Basic Soil Erosion and Types

2015 Wisconsin Lakes Convention

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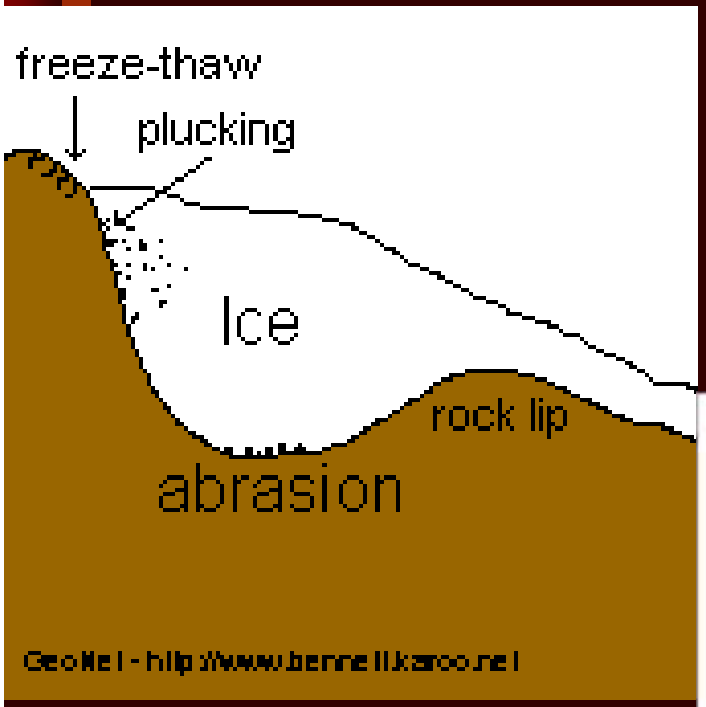
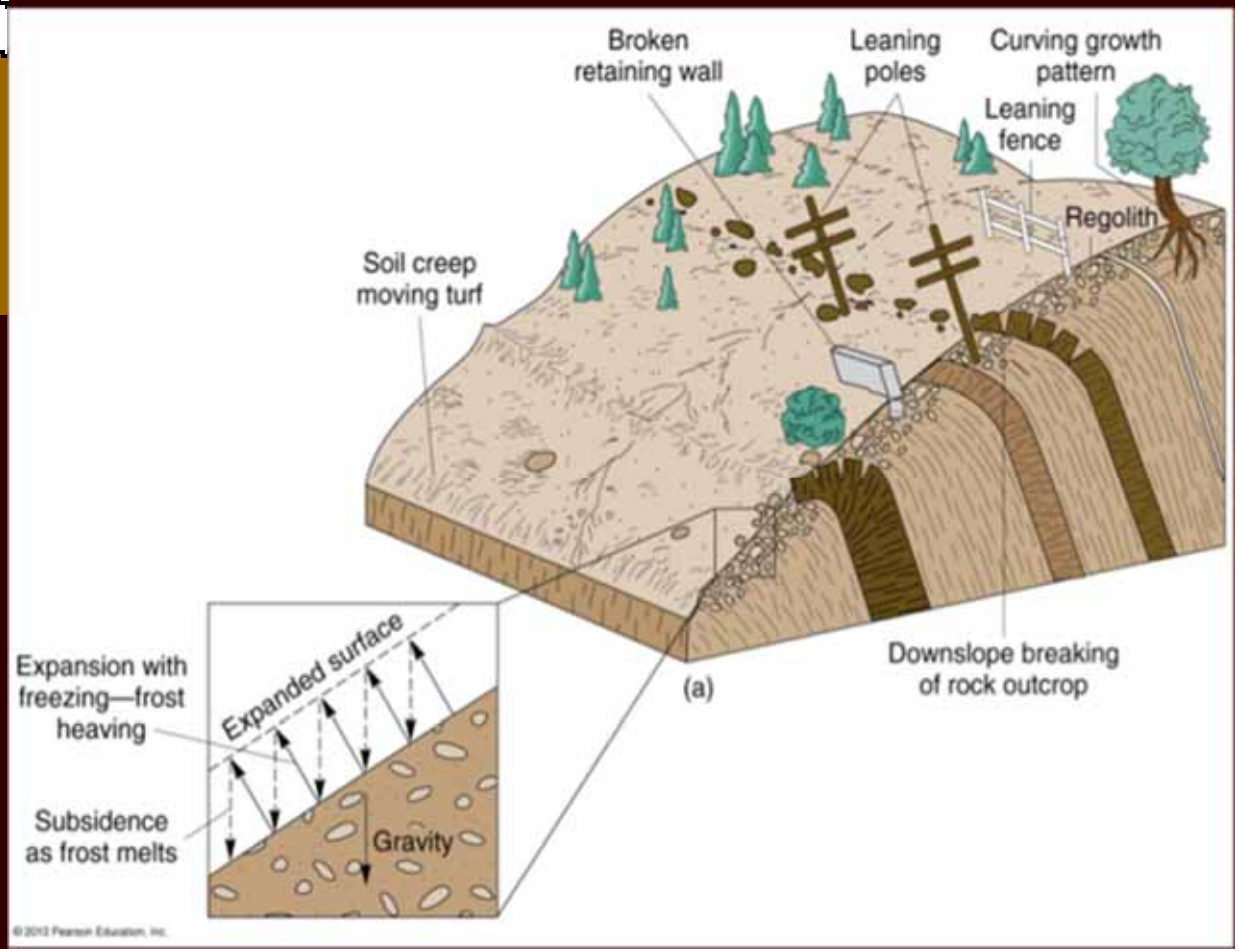
DATCP Engineer

TABLE 2-1. Agents and Types of Erosion

Agent	Type of Erosion or Degradation Process
Water	1. Raindrop splash
	2. Sheet erosion
	3. Rilling
	4. Gullying
	5. Stream channel erosion
	6. Wave action
	7. Piping and sapping
Ice	1. Solifluction
	2. Glacial scour
	3. Ice plucking
Wind	Wind erosion cannot be subclassified into "types"; instead it varies mainly by "degree."
Gravity	1. Creep
	2. Earth flow
	3. Avalanche
	4. Debris slide

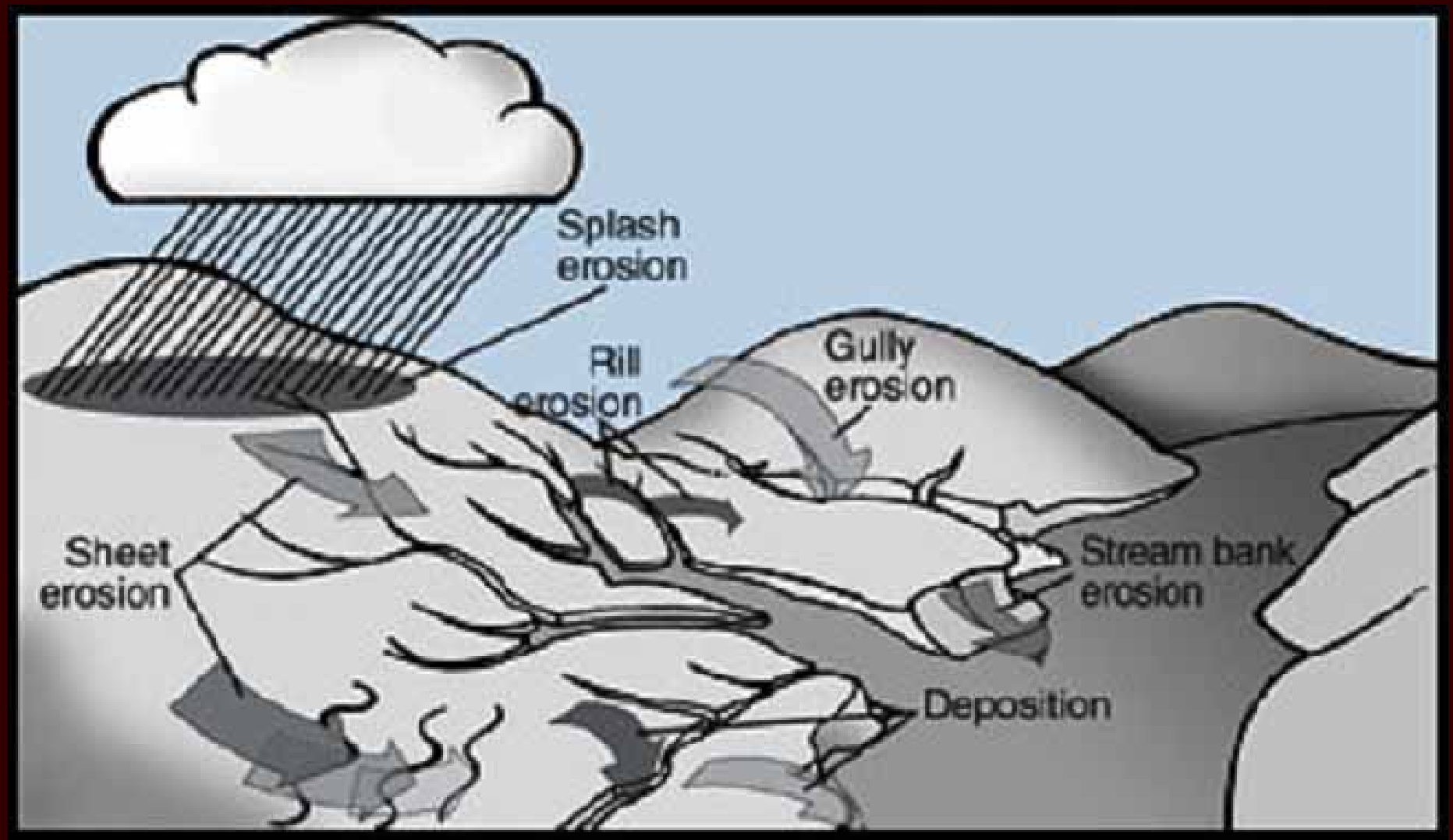
These are usually classified under mass wast-ing, but they often act in conjunction with erosion


freeze-thaw
plucking
Ice
rock lip
abrasion
GeoNet - http://www.bennellkaroo.net


Broken retaining wall
Leaning poles
Curving growth pattern
Leaning fence
Regolith
Soil creep moving turf
(a)
Downslope breaking of rock outcrop
Expansion with freezing—frost heaving
Expanded surface
Subsidence as frost melts
Gravity

Types of Soil Erosion

- **Rain drop or splash erosion:**
  - Erosion preceded by the destruction of the crumb structure due to the impact of falling raindrop on the surface of soil is termed as splash erosion.
- **Sheet erosion:**
  - It is the fairly uniform removal of soil in thin layers from the land surface, often scarcely perceptible, especially when caused by wind. Areas where loose, shallow topsoil overlies compact soil are most susceptible to sheet erosion.
- **Rill erosion:**
  - A form of water erosion in which numerous very small and more or less straight channels are produced; the channels get obliterated by ordinary use. It can be removed by normal tillage operations.
- **Gully erosion:**
  - A form of water erosion in which gullies are produced by combination of unattended rills.
- **Stream bank erosion:**
  - Stream banks are eroded by water either flowing over the sides of a stream or scouring at the base. It is aggravated by removal of vegetation, over grazing or cultivation near the stream banks.


