SLIP SLIDIN' AWAY: Soil Erosion

SUBJECTS: General Science, Earth Science, Physical Science, Ecology, Physics, Algebra

TIME: 2 class periods

MATERIALS:
Site information cards (one per team; included)

Overhead transparency or Powerpoint of USLE

Problem example (included)

Handouts of Figures and Tables (one per team or place a copy on a shared drive; included)

Calculators (one per team)

U.S. map with state boundaries (optional)

U.S. soil map (included)

OBJECTIVES

The students will do the following:

1. Predict the amount of erosion from hypothetical sites using the Universal Soil Loss Equation (USLE).
2. Determine the effect soil type, rainfall, and topography have on soil erosion.
3. Determine what measures need to be taken to prevent soil loss from hypothetical sites.

BACKGROUND INFORMATION

Erosion is the gradual weathering of the earth's surface. It is a natural process which results in soil being washed into water bodies. Human activities, however, can greatly increase the rate of erosion by removing vegetative cover and exposing bare soil to winds and rain. When this happens, heavy rains can wash a variety of suspended materials, including soil, into water bodies. This makes the water cloudy or turbid. Turbidity is a measure of the amount of suspended particles (cloudiness) in the water.

Sediment can interfere with aquatic life, commercial and recreational activities, hydroelectric power generation, and drinking water and wastewater treatment operations. Sediment can decrease light transmission through water, thus decreasing plant photosynthesis and reproduction. Also, sediment increases the amount of heat that can be absorbed and stored in water. A decrease in photosynthesis and an increase in water temperature usually results in a decrease in the dissolved oxygen (DO) content. Low DO can stress and kill aquatic organisms. Sediment can also interfere with feeding and reproductive patterns of aquatic life. When sediment settles, it can create a blanket which smothers aquatic habitat and disrupts the food chain. Sediment can gradually fill lakes and streams. This can reduce flood storage capacity, cause navigation problems, and interfere with generation of hydroelectric power. Many other pollutants such as bacteria, nutrients, and harmful chemicals can be transported into a water body attached to sediment.

What is an acceptable rate of erosion? Generally speaking, the rate of soil loss should not exceed the rate of soil formation. The accepted rate of soil formation on many agricultural soils is approximately 5 tons/acre-year (11.25 metric tons/hectare-year), and so this figure is often used as the target figure for average soil loss on those soils. Acceptable ranges vary depending upon land use and soil type.

The Universal Soil Loss Equation (USLE) has been one of the most powerful, widely used, and practical tools for (1) on-farm planning of soil conservation practices, (2) inventorying and assessing regional and national impacts of erosion, and (3) developing and implementing public policy related to soil conservation. The USLE was developed by the U.S. Department of Agriculture (USDA) Agricultural Research Service (ARS), Soil Conservation Service (SCS), and Purdue University in the late 1950s. The USLE is used to predict soil loss from a specific site. The USLE estimates the amount of soil that will erode from a site (in tons or metric tons/year) based on the topography, soil type, rainfall, and other factors of the area. The USLE also incorporates the effects of soil erosion control, ground cover, and management practices. The USLE for one acre (hectare) is E = R x K x LS x C x P, where E is the soil loss by water erosion in tons per acre (metric tons per hectare) per year; R is the rainfall factor; K is the soil erodibility factor; LS is the topographic factor; C is the management factor, and P is the erosion-control practice.

In 1993, a revised USLE (RUSLE) was released by the USDA Agricultural Research Service as an on-line program. The RUSLE uses the exact same equation as the USLE, but the data used for R, K, C, LS, and P values have been revised to incorporate new information derived from research, experience, and improved technology developed in the previous three decades. The RUSLE estimates are more site specific than USLE estimates and should provide a more accurate picture of both soil loss and the effects of soil conservation practices to reduce erosion.

This exercise uses the old USLE and only two soil types, mollisols and non-mollisols, to demonstrate how the equation works. For more updated information on RUSLE visit the USDA website found in the Resource section.

ADVANCED PREPARATION

A. Copy and cut apart the 16 information cards (included).

B. Copy the tables and figures included, each team will need a copy of each.

C. Make overheads (or powerpoint) of the figures, tables, and example problem (included).

PROCEDURE

I. Setting the Stage

A. Have the students define the term erosion.

B. List the land use activities that cause erosion and the negative consequences that result. Note: Is this covered in the Background section?

