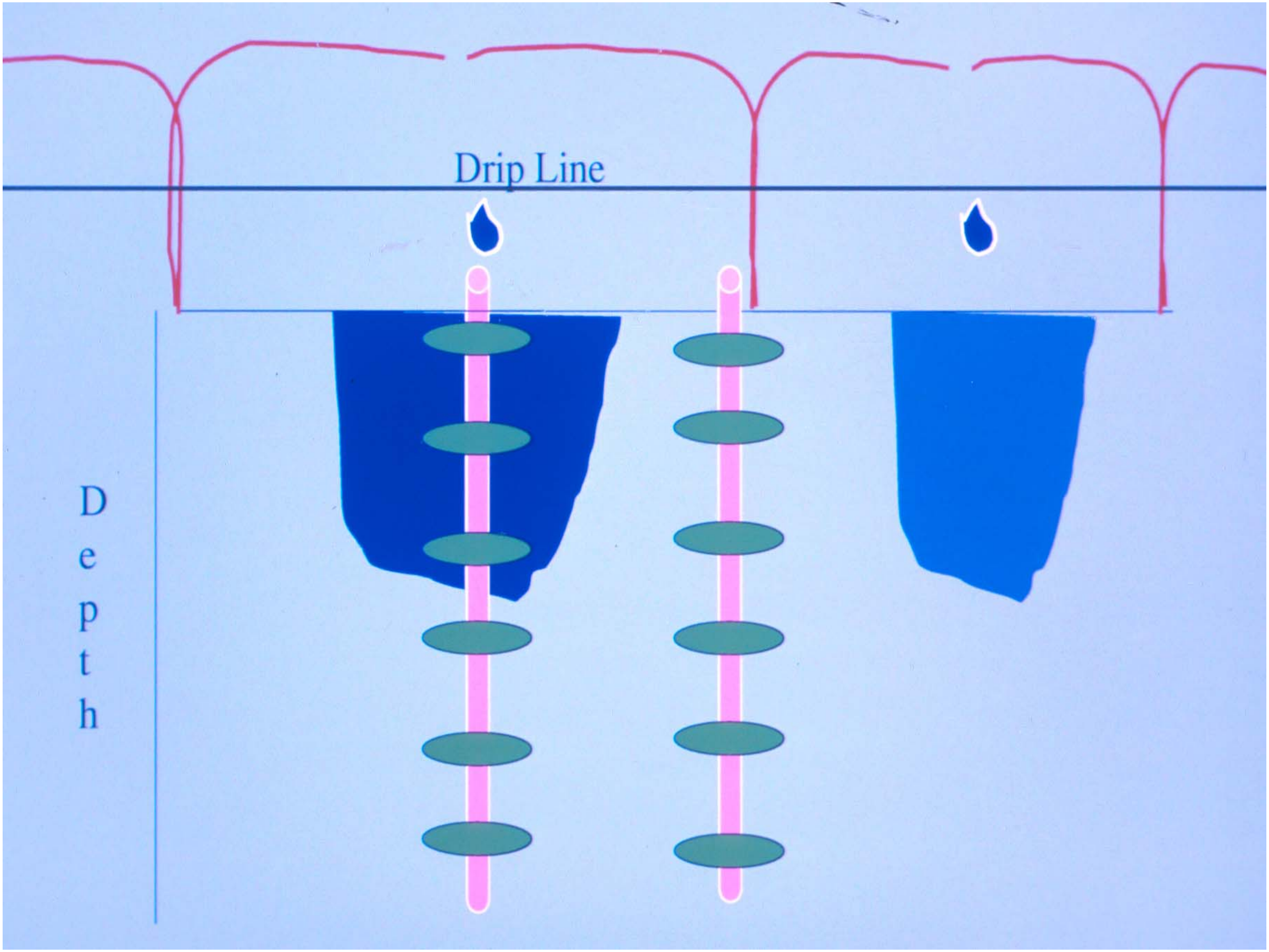
Sensor Area of Measure

- Most sensors read a small area
  - Tensiometers and Gypsum Blocks
    - Smallest area– a few cubic centimeters
  - Dielectric methods
    - Narrow disk shaped measurement area a few cm outside the well or from thee waveguides
  - Neutron Probe
    - Largest area – a few inches in radius of the detector

Sensor Placement

- Depends on the goal of the measurement

- If measuring soil water depletion before irrigation--- not too important
- If measuring after irrigation– proximity to the emitter will effect the reading