Splash erosion
Rill erosion
Gully erosion
Sheet erosion
Stream bank erosion
Deposition

Types of Water Induced Erosion

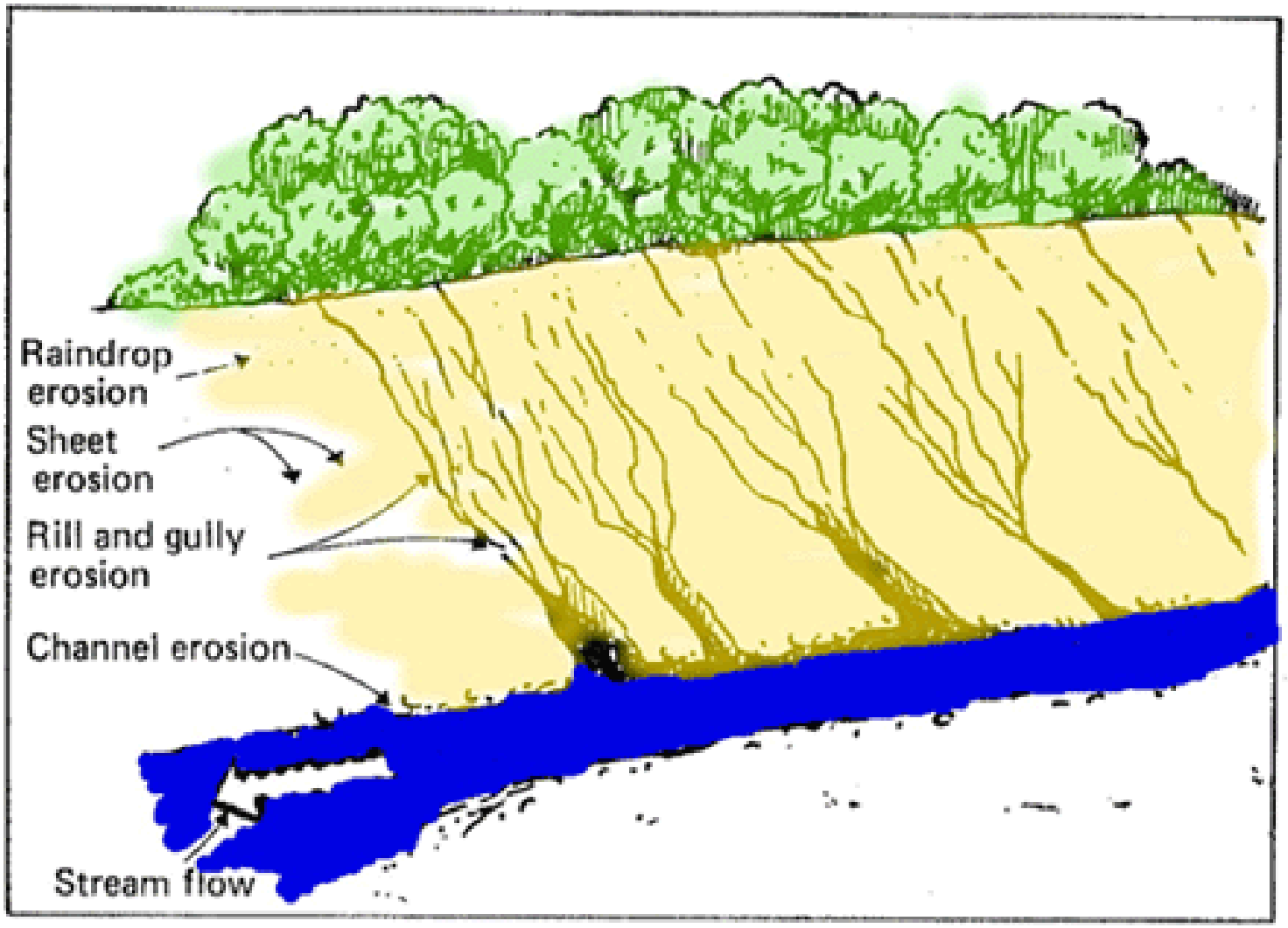


Fig. 1.3 Types of erosion. (Adapted from 1)


Sheet Erosion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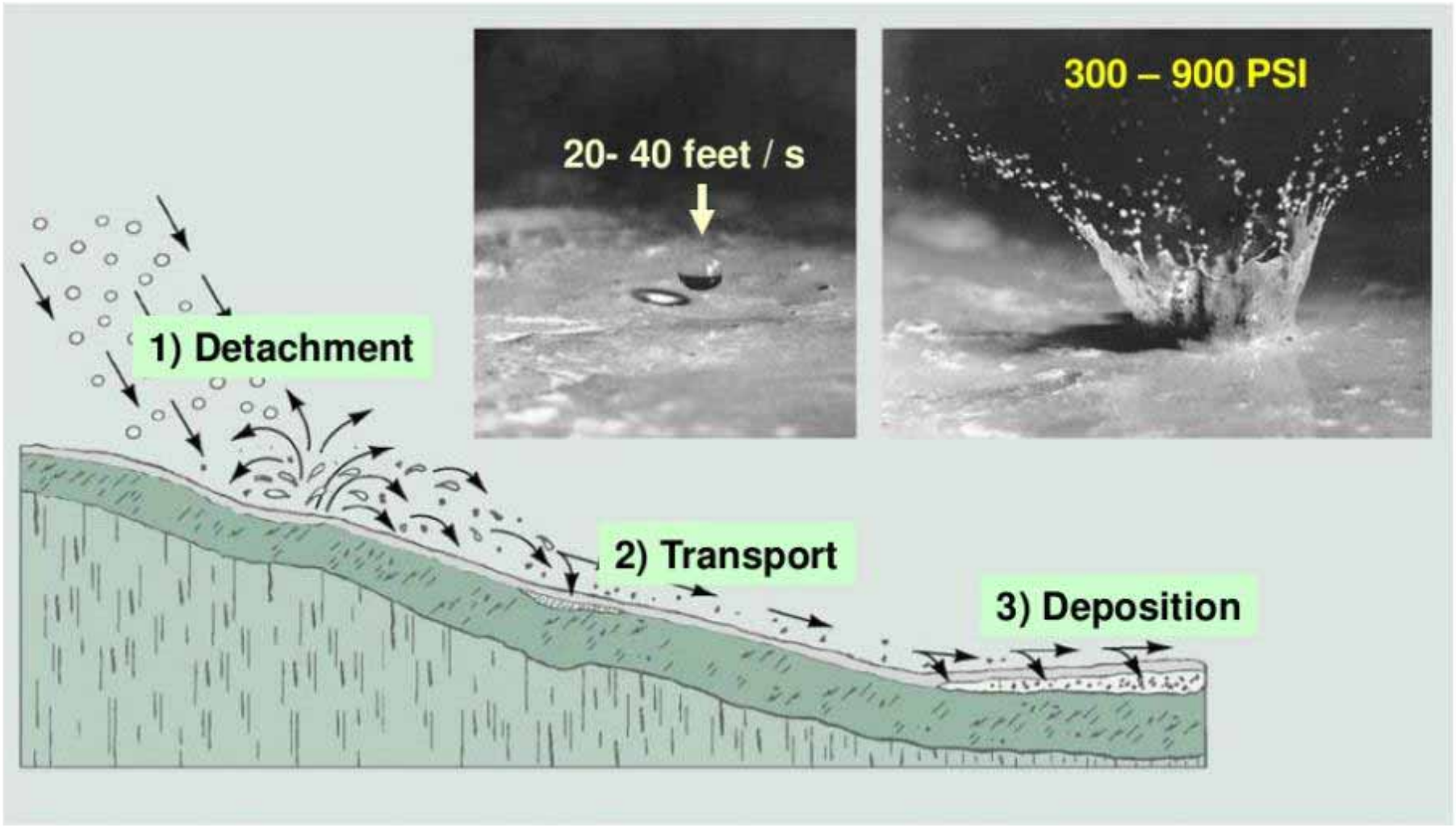
Understanding water erosion processes



Brady and Weil (2002)

Slope angle and length affects runoff generated when rain falls to the surface. Examine the diagram below showing the relationship between hill slope position, runoff, and erosion.

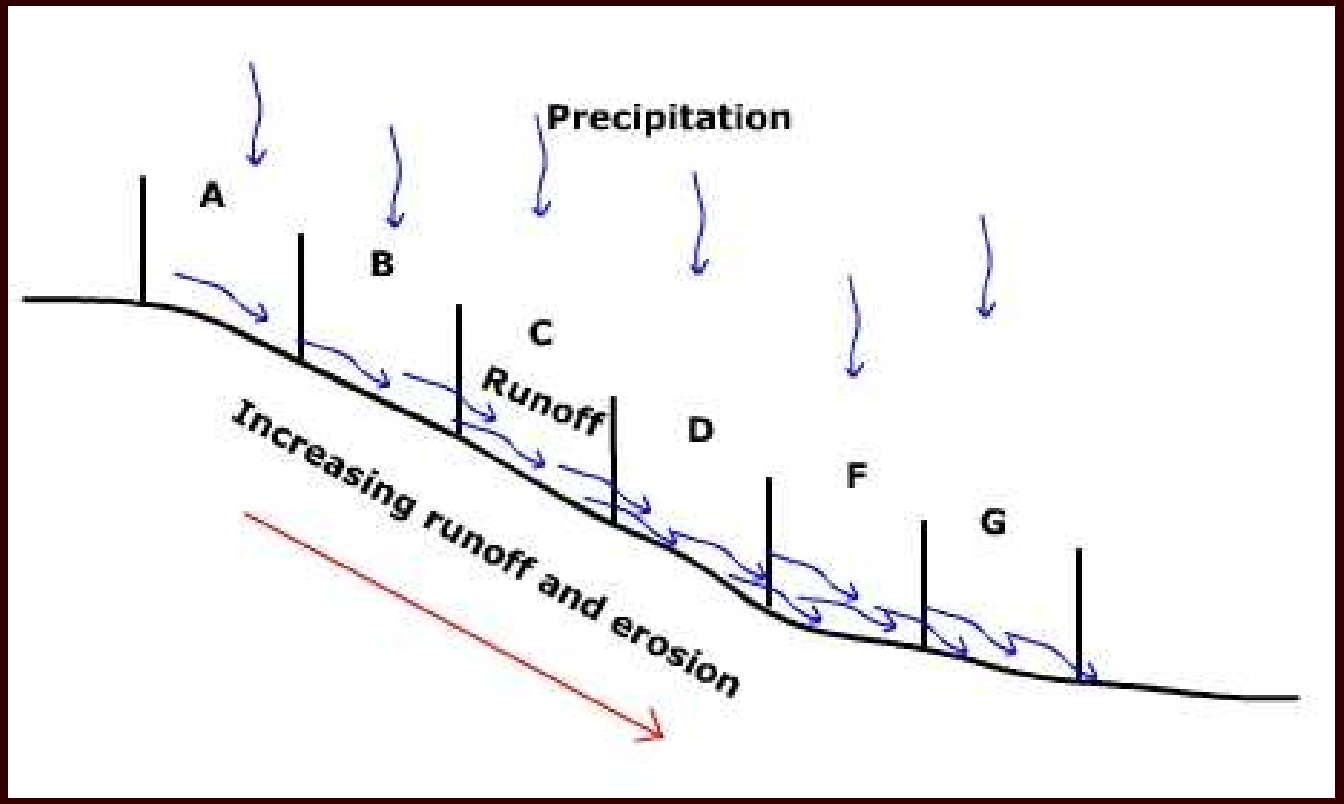


Figure 11.10 Hill slope position, runoff & erosion

Soil Types

Ability to resist erosion forces

Soil Has Different Properties From:

- Geologic Origin
- Composition
- Chemical and Physical
- Erosion based on:
  - Cohesive (clay) vs. Non cohesive (sand)
  - Density and Particle Size
  - Permeability and Change due to COMPACTION
  - Strength – Tensile, Shear, Bearing Capacity
  - Water Table and Saturation
  - Vegetation and Roots

Geologic Origin

- Parent Material
  - character and chemical composition of the parent material plays an important role in determining soil properties
- Glaciers, Floods, and Water Movement
  - As glaciers pushed, they act like giant bulldozers pushing soil ahead of them. Glacial ‘till’ or ‘drift’ deposits resulted many tens or even hundreds of miles from where the soils were first formed.
  - Water is also very important in moving soils. As rivers flow, they transport soil particles along. If soil is washed into a river, the smallest particles will be carried the furthest by the water as they weigh the least. Heavier particles, such as sand, will be dropped earlier. Soils dropped around streams are termed ‘alluvial’. Soils deposited in lakes are called 'lacustrine', soils deposited by rivers 'riverine' and by sea 'marine' alluvial soils

Composition

- Percent Silt, Clay, Sand, Gravel
- Uniform or Poorly Graded
- Layered Horizontally or Diagonally
- Densely Packed or Loose
- Particle Sizes

Chemical and Physical Properties

pH, Conductivity, Calcium Carbonate and plant survival

Soil Structure

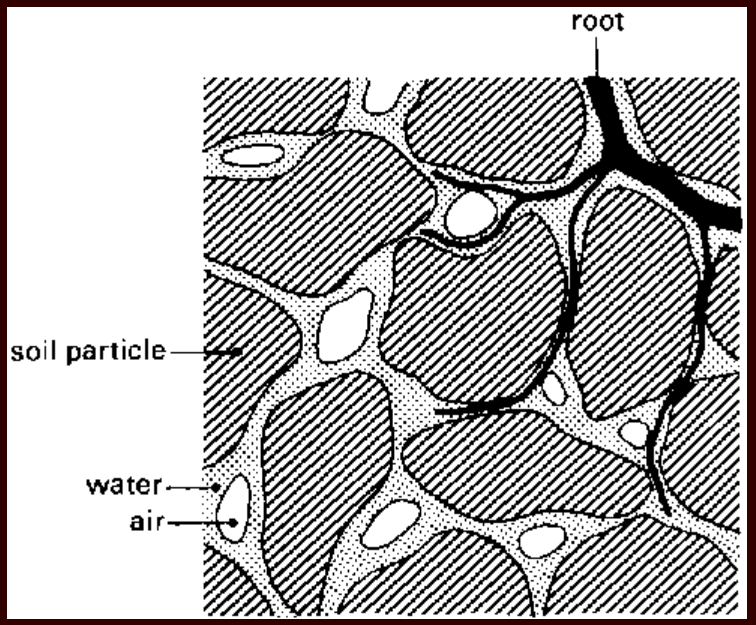
Susceptibility of soil to sheet and rill erosion by water

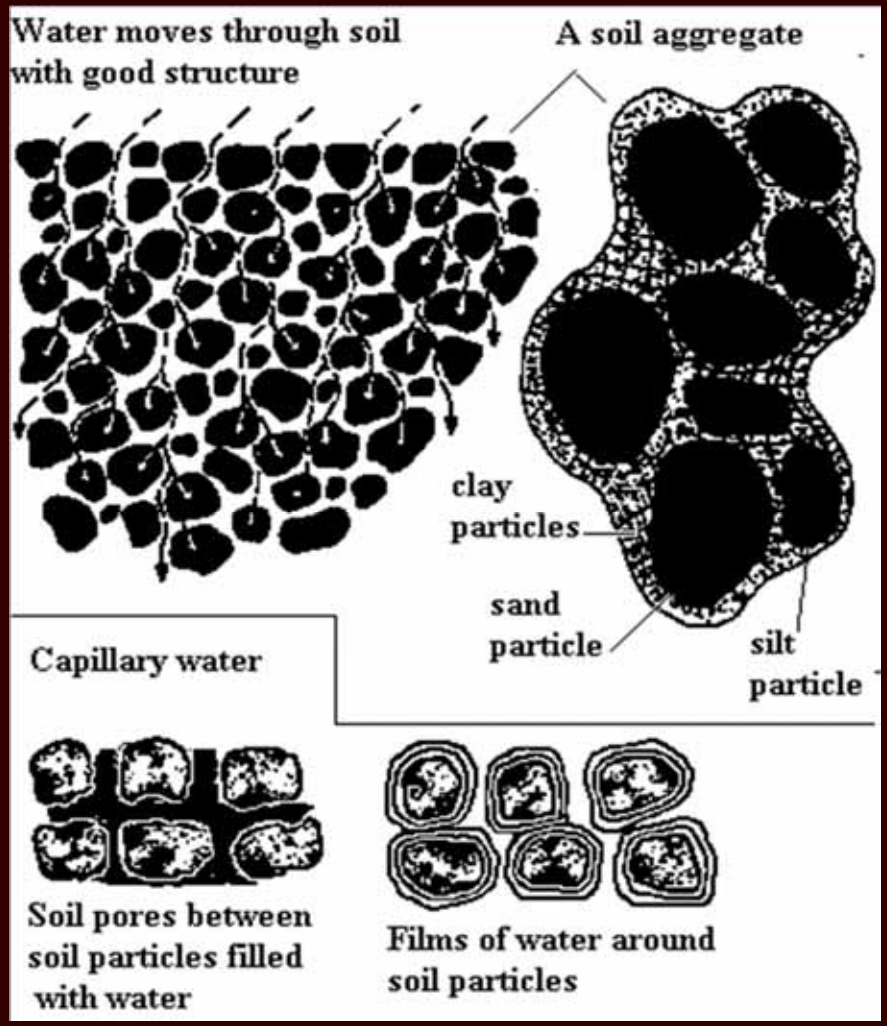
Plasticity Index

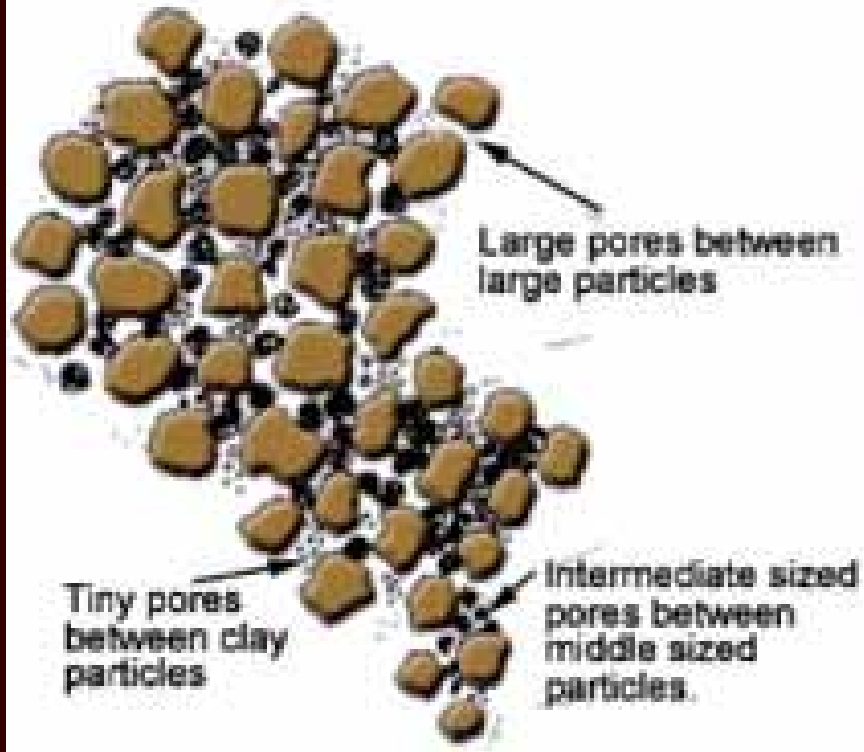
Water Content


Sandy Soil
Clay Soil
Chalky Soil
Silty Soil
Peaty Soil
Loamy Soil

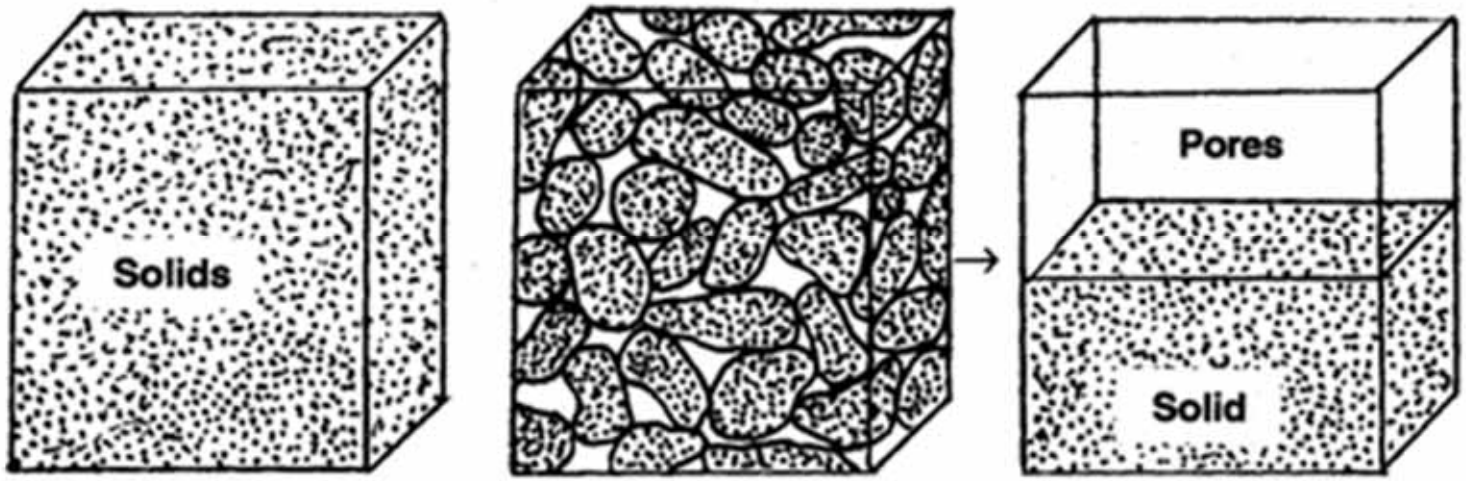

Sand
Silt
Clay


root
soil particle
water
air


Water moves through soil with good structure
A soil aggregate
clay particles
sand particle
silt particle
Capillary water
Soil pores between soil particles filled with water
Films of water around soil particles



Soil Type	Average Bulk Density (g/cm^3)
sand	1.2 - 1.8
silt	1.0 – 1.3
clay	0.51 – 1.2