C. Explain that soil loss or erosion can be predicted using a Universal Soil Loss Equation (USLE). Explain that this equation has been revised and is now called RUSLE. Explain that USLE and RUSLE are the same equation, but RUSLE uses more up-to-date information for the variables. Explain that in this activity they will see how to use the formula as a tool for planning.

D. Introduce the USLE and go over the symbols with the students. The USLE for one acre (hectare) is:

$E = R \times K \times LS \times C \times P$

Where:

E is the soil loss by water erosion in tons/acre/year (metric tons/hectare/year)

R is the rainfall factor, which accounts for the erosive forces of rainfall and runoff in erosion index units/year

K is the soil erodibility factor of a particular soil in tons/acre/erosion index unit (metric tons/hectare/erosion index unit)

LS is the topographic factor

C is the cover and management factor reflecting the influence of vegetation and mulch

P is the erosion control practice factor which accounts for practices superimposed on the land surface such as contouring, sediment basins, terracing, etc.

Go over example problem (included).

E. Define the terms mollic and mollisol. Explain that there are hundreds of types of soil, but for the purpose of this activity, you will be comparing two general types: mollisols and non-mollisols.

1. Mollic soils or mollisols occur in regions with moderate rainfall and are perhaps the world's most productive soils or "prime farmland."
2. Mollisols are brownish soils with high organic matter and moderate clay content in the subsoil.

II. Activity

A. Assign teams, distribute materials, and review tasks.

1. Tell the students they will be playing the role of site assessment experts for the United States Soil Conservation Service or the Canadian equivalent.
2. The students will work in teams of two.
3. Each team will be in charge of assessing a hypothetical proposed construction site.

4. Each team will assess their site's susceptibility to erosion and recommend appropriate soil erosion control practices and management.

5. In addition to the general soil characteristics (such as silty and claylike), students will need to determine whether or not a soil is likely to be mollic. For the purposes of this activity, students will use a simplified map that shows where mollisols are located in the United States (included). If the location of their site lies within an area generally known as having mollisols, then their site's soil will be considered to be mollic. In the U.S., most of the large areas of mollisols are in the Great Plains. These areas support dense stands of grass which produce an abundance of organic matter. The decomposition of this organic matter, in the presence of calcium, leads to the formation of mollic soils.

6. Using the USLE, each team will calculate the predicted soil loss by water erosion for their site if the soil were bare and no erosion control methods were practiced.

7. Then they will determine and recommend the types and amount of cover, management, and erosion-control practices needed to reduce the amount of erosion to the recommended rate of five tons per acre (11.25 metric tons/hectare) annually. (NOTE: Five tons per acre (11.25 metric tons/hectare) is a recommended average loss per year for agricultural soils. Acceptable ranges vary depending upon land use and soil type.)

B. Calculate soil loss.

1. Distribute to each team site information cards and a copy of each table and figure. Have each team determine the rainfall factor (R) from Figure 1. You may need to explain how to read the contour lines used in Figure 1. (See explanation of contour lines, see Student Worksheet.) Also, from Figure 1, students should note if the soil is likely to be mollic (or mollisol) or not.

2. From the soil information on their cards and Table 1, the students can determine the soil erodibility factor (K) for their sites.

3. The topographic factor (LS) is determined using the slope length, percent slope, and Figure 2. To do this, locate the point at which the slope length (on the x-axis) intersects with the appropriate percent slope line within the graph. Use a straight edge to read the value of LS on the y axis.

4. The values for the cover and management factor (C) and the erosion-control practice factor (P) are given in Tables 2 and 3, respectively. Note that C and P both equal 1.0 for bare soil with no soil erosion control. Thus, to determine the amount of soil loss by water erosion for bare soil with no erosion-control

practices, simply multiply R, K, and LS together. Assume the site has bare soil and you need to recommend control practices.

5. Next, determine what soil erosion-control practice, ground cover, and management practices to recommend.

6. Determine the percent (y), in decimal form, by which the amount of soil erosion must be decreased for it to be less than or equal to five tons/acre-year (11.25 metric tons/hectare/year)

   y = five tons/acre-year (11.25 metric tons/hectare-year) / E (bare without controls)

7. Now, from Tables 2 and 3, determine which values for C and P will, when multiplied together, be less than or equal to y.

   a. If a value less than or equal to y is unattainable, what is the lowest attainable value?

   b. What are the practices represented by C and P?