Drip Line
Depth

When To Measure Soil Moisture Quantitative(N Probe)

- Most valuable times:
  - Bud break
  - Just prior to 1st irrigation
  - Dry point

Bud break – Dry Point = Available water

Bud break – Prior to 1st irr = Water consumed

Prior to 1st irr – Dry Point = water remaining

Measuring Effective In-Season Rainfall

Effective Rainfall = [rainfall (in) - 0.25 in] × 0.8

Table C-3. Effective rainfall

Day	Rainfall (inches)	Effective Rainfall (inches)
1	0.39	0.11
2	0.62	0.30
3	0	0
4	0	0
5	0	0
6	0	0
7	0.25	0
Weekly Total	1.26	0.41

Measuring Water

Volume Units	Flow Rate
▪ Gallons	gpm
▪ Cubic feet	cfs

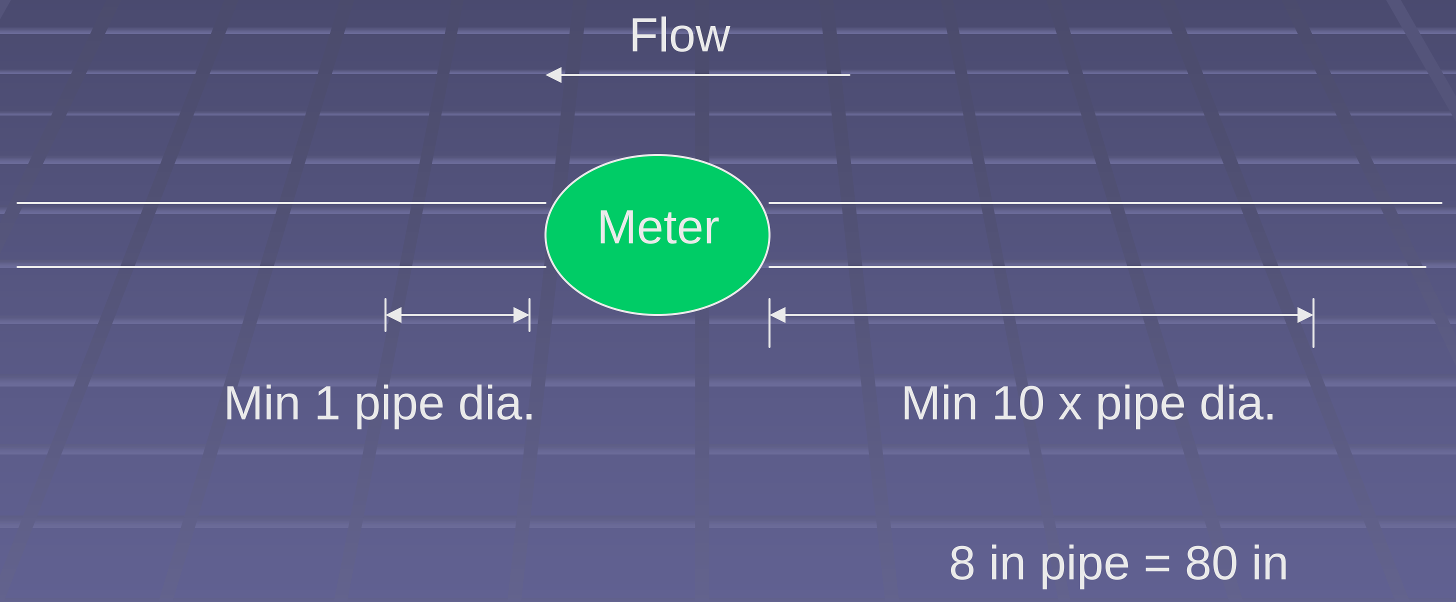
- Depth
  - Inches — in/hr
    - Rainfall
    - Crop Water Use
    - Irrigation

Measuring Irrigation Water

- Flowmeters
- Emitter Discharge

Totalizing Water Meter

Proper Water Meter Installation



Doppler Water Meter

Portable totalizing and instantaneous readings 2” to 9 ft dia.