Particle Density

100% solid
Weight = 2.66 g
Volume = 1 cm^3

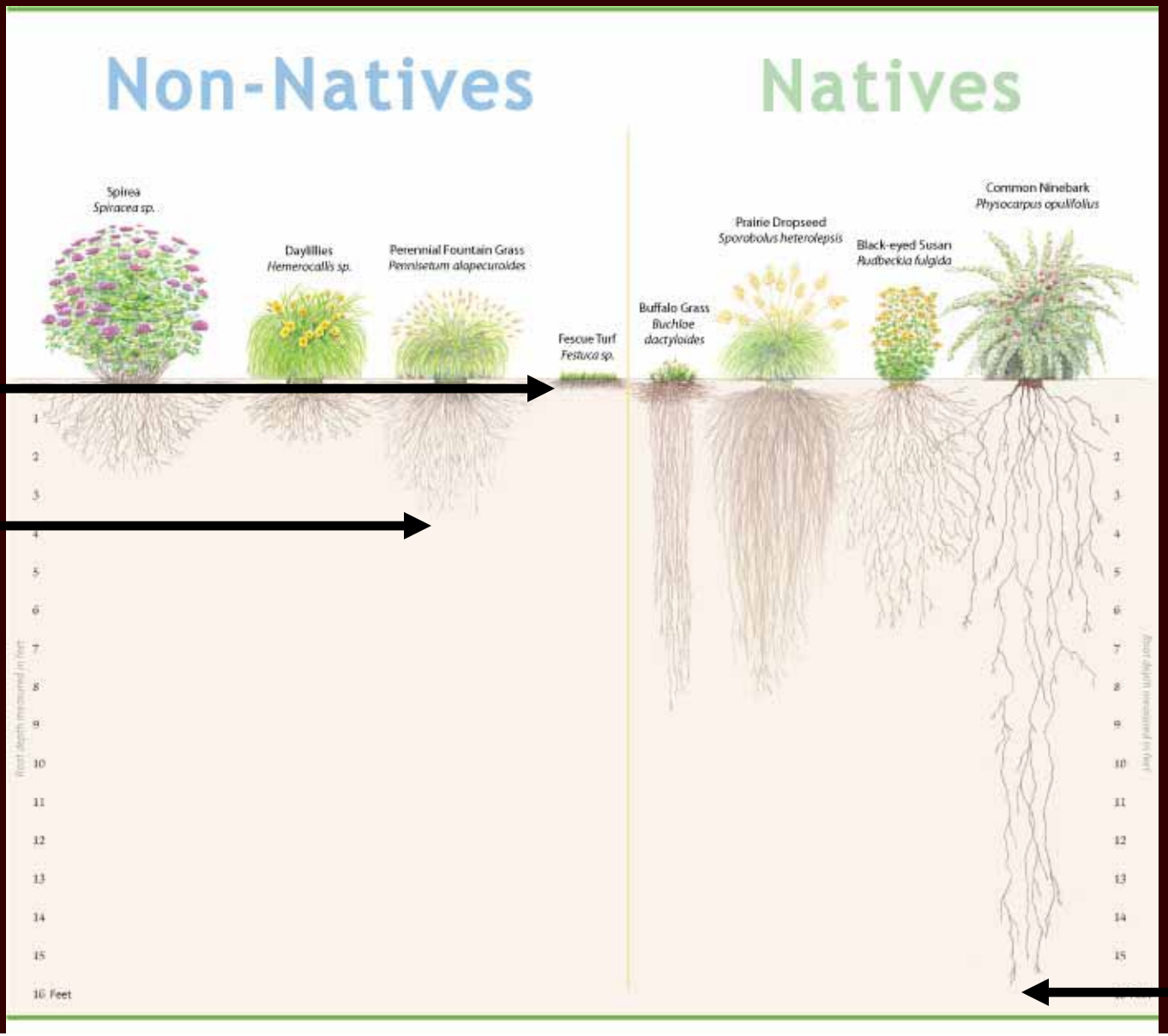
Bulk Density

50% solid, 50% pore space
Weight = 1.33 g
Volume = 1 cm^3

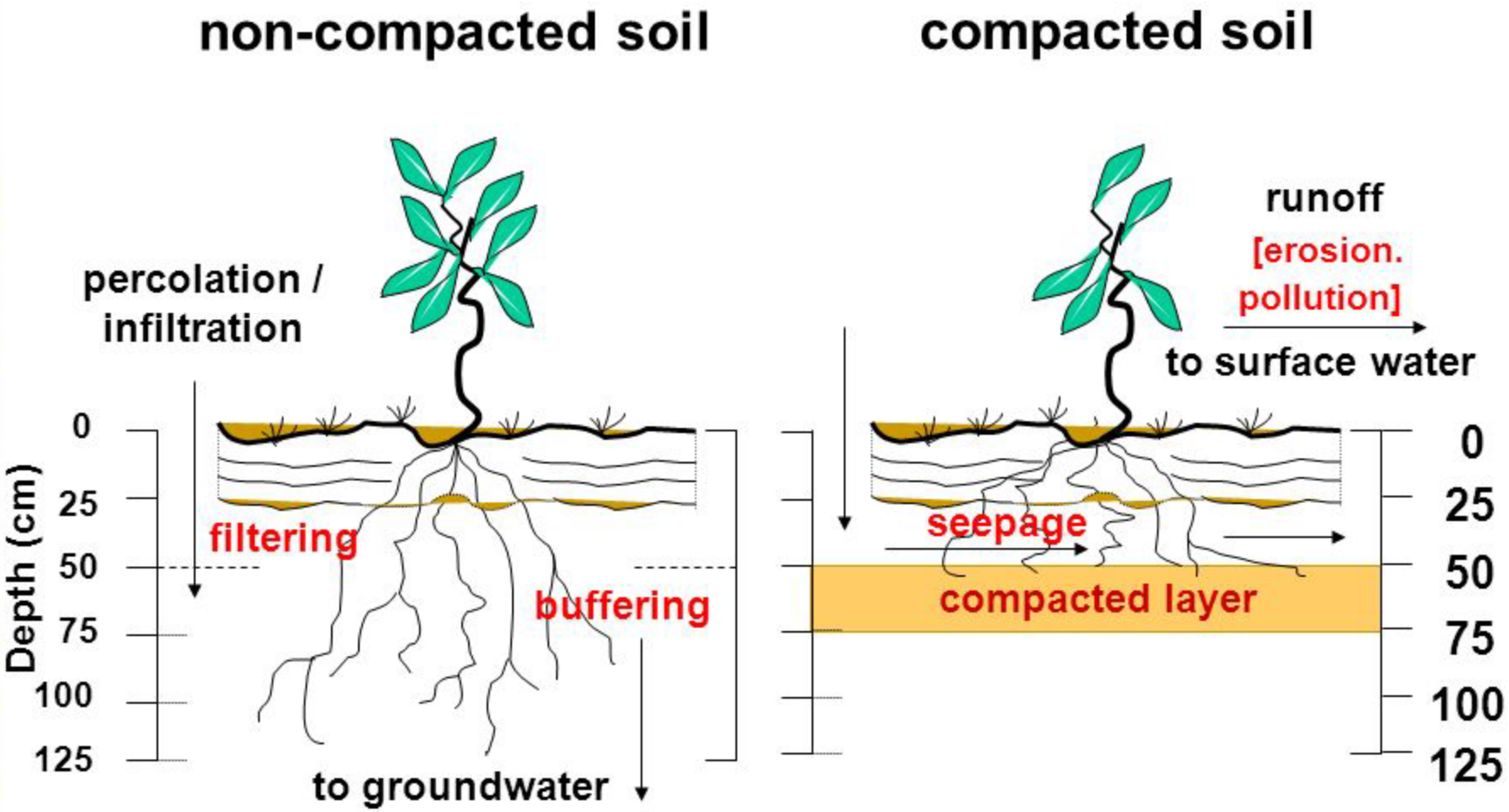
Vegetation Holds Soil

Turf Grass

4.0 Ft



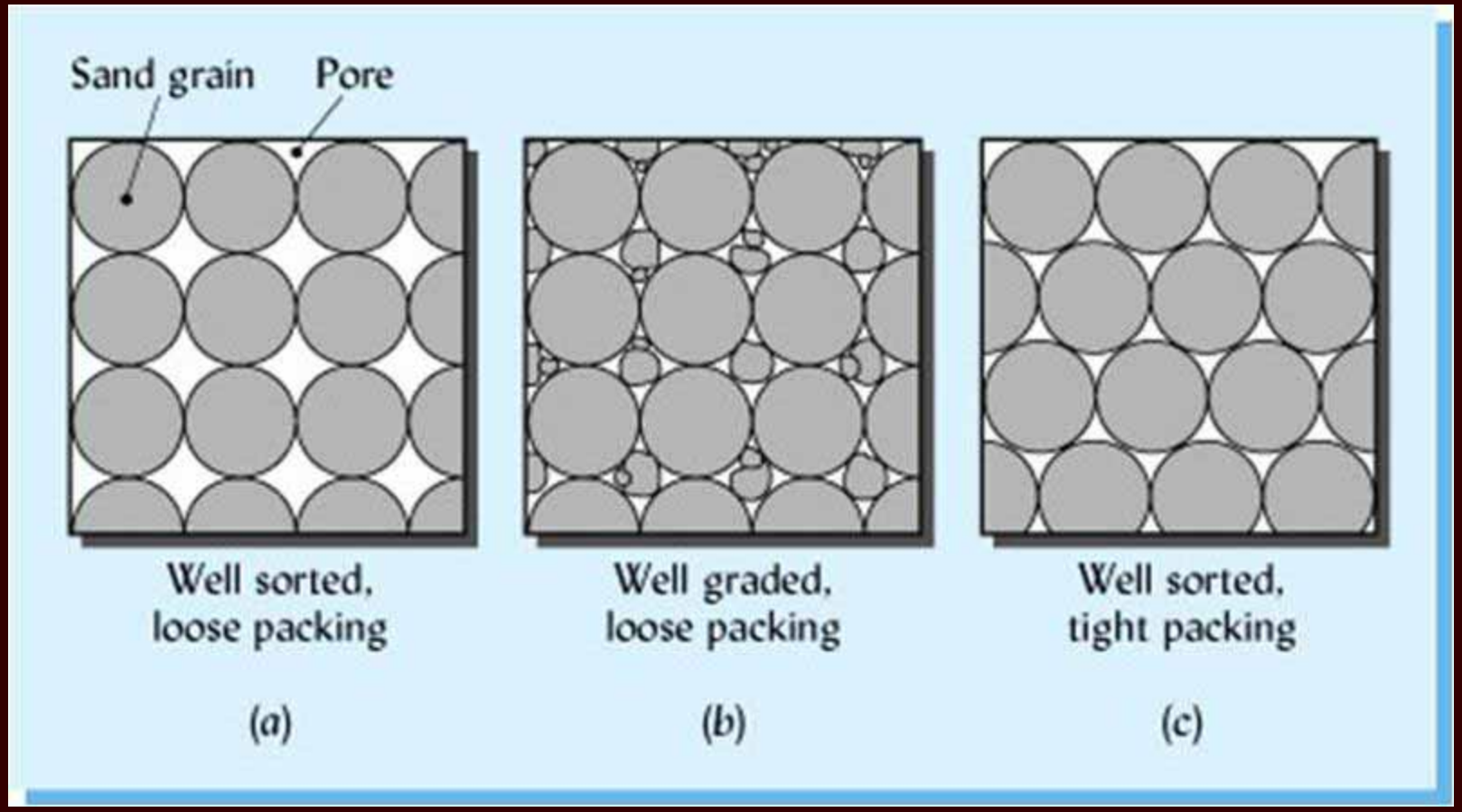
16 Ft



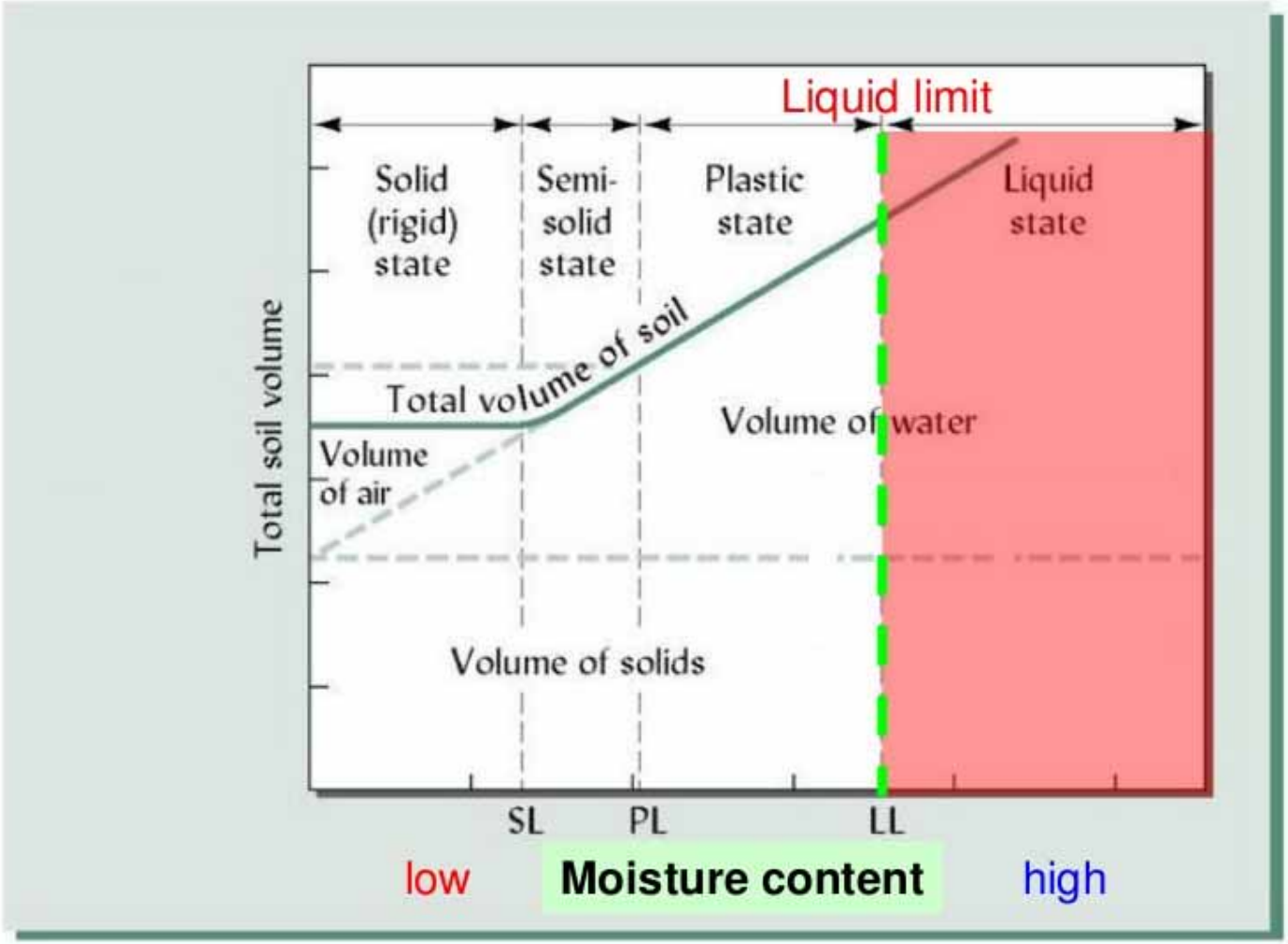
Bulk density higher than 1.9 g.cm^{-3} stops the ability of plant roots to grow

Erosion

- Depends on Soil Properties
- Highly Erodible Lands (Parent Material)
- Cohesive Clays or Non-cohesive sands
- Densely Packed or Loose Materials
- Permeability and Water Movement (seeps)
- How Soils perform under loading (structures)
- Effective stress and water table fluctuations


Sand grain
Pore
Well sorted, loose packing
(a)
Well graded, loose packing
(b)
Well sorted, tight packing
(c)

Engineering properties of soil



Brady and Weil, 2002

When moistened to its liquid limit, a soil starts to flow.

Most Erodible $\longrightarrow$ Least Erodible

$$ML > SM > SC > MH > OL \gg CL > CH > GM > SW > GP > GW$$

where:

GW = well graded gravel
GP = poorly graded gravel
GM = silty gravel
SW = well graded sand
SM = silty sand
SC = clayey sand
ML = low plasticity silt
MH = high plasticity silt
CL = low plasticity clay
CH = high plasticity clay
OL = low plasticity organic soil

This erodibility hierarchy is simple, but based on gradation and plasticity indices of remolded or disturbed soils. Accordingly, it fails to take into account effects of soil structure, void ratio, and antecedent moisture content. Wischmeir

TABLE 2-10. Causes of Slope Failure

Increase in Shear Stress

1. Surcharging slope (structures and fills at top)
2. Removal of lateral support (cuts and excavations at toe)
3. Rapid changes in water level adjacent to slope ("sudden drawdown")
4. Increase in lateral stress (water filled cracks and fissures)
5. Earthquake loading (increases in horizontal or downslope driving forces)

Decrease in Shear Strength