C. Discuss the results.

1. Have the students summarize and report their recommendations for their sites. Do any groups recommend not disturbing the site? How do topography, location, and soil type affect the rate of erosion, and hence, water quality?

2. Have each group present their findings to the class.

III. Follow-up

A. Have students research the types of soil erosion-control practices used in construction and have student teams design a hypothetical construction site. NOTE: Should we add a resource for this?

1. They should describe the characteristics of their site, such as location, soil type, acreage, slope length, percent slope, rainfall factor, distance from stream, and other information regarding the nature of the watershed and water body.

2. Have them predict the total amount of soil loss by water erosion or bare soil without erosion control and the likely affects on the water body. You may want to select sites on actual topographic maps proposed for local development and have students determine the percent slope themselves.

3. Have them determine the types and amount of erosion-control practices needed.

4. Have them draw a diagram depicting the construction site, distance from a stream, and use of erosion-control practices. In addition to the erosion-control

practices included in Tables 2 and 3, the students can also use sediment basins, silt screens, straw bale diversions, diversion ditches, clover, or other alternative ground covers. (See Figure 3 as a sample plan.)

B. Have students obtain permission to visit a construction site and interview the owner/site manager. What evidence of erosion is present? What is being done to reduce erosion? How long will the operation take? How far is the site from a water body? What other types of pollutants could enter the water body from the site? Sketch the site and note problem areas and corrective practices. Have students share their findings with the class.

IV. Extension

A. Have the students write letters to local developers, contractors, local or state departments of transportation, or others involved in some form of land disturbance which causes erosion and encourage them to use best management practices (BMPs) to prevent erosion.

B. Invite a guest speaker to talk about erosion-control practices.

RESOURCES

Foth, H.D., and L.M. Turk, Fundamentals of Soil Science, John Wiley and Sons, Inc., New York, New York, 1981, Figures 10-19.

USDA, About the Universal Soil Loss Equation, www.ars.usda.gov/Research/docs.htm?docid=10626

USDA Revised Universal Soil Loss Equation www.ars.usda.gov/southeast-area/oxford-ms/national-sedimentation-laboratory/watershed-physical-processes-research/docs/revised-universal-soil-loss-equation-rusle-welcome-to-rusle-1-and-rusle-2/