pipe cross-sectional area X water velocity = Flow rate

Discharge Method

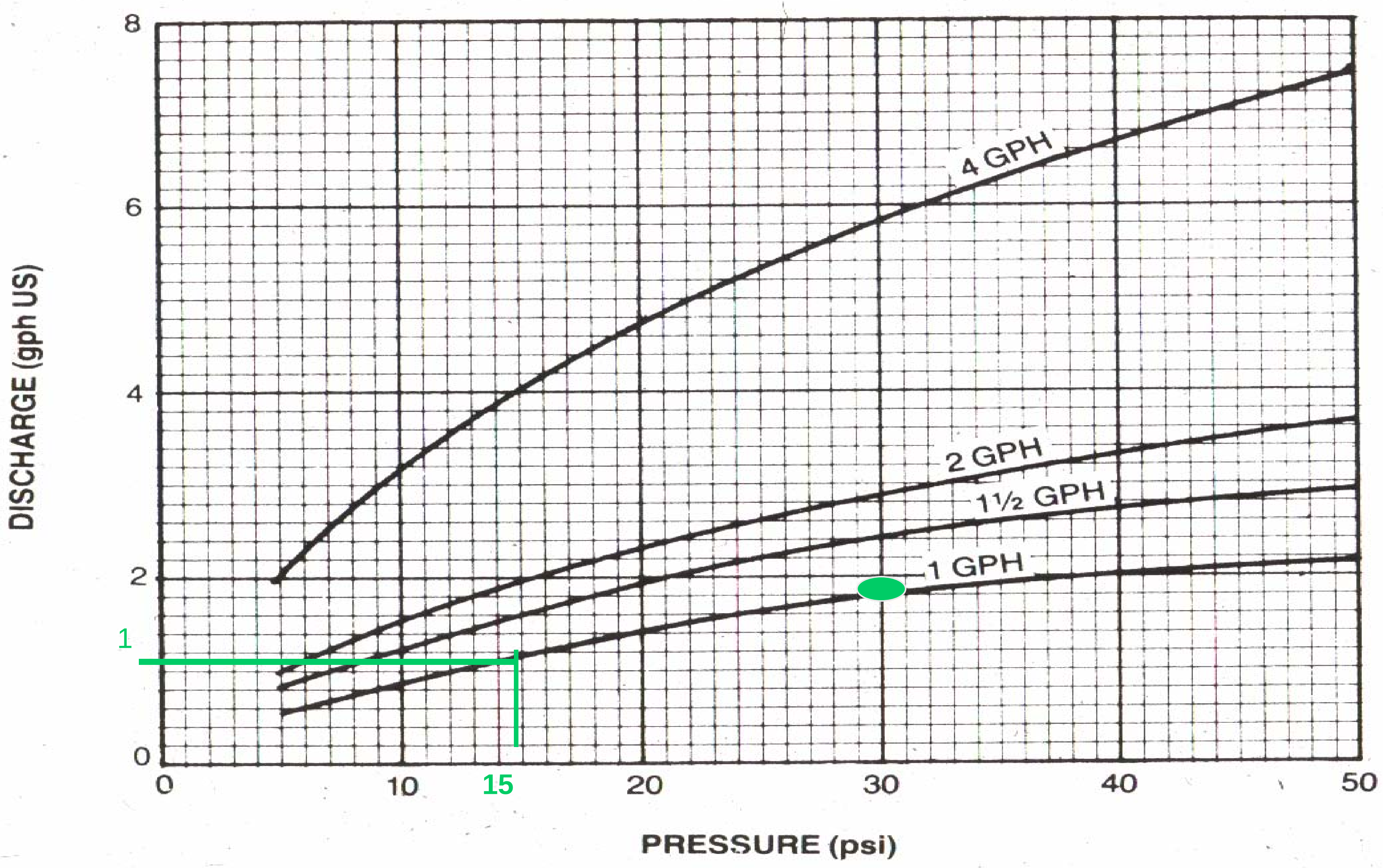
Measure the flow rate at the discharge point