1. Increased pore water pressure, which reduces effective stress (storm water infiltration into slope, uncontrolled discharge of water from drains, earthquake induced pure water pressure)
2. Presence of swelling clays (uptake of water with loss of intrinsic cohesion)
3. Weathering and physicochemical degradation (ion exchange, hydrolysis, solutioning, etc.)
4. Progressive failure by shear strain softening

TABLE 6-1. Classification of Site Conditions for Revegetation

Area of Classification	Range of Classification	Influencing Factors
A. Soil conditions	1 = very good 2 = good 3 = medium 4 = poor (bad) 5 = very poor	Grain size distribution; permeability; texture; moisture and water retention; soil reaction (pH); fertility (especially soil nutrient levels); toxic materials; density (degree of compaction)
B. Climate	1 = very good 2 = good 3 = medium 4 = poor (bad) 5 = very poor	Amount and distribution of precipitation; humidity; evaporation (wind, sun); frequency of dry periods; duration of snow cover; average temperature and fluctuations; light conditions
C. Erosion hazard	1 = very good 2 = good 3 = medium 4 = poor (bad) 5 = very poor	Steepness (slope inclination); soil erodibility; weather (storm frequency and intensity); frost action; groundwater (seeps); geology (orientation of joint surfaces and bedding planes)

and ratings in the table allow a site to be evaluated or classified in terms of its climate, soils, and erosion hazard. This is accomplished by considering each of the influencing factors for a specific classification area. As an example, suppose that a site has been classified as follows: soil (A4) poor, climate (B2) good, and erosion hazard (C3) medium. In this case it would be advisable to choose plant species that are capable of deep rooting, fast growth, and which do not require high fertility.

Various Techniques or Combinations of Techniques to “Help” Soils Prevent Erosion

- Natural Shoreline
- Native Plantings
- Biolog w/ Plantings
- Branch Box Breakwater
- Brush Mattress
- Live Fascine
- Branch Packing
- Vegetated Geogrid
- Rock Riprap
- Rock Riprap w/ Live Stakes; “vegetated riprap”
- Demo/Experimental