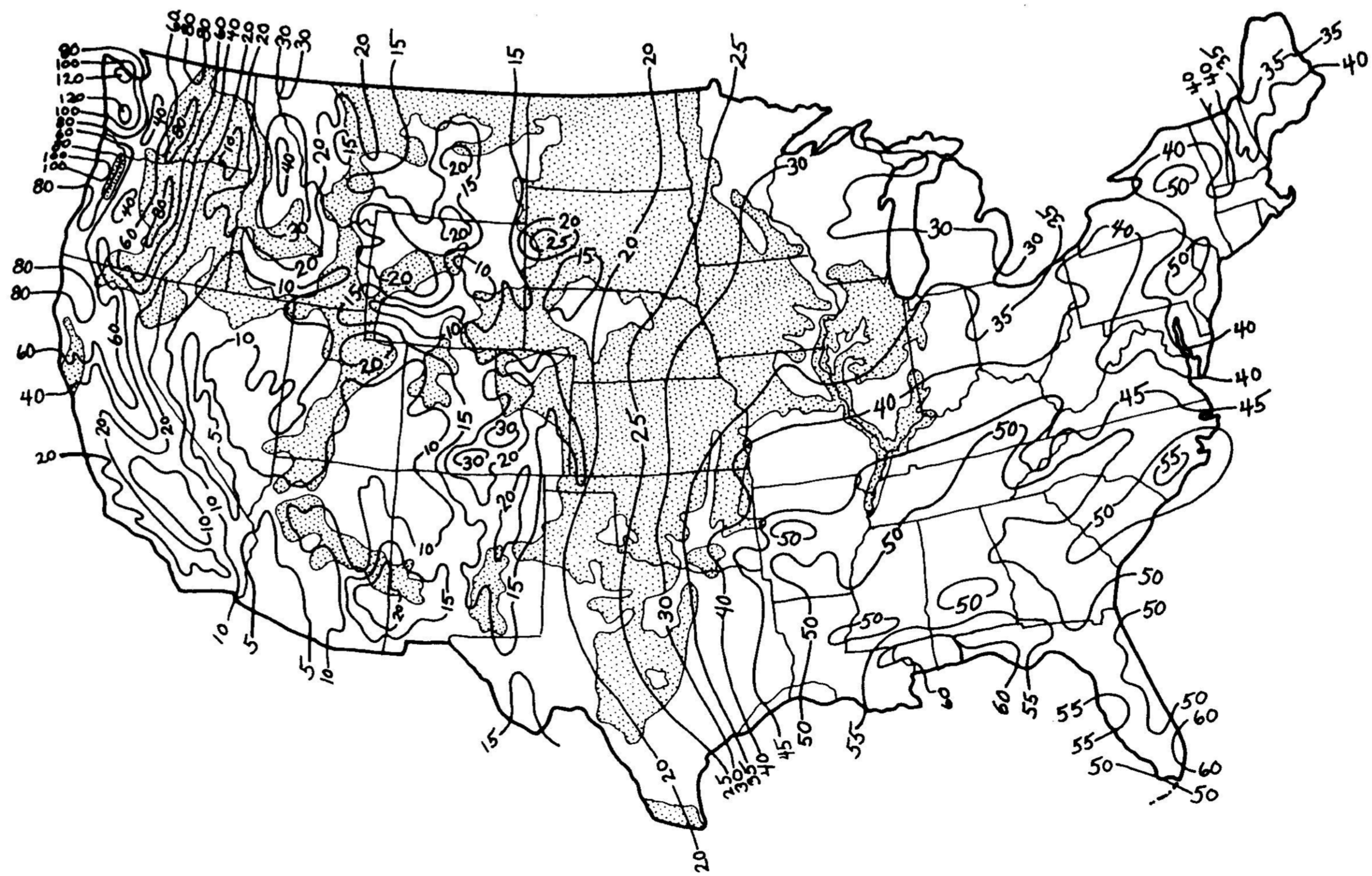
USDA Natural Resources Conservation Services Mollisols Map: www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/maps/?cid=nrcs142p2_053604

Walesh, S. G., Urban Surface Water Management, Chapter 7, "Nonpoint Source Pollution Load Techniques," John Wiley and Sons, Inc., New York, New York, 1989.

Wischmeier, Walter H., and Dwight D. Smith, Predicting Rainfall Erosion Losses: A Guide To Conservation Planning, U.S. Department of Agriculture, Washington, DC, 1978. A pdf version of this document is available at: www.ars.usda.gov/SP2UserFiles/ad_hoc/36021500USLEDatabase/AH_537.pdf

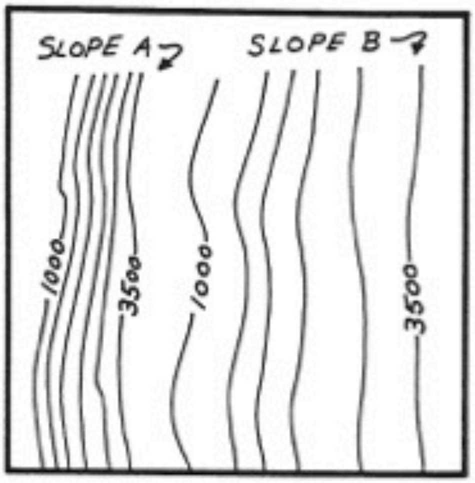
FIGURE 1

Rainfall factors (in inches) for use with the Universal Soil Loss Equation (USLE). (Adapted from Wischmeier and Smith, 1978 map. Locations of mollic soils in the U.S. adapted from Foth and Turk, 1981. NOTE: To convert to centimeters, multiply inches by 2.5.)