Orchard / Vineyard Pots

Emitters

½ or 1 gph at nominal pressure

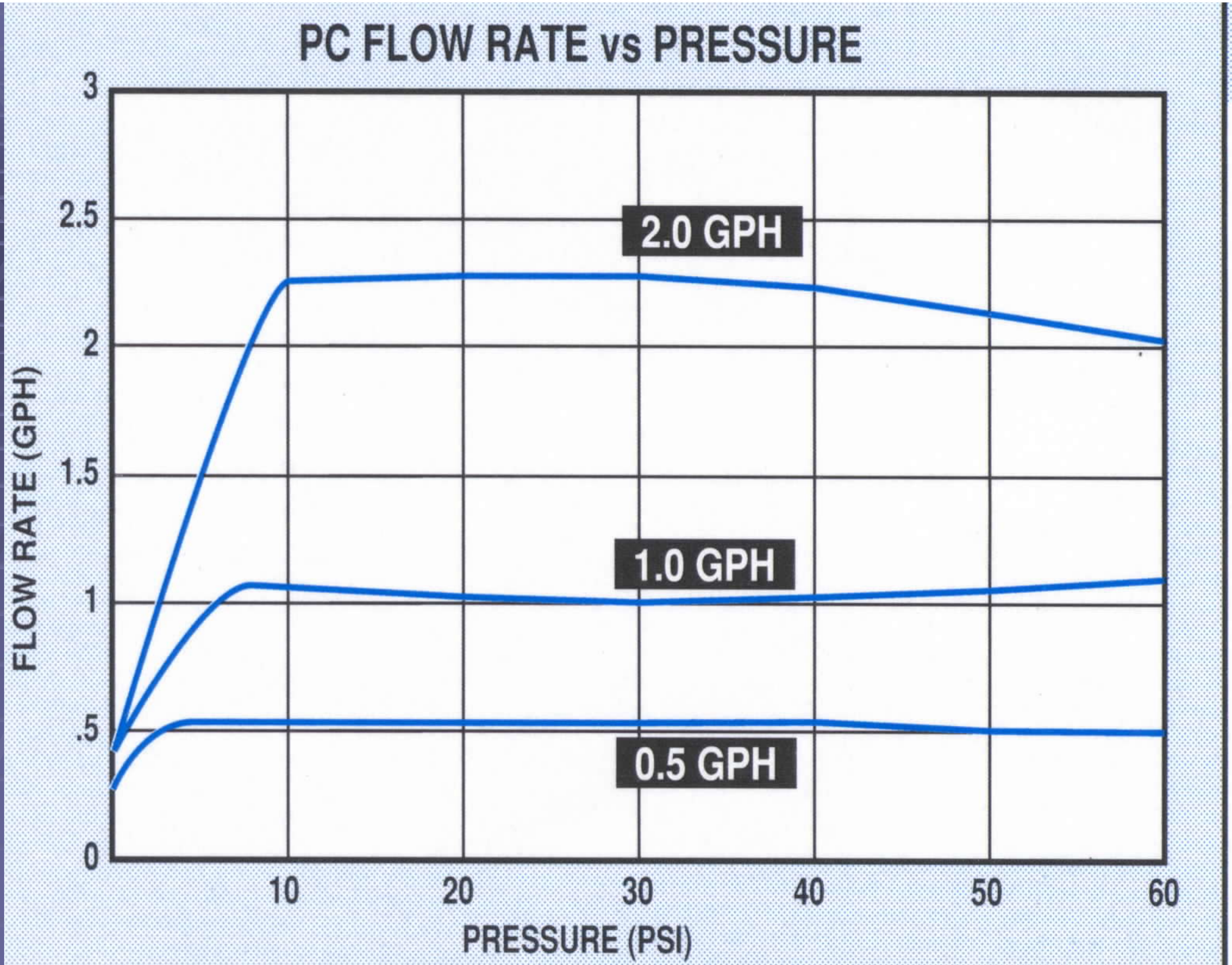
Emitter discharge vs pressure



Emitters:

- Pressure-compensating emitters are available.
  - Particularly good where you have significant elevation changes.

2.31 ft. of elevation change = 1 psi


PC FLOW RATE vs PRESSURE
FLOW RATE (GPH)
3
2.5
2
1.5
1
.5
0
2.0 GPH
1.0 GPH
0.5 GPH
10
20
30
40
50
60
PRESSURE (PSI)

Measuring Micro Irrigation Discharge Rate

Micro system discharge rate

Volume of water collected (ml) in 30 sec X 0.0317 = Discharge rate (gph)

Average discharge rate to applied inches

Ave. Discharge Rate (gph) x
no. discharge devices per plant /
plant spacing (sq ft) x 1.6 =
ave. application rate (in/hr)

Applied Water
in/hr x hrs of operation = applied inches

Average discharge rate to applied inches

Ave. Discharge Rate

gph) x no. discharge devices per plant /

plant spacing (sq ft) x 1.6 =ave. application rate (in/hr)

0.5 gph x 2 emitter/plant / 7x10 ft x 1.6 = 0.0229 in /hr

Applied Water

in/hr x hrs of operation = applied inches

0.0229 in/hr x 24 hrs = 0.52 in

Applied inches to Gallons per vine

- 0.52 inches X 27158 / vines/acre
- For a spacing of 7 x11 ft = 566 vines/acre

- 0.52 x 27158 / 566 = 25 gal/vine