Biolog

3 YEAR OLD BIOLOG

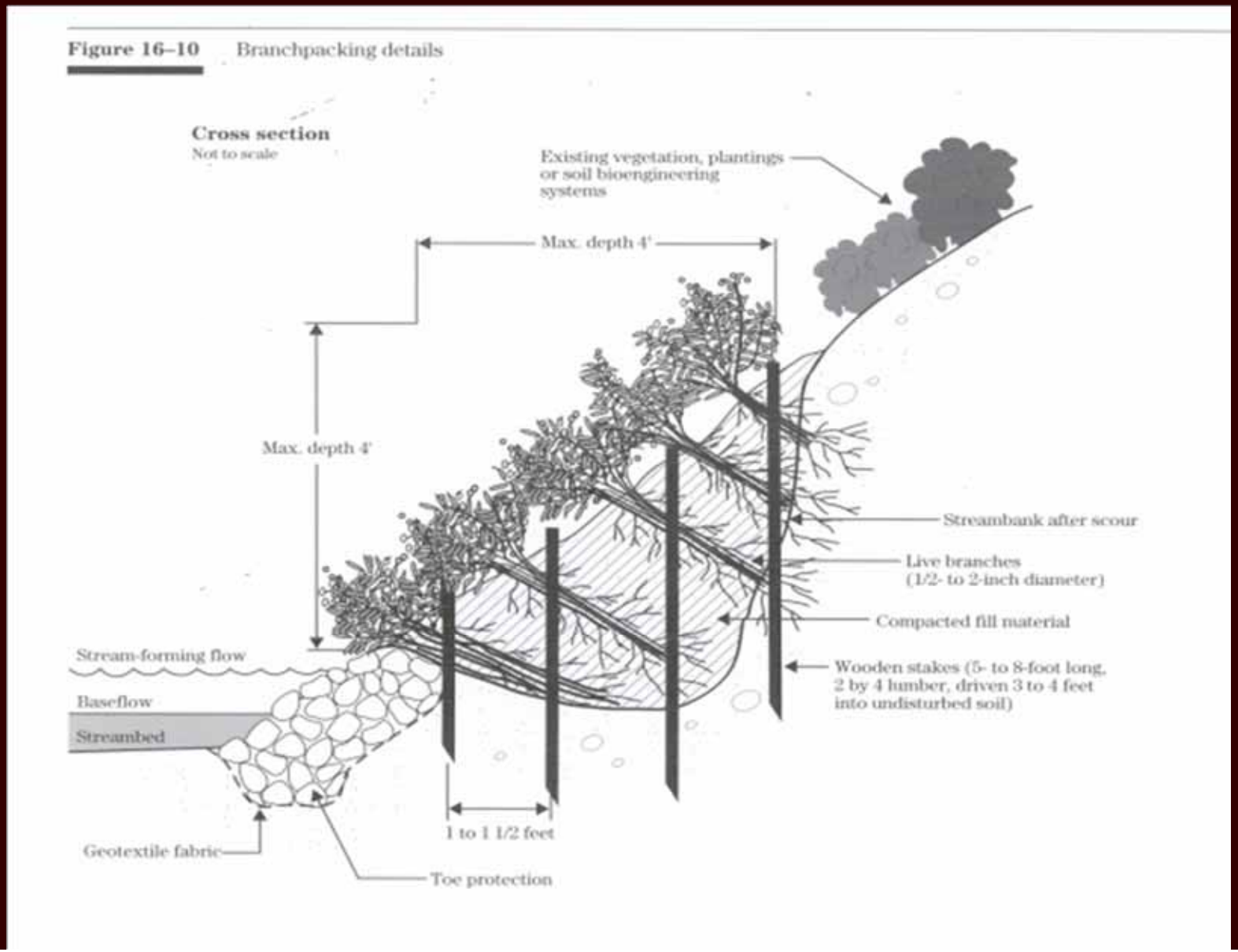
Brush Mattress

Live Fascine

Branchbox Breakwater

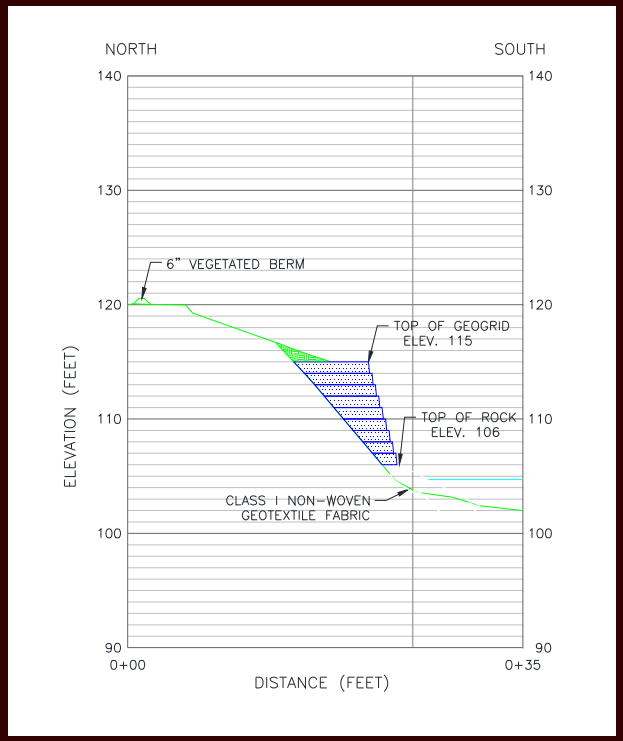
Techniques

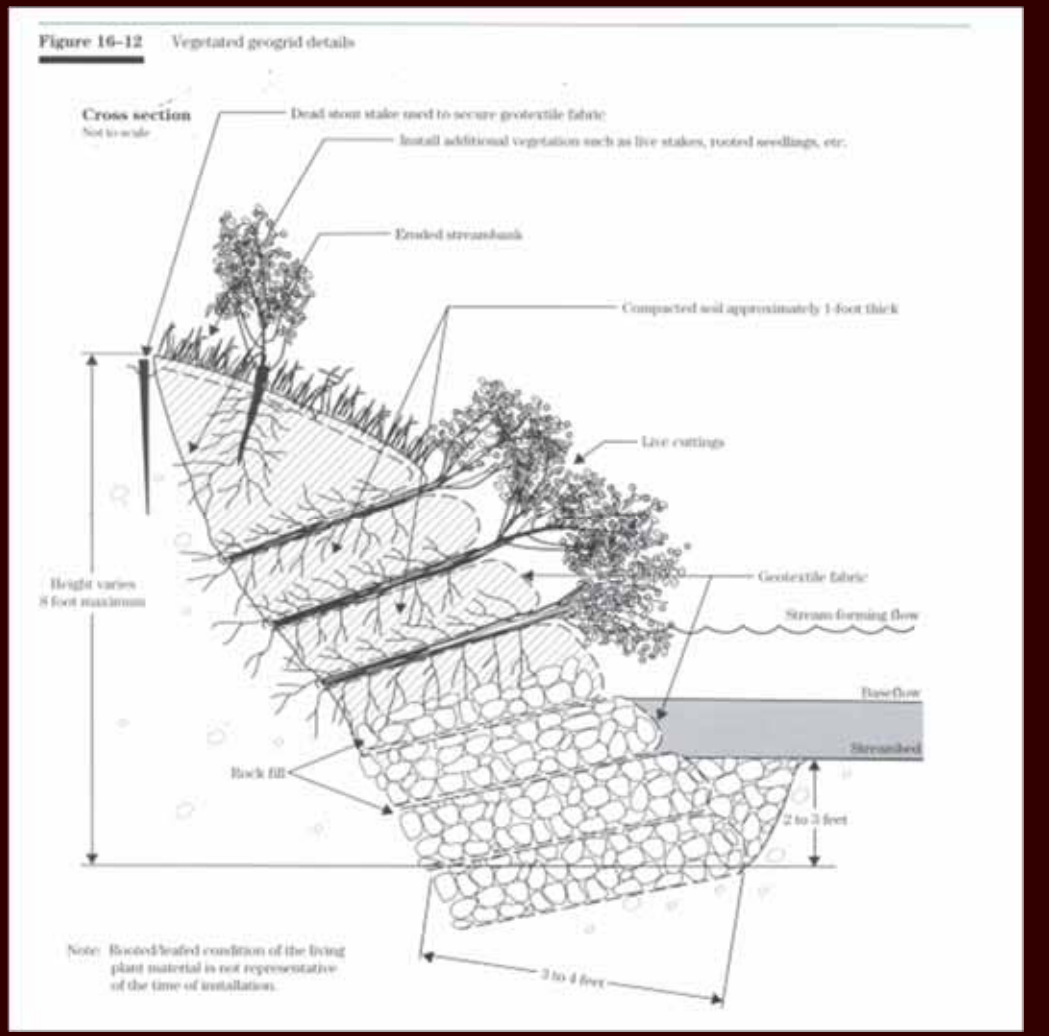
Branch Packing



Techniques

Vegetated Geogrid





Vegetated Riprap

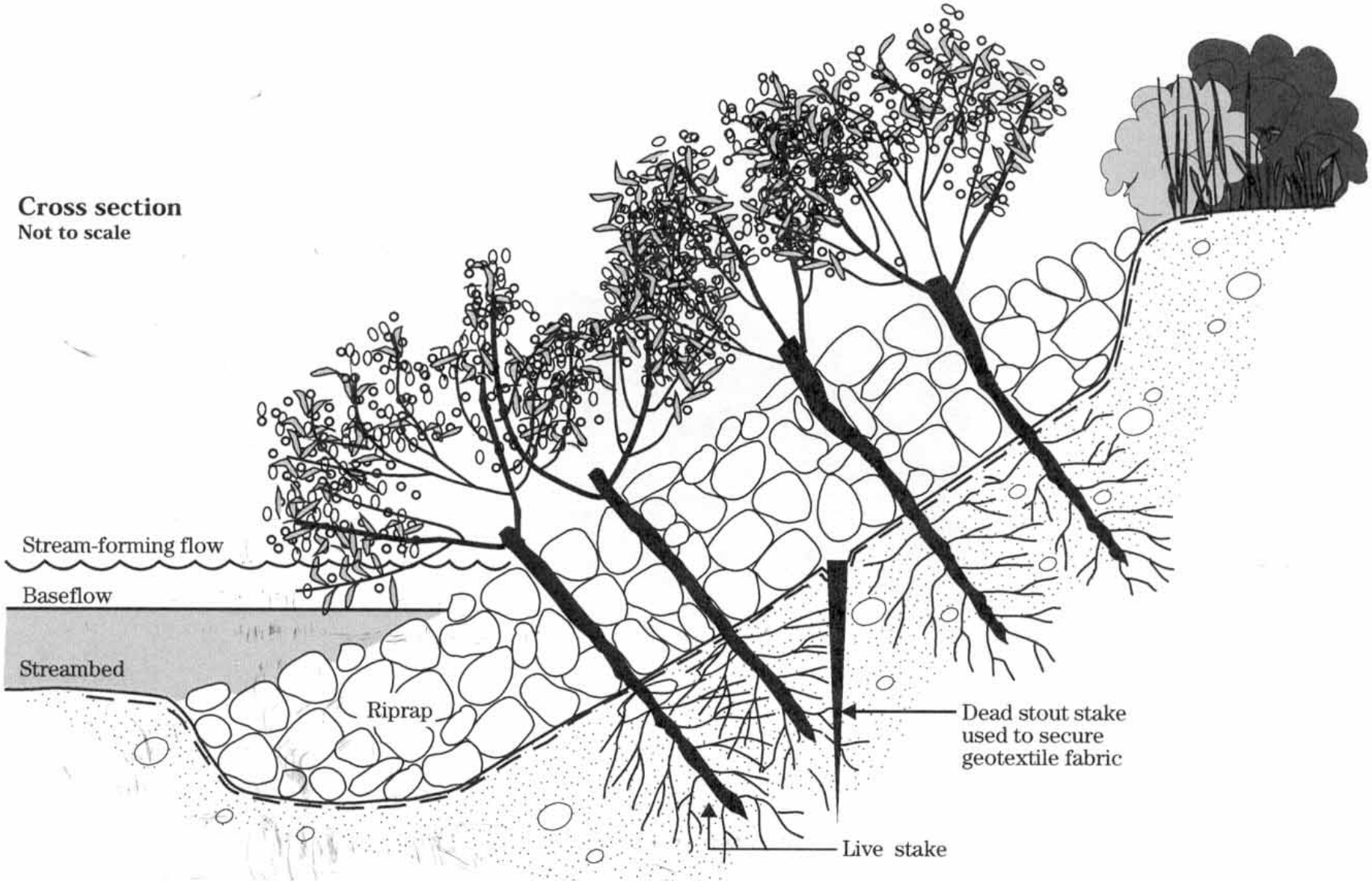


TABLE 7-5. Unit Costs for Soil Bioengineering Measures (in 1994 Dollars)

Method	Installed Unit Cost[a]
Live staking	$1.50 → 3.50 per stake
Joint planting	$2.00 → 9.00 per stake
Live fascine	$5.00 → 9.00 per lineal foot
Live crib wall	$10.00 → 25.00 per square foot of front face
Brushlayer—cut	$8.00 → 13.00 per lineal foot
Brushlayer—fill	$12.00 → 25.00 per lineal foot
Vegetated geogrid	$12.00 → 30.00 per lineal foot
Live slope grating	$25.00 → 50.00 per square foot of front face

[a] Installation includes: (1) harvesting, (2) transportation, (3) storage, and (4) placement.

Case Studies (1) Problem ID & Techniques used

Web Soil Survey

Vilas County, Wisconsin (WI125)

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
CrA	Croswell sand, 0 to 3 percent slopes	17.5	8.4%
Kr	Kinross mucky sand, 0 to 2 percent slopes	5.3	2.5%
Lo	Loxley and Dawson peats, 0 to 1 percent slopes	20.6	9.9%
RoB	Rubicon sand, 0 to 6 percent slopes	69.2	33.2%
RoC	Rubicon sand, 6 to 15 percent slopes	0.3	0.2%
RoD	Rubicon sand, 15 to 30 percent slopes	0.7	0.3%
SaC	Sayner-Rubicon complex, 6 to 15 percent slopes	63.5	30.4%
SaD	Sayner-Rubicon complex, 15 to 35 percent slopes	3.1	1.5%
W	Water	28.4	13.6%
Totals for Area of Interest		**208.7**	**100.0%**