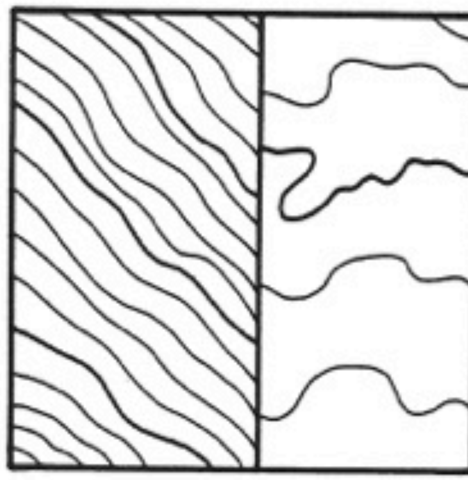


PROPERTIES OF CONTOURS

1. Contours are perpendicular to the direction of maximum slope.



2. The distance between contours indicates the steepness of a slope; close spacing denotes steep slopes; wide spacing denotes gentle slope.

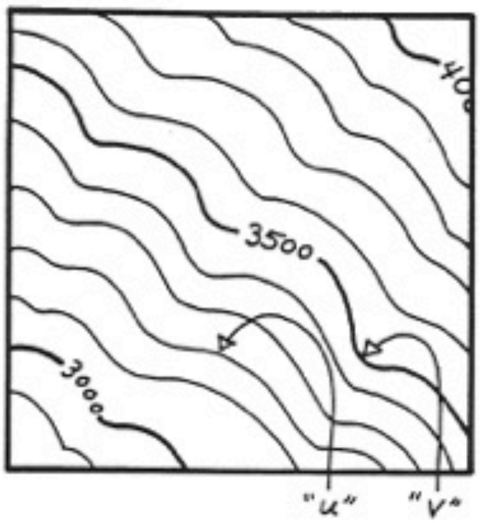


3. Concentric closed contours which increase in elevation represent hills.

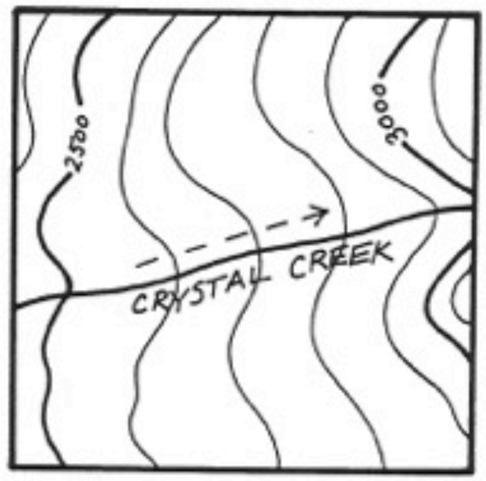
4. Irregular contours signify rough, rugged country. Smooth lines designate gradual slopes and changes.

PROPERTIES OF CONTOURS
(continued)

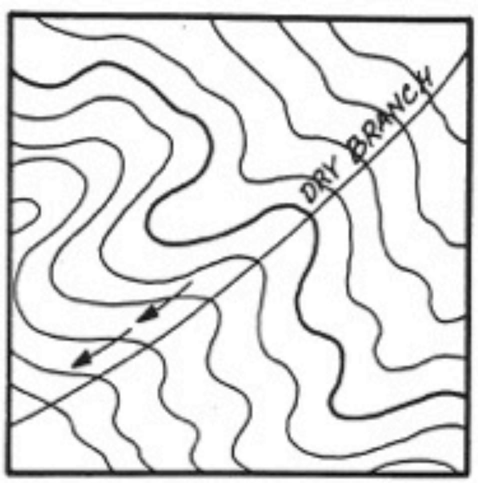
5. Valleys are usually characterized by V-shaped contours, and ridges by U-shaped contours.



6. The V's formed by contours crossing a stream point upstream.



7. The U's made by contours crossing ridge lines point down the stream.



8. Contours tend to parallel streams and have an M-shape just above stream junctions.

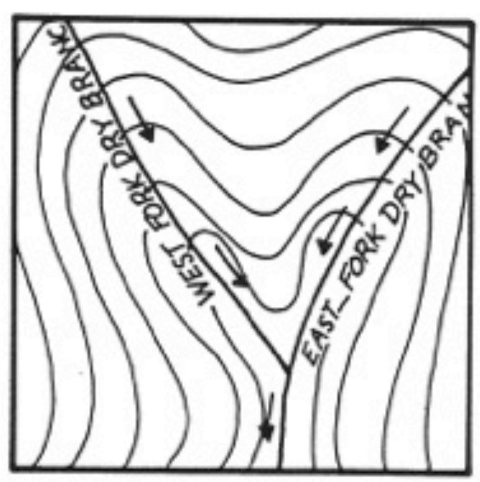


FIGURE 2

Topographic factor as a function of slope and slope length for use with the Universal Soil Loss Equation (USLE). (Adapted from Wischmeier and Smith, 1978, and Foth and Turk, 1981).

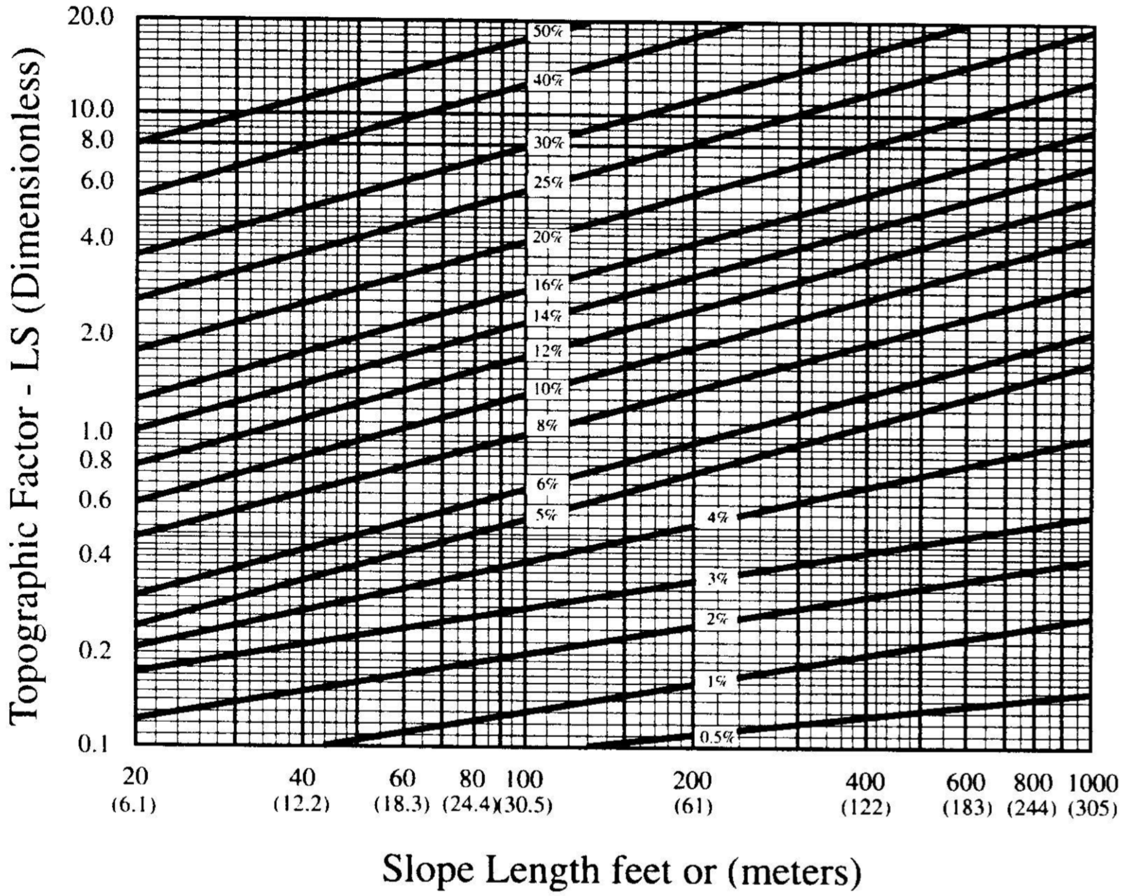


TABLE 1

Typical soil erodibility factors for use with the Universal Soil Loss Equation (USLE).

Soil	Soil Erodibility Factor (K) tons/acre or metric tons/hectare-erosion index unit
sands & gravels	0.10
loamy coarse sands, sand & fine sand	0.15
loamy fine sand & loamy sand	0.17
fine sandy loam & sandy loam, mollic	0.20
fine sandy loam & sandy loam, nonmollic	0.24
loam, clay loam & sandy clay loam, mollic	0.28
loam, clay loam & sandy clay loam, nonmollic	0.32
silt loam & silty clay loam, mollic	0.32
silt loam & silty clay loam, nonmollic	0.37
silt loam & silty clay loam, subsoil	0.43
clay & silty clay, less than 50% clay	0.32
clay & silty clay, over 50% clay	0.28

Source: Walesh, 1989.