Web Soil Survey

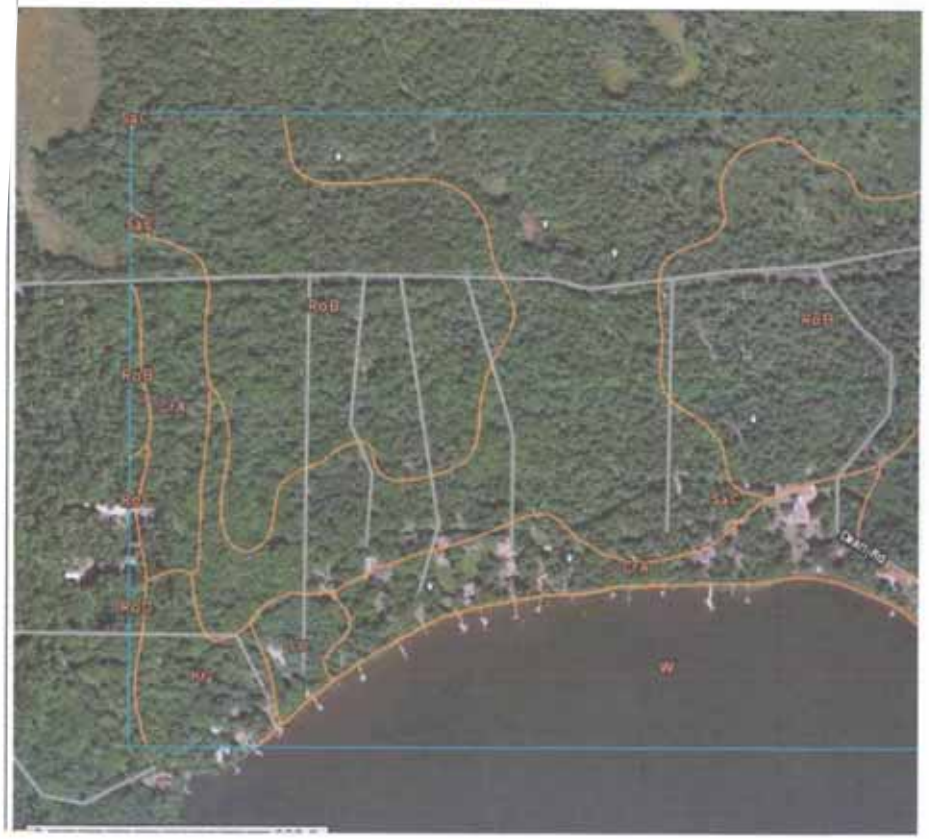
Status | Glossary | Preferences | Link | Logout | Help

Explorer | Download Soils Data | Shopping Cart (Free)

Printable Version | Add to Shopping Cart

Soil Map

Scale (not to scale)



Vilas County, Wisconsin

CrA—Croswell sand, 0 to 3 percent slopes

Map Unit Setting

National map unit symbol: g4b4
Elevation: 600 to 1,600 feet
Mean annual precipitation: 27 to 34 inches
Mean annual air temperature: 41 to 45 degrees F
Frost-free period: 90 to 150 days
Farmland classification: Not prime farmland

Map Unit Composition

Croswell and similar soils: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Croswell

Setting

Landform: Depressions on outwash plains, drainageways on stream terraces
Landform position (two-dimensional): Footslope
Down-slope shape: Concave, linear
Across-slope shape: Concave
Parent material: Sandy outwash

Typical profile

E - 0 to 4 inches: sand
Bs1-Bs3 - 4 to 25 inches: sand
C1,C2 - 25 to 60 inches: sand

Properties and qualities

Slope: 0 to 3 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Moderately well drained
Runoff class: Negligible
Capacity of the most limiting layer to transmit water (Ksat): High to very high (5.95 to 19.98 in/hr)
Depth to water table: About 24 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Low (about 4.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4s
Hydrologic Soil Group: A

Open All | Close All

-7)

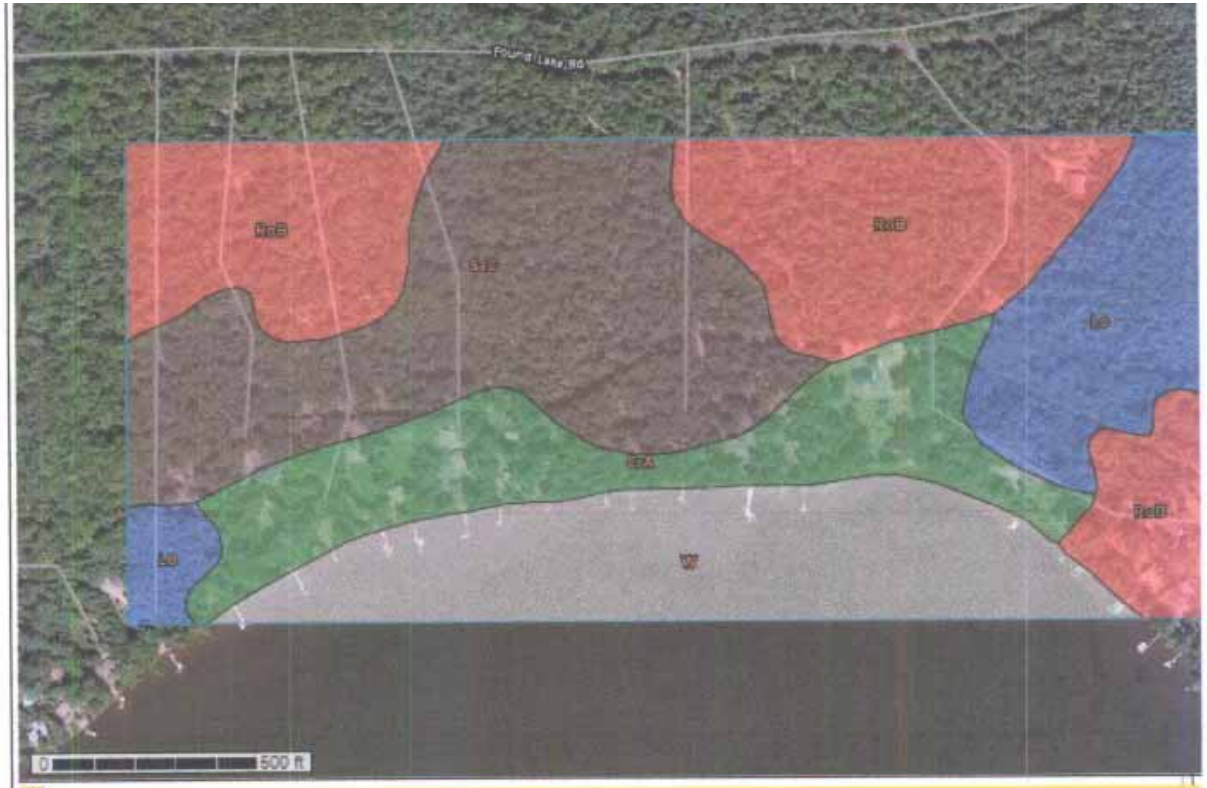
city (ECEC)

0 cm

0 cm

cm

cm



Warning: Soil Ratings Map may not be valid at this scale.

You have zoomed in beyond the scale at which the soil map for this area is intended to be used. Mapping d done at a particular scale. The soil surveys that comprise your AOI were mapped at 1:20,000. The design o units and the level of detail shown in the resulting soil map are dependent on that map scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping an accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have b shown at a more detailed scale.

Tables — Parent Material Name — Summary By Map Unit

Summary by Map Unit — Vilas County, Wisconsin (WI125)

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
CrA	Croswell sand, 0 to 3 percent slopes	sandy outwash	11.3	15.5%
Lo	Loxley and Dawson peats, 0 to 1 percent slopes	herbaceous organic material	8.7	11.9%
RoB	Rubicon sand, 0 to 6 percent slopes	sandy glaciofluvial deposits	20.5	28.1%
SaC	Sayner-Rubicon complex, 6 to 15 percent slopes	sandy and gravelly outwash	19.2	26.2%

Surface)

ctive Layer

ayer

Surface)

escription | View Rating

ailed Description

Condition

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Tables — Unified Soil Classification (Surface) — Summary By Map Unit

Summary by Map Unit — Vilas County, Wisconsin (WI125)

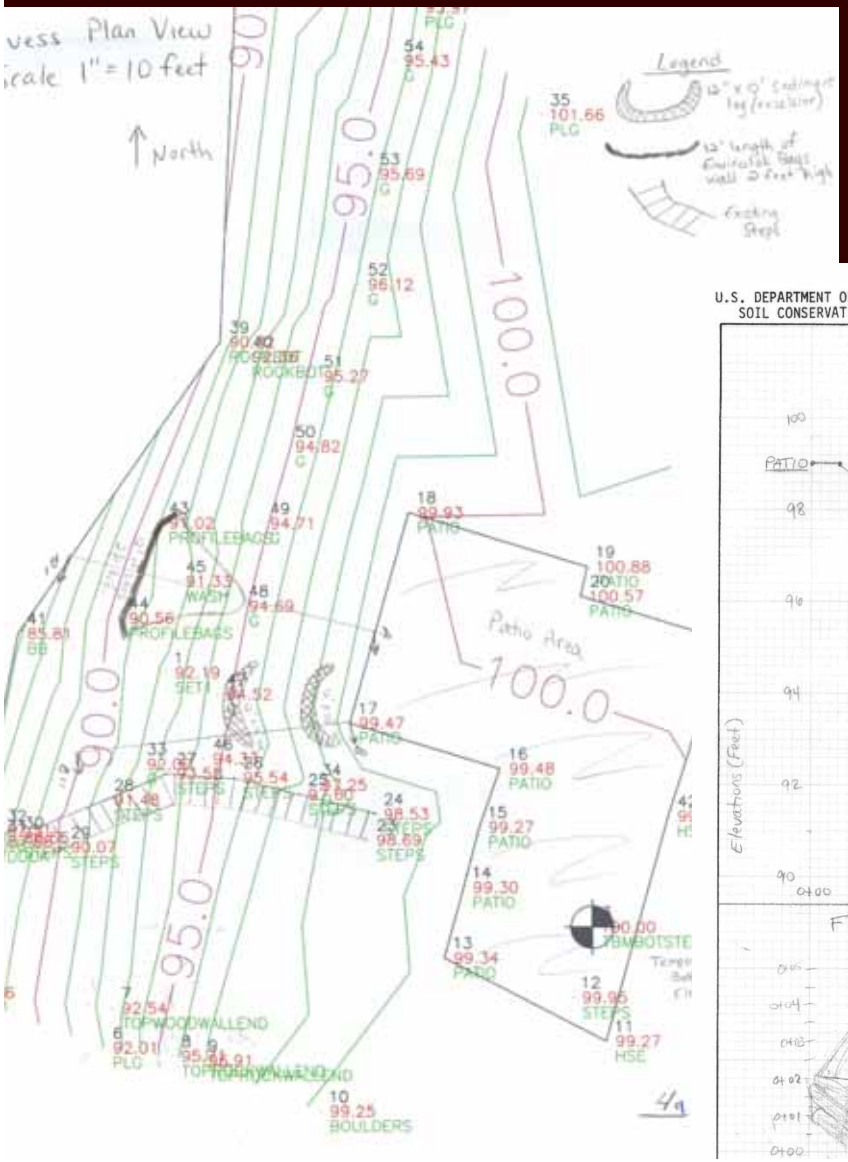
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
CrA	Croswell sand, 0 to 3 percent slopes	SP-SM	11.3	15.5%
Lo	Loxley and Dawson peats, 0 to 1 percent slopes	PT	8.7	11.9%
RoB	Rubicon sand, 0 to 6 percent slopes	SP-SM	20.5	28.1%
SaC	Sayner-Rubicon complex, 6 to 15 percent slopes	SM	19.2	26.2%
W	Water		13.4	18.4%
Totals for Area of Interest			**73.1**	**100.0%**