TABLE 2

Cover and management factors for use with the Universal Soil Loss Equation (USLE).

Cover or Management Measure	Cover & Management Factor C (dimensionless)
Bare soil	1.0
Straw mulch*	
0.5 tons per acre (1.13 metric tons per hectare)	0.35
1.0 tons per acre (2.25 metric tons per hectare)	0.18
1.5 tons per acre (3.38 metric tons per hectare)	0.06
3.0 tons per acre (6.75 metric tons per hectare)	0.03
4.0 tons per acre (9.0 metric tons per hectare)	0.02
Grass	0.011

Source: Adapted Walesh, 1989.

*Mulch assumed to be anchored by means such as punching into soil with a disk or using mulch net.

TABLE 3

Erosion-control practice factor for use with the Universal Soil Loss Equation (USLE).

Erosion-Control Practice And Resulting Factor P (dimensionless)			
Land slope (percent)	No Erosion-Control Practice	Contouring	Terracing
1-2	1.0	0.6	0.12
3-8	1.0	0.5	0.10
9-12	1.0	0.6	0.12
13-16	1.0	0.7	0.14
17-20	1.0	0.8	0.16
21-25	1.0	0.9	0.18

Sources: Adapted from Foth and Turk, 1981, and Walesh, 1989.

SITE INFORMATION CARDS

Location: southeastern Colorado Percent Slope: 30 Slope Length: 50 ft (15.2 m) Soil: loam, clay loam, and sandy clay loam	Location: northern Texas Panhandle Percent Slope: 30 Slope Length: 100 ft (30.5 m) Soil: silt loam and silty clay loam
Location: central Michigan Percent Slope: 30 Slope Length: 200 ft (61 m) Soil: loam, clay loam, and sandy clay loam	Location: central Missouri Percent Slope: 30 Slope Length: 400 ft (122 m) Soil: silt loam, silty clay loam
Location: central Florida Percent Slope: 20 Slope Length: 50 ft (15.2 m) Soil: silt loam and silty clay loam	Location: northern Illinois Percent Slope: 20 Slope Length: 100 ft (30.5 m) Soil: fine sandy loam and sandy loam
Location: upstate Vermont Percent Slope: 20 Slope Length: 200 ft (61 m) Soil: silt loam and silty clay loam	Location: western Pennsylvania Percent Slope: 20 Slope Length: 400 ft (122 m) Soil: fine sandy loam and sandy loam
Location: northern Maine Percent Slope: 10 Slope Length: 50 ft (15.2 m) Soil: loam, clay loam, and sandy clay loam	Location: central Tennessee Percent Slope: 10 Slope Length: 100 ft (30.5 m) Soil: silt loam and silty clay loam
Location: north-central Oregon Percent Slope: 10 Slope Length: 200 ft (61 m) Soil: loam, clay loam and sandy clay loam	Location: northeastern North Carolina Percent Slope: 10 Slope Length: 400 ft (122 m) Soil: silt loam, silty clay loam
Location: central North Dakota Percent Slope: 5 Slope Length: 50 ft (15.2 m) Soil: silt loam and silty clay loam	Location: southeastern Arizona Percent Slope: 5 Slope Length: 100 ft (30.5 m) Soil: fine sandy loam and sandy loam
Location: north-central Nebraska Percent Slope: 5 Slope Length: 200 ft (61 m) Soil: silt loam and silty clay loam	Location: central Massachusetts Percent Slope: 5 Slope Length: 400 ft (122 m) Soil: fine sandy loam and sandy loam

UNIVERSAL SOIL LOSS EQUATION (USLE)

EXAMPLE PROBLEM: Calculate the Soil Loss

Example Card:

Location: Central, TN

Percent Slope: 30

Slope Length: 300 ft (91.5 m)

Soil: Silt loam and silty clay loam, subsoil

USLE:
E = R x K x LS x C x P

R (Rainfall Factor) from Figure 1
Central Tennessee has a 50 inch Isopleth running through it
R = 50 inches