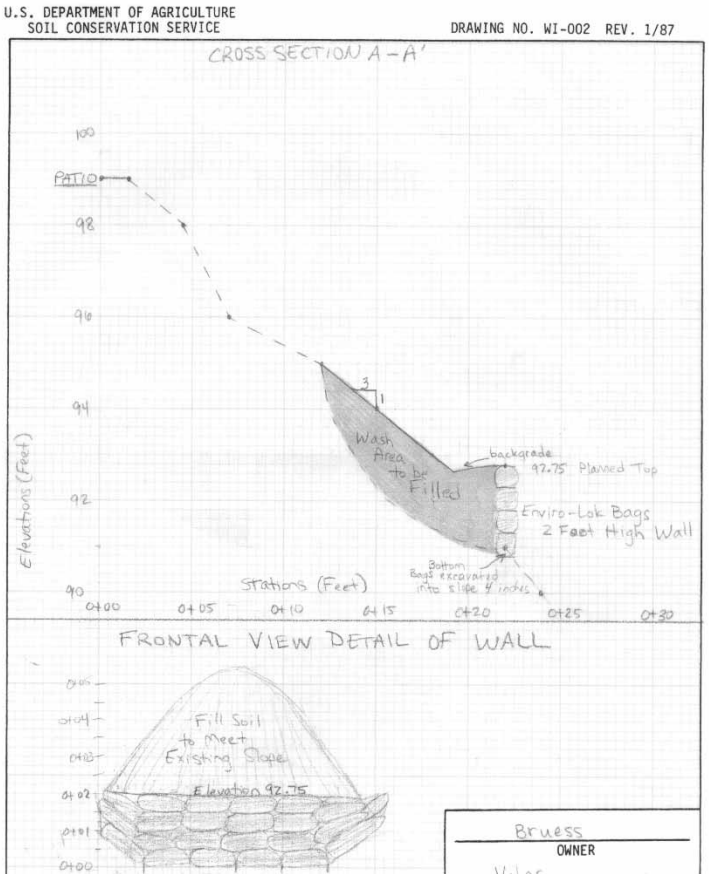
Description — Unified Soil Classification (Surface)

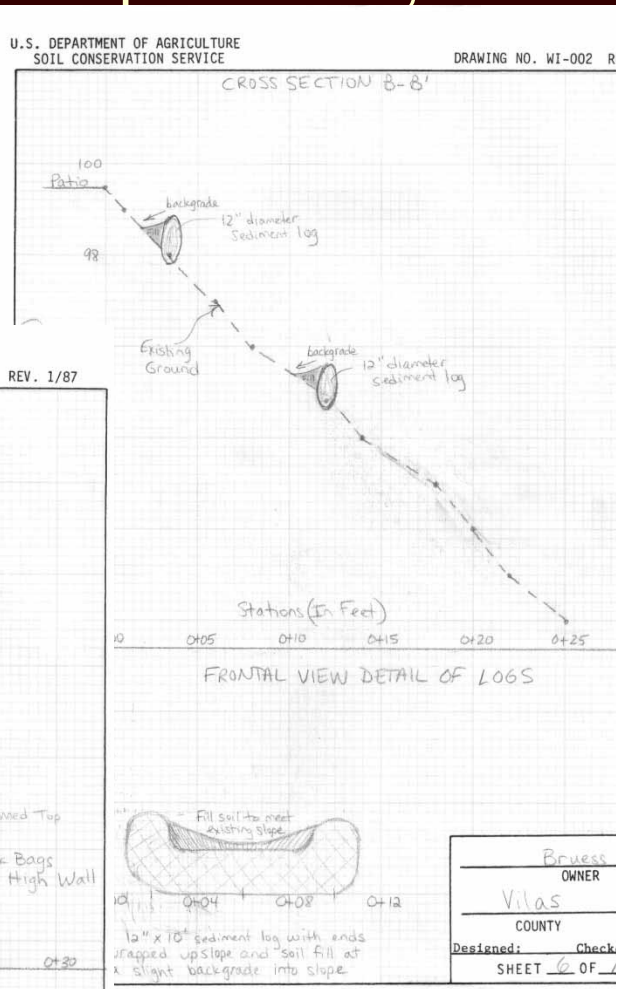
The Unified soil classification system classifies mineral and organic mineral soils for engineering purposes on the basis of particle-size characteristics, liquid limit, and plasticity index. It identifies three major soil divisions: (i) coarse-grained soils having less than 50 percent, by weight, particles smaller than 0.074 mm in diameter; (ii) fine-grained soils having 50 percent or more, by weight, particles smaller than 0.074 mm in diameter; and (iii) highly organic soils that demonstrate certain organic characteristics. These divisions are further subdivided into a total of 15 basic soil groups. The major soil divisions and basic soil groups are determined on the basis of estimated or measured values for grain-size distribution and Atterberg limits. ASTM D 2487 shows the criteria chart used for classifying soil in the Unified system and the 15 basic soil groups of the system and the plasticity chart for the Unified system.

The various groupings of this classification correlate in a general way with the engineering behavior of soils. This correlation provides a useful first step in any field or laboratory investigation for engineering purposes. It can serve to make some general interpretations relating to probable performance of the soil for engineering uses.

Case Studies (1) Problem ID & Techniques Used, cont







Case Studies (1) Design Standards & Lessons Learned

Case Studies (2)

Problem ID & Techniques Used

Case Studies (2) Design Standards & Lessons Learned

Case Studies (3)

Problem ID & Techniques Used

arned


Upland Runoff
Erosion Factor
10/6/00

Search

Map Unit Legend

Forest County, Wisconsin (WI041)

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Mn	Minocqua muck, 0 to 2 percent slopes	1.6	1.3%
PeC	Padus-Pence sandy loams, 6 to 15 percent slopes	1.9	1.6%
PeD	Padus-Pence sandy loams, 15 to 35 percent slopes	27.0	22.4%
StB	Stambaugh silt loam, 0 to 6 percent slopes	9.9	8.2%
StC	Stambaugh silt loam, 6 to 15 percent slopes	11.6	9.7%
StD	Stambaugh silt loam, 15 to 25 percent slopes	18.8	15.6%
VaB	Vanzile silt loam, 0 to 6 percent slopes	1.2	1.0%
W	Water	48.4	40.2%
Totals for Area of Interest		**120.3**	**100.0%**

Soil Map

Scale (not to scale)

Warning: Soil Map may not be valid at this scale.

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Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accura of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Report — Hazard of Erosion and Suitability for Roads on Forestland

Onsite investigation may be needed to validate the interpretations in this table and to confirm the identity of the soil on a given site. The numbers in the value columns range from 0.01 to 1.00. The larger the value, the greater the potential limitation. The table shows only the top five limitations for any given soil. The soil may have additional limitations.

Forest County, Wisconsin

Map symbol and soil name	Pct. of map unit	Hazard of off-road or off-trail erosion		Hazard of erosion on roads and trails		Suitability for roads (natural surface)	
		Rating class and limiting features	Value	Rating class and limiting features	Value	Rating class and limiting features	Value
Mn—Minocqua muck, 0 to 2 percent slopes							
Minocqua	100	Slight		Slight		Poorly suited	
						Wetness	1.00
						Low strength	0.50
						Ponding	0.50
						Dusty	0.01
PeC—Padus-Pence sandy loams, 6 to 15 percent slopes							
Padus	65	Slight		Severe		Moderately suited	
				Slope/erodibility	0.95	Slope	0.50
						Dusty	0.01
Pence, sandy substratum	35	Slight		Severe		Moderately suited	
				Slope/erodibility	0.95	Slope	0.50
PeD—Padus-Pence sandy loams, 15 to 35 percent slopes							

Padus	65	Moderate		Severe		Poorly suited	
		Slope/erodibility	0.50	Slope/erodibility	0.95	Slope	1.00
						Dusty	0.01
Pence, sandy substratum	35	Moderate		Severe		Poorly suited	
		Slope/erodibility	0.50	Slope/erodibility	0.95	Slope	1.00
StB—Stambaugh silt loam, 0 to 6 percent slopes							
Stambaugh	100	Slight		Moderate		Moderately suited	
				Slope/erodibility	0.50	Low strength	0.50
						Dusty	0.01
StC—Stambaugh silt loam, 6 to 15 percent slopes							
Stambaugh	100	Moderate		Severe		Moderately suited	
		Slope/erodibility	0.50	Slope/erodibility	0.95	Slope	0.50
						Low strength	0.50
						Dusty	0.01
StD—Stambaugh silt loam, 15 to 25 percent slopes							
Stambaugh	100	Moderate		Severe		Poorly suited	
		Slope/erodibility	0.50	Slope/erodibility	0.95	Slope	1.00
						Low strength	0.50
						Dusty	0.01
VaB—Vanzile silt loam, 0 to 6 percent slopes							
Vanzile	100	Slight		Moderate		Moderately suited	
				Slope/erodibility	0.50	Low strength	0.50
						Dusty	0.01
W—Water							
Water	100	Not rated		Not rated		Not rated	

Hazard of Erosion and Suitability for Roads on Forestland

This table can help forestland owners or managers plan the use of soils for wood crops. Interpretive ratings are given for the soils according to the limitations that affect various aspects of forestland management. The ratings are both verbal and numerical.

Numerical ratings in the table indicate the severity of individual limitations. The ratings are shown as decimal fractions ranging from 0.01 to 1.00. They indicate gradations between the point at which a soil feature has the greatest negative impact on the specified aspect of forestland management (1.00) and the point at which the soil feature is not a limitation (0.00).

The paragraphs that follow indicate the soil properties considered in rating the soils. More detailed information about the criteria used in the ratings is available in the **National Forestry Manual**, which is available in local offices of the Natural Resources Conservation Service or on the Internet.

Ratings in the column **hazard of off-road or off-trail erosion** are based on slope and on soil erosion factor K. The soil loss is caused by sheet or rill erosion in off-road or off-trail areas where 50 to 75 percent of the surface has been exposed by logging, grazing, mining, or other kinds of disturbance. The hazard is described as slight, moderate, severe, or very severe. A rating of *slight* indicates that erosion is unlikely under ordinary climatic conditions; *moderate* indicates that some erosion is likely and that erosion-control measures may be needed; *severe* indicates that erosion is very likely and that erosion-control measures, including revegetation of bare areas, are advised; and *very severe* indicates that significant erosion is expected, loss of soil productivity and off-site damage are likely, and erosion-control measures are costly and generally impractical.

Ratings in the column **hazard of erosion on roads and trails** are based on the soil erosion factor K, slope, and content of rock fragments. The ratings apply to unsurfaced roads and trails. The hazard is described as slight, moderate, or severe. A rating of *slight* indicates that little or no erosion is likely; *moderate* indicates that some erosion is likely, that the roads or trails may require occasional maintenance; and that simple erosion-control measures are needed; and *severe* indicates that significant erosion is expected, that the roads or trails require frequent maintenance, and that costly erosion-control measures are needed.

Ratings in the column **suitability for roads (natural surface)** are based on slope, rock fragments on the surface, plasticity index, content of sand, the Unified classification, depth to a water table, ponding, flooding, and the hazard of soil slippage. The ratings indicate the suitability for using the natural surface of the soil for roads. The soils are described as well suited, moderately suited, or poorly suited to this use. *Well suited* indicates that the soil has features that are favorable for the specified kind of roads and has no limitations. Good performance can be expected, and little or no maintenance is needed. *Moderately suited* indicates that the soil has features that are moderately favorable for the specified kind of roads. One or more soil properties are less than desirable, and fair performance can be expected. Some maintenance is needed. *Poorly suited* indicates that the soil has one or more properties that are unfavorable for the specified kind of roads. Overcoming the unfavorable properties requires special design, extra maintenance, and costly alteration.

Reference:
United States Department of Agriculture, Natural Resources Conservation Service, National forestry manual.

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Questions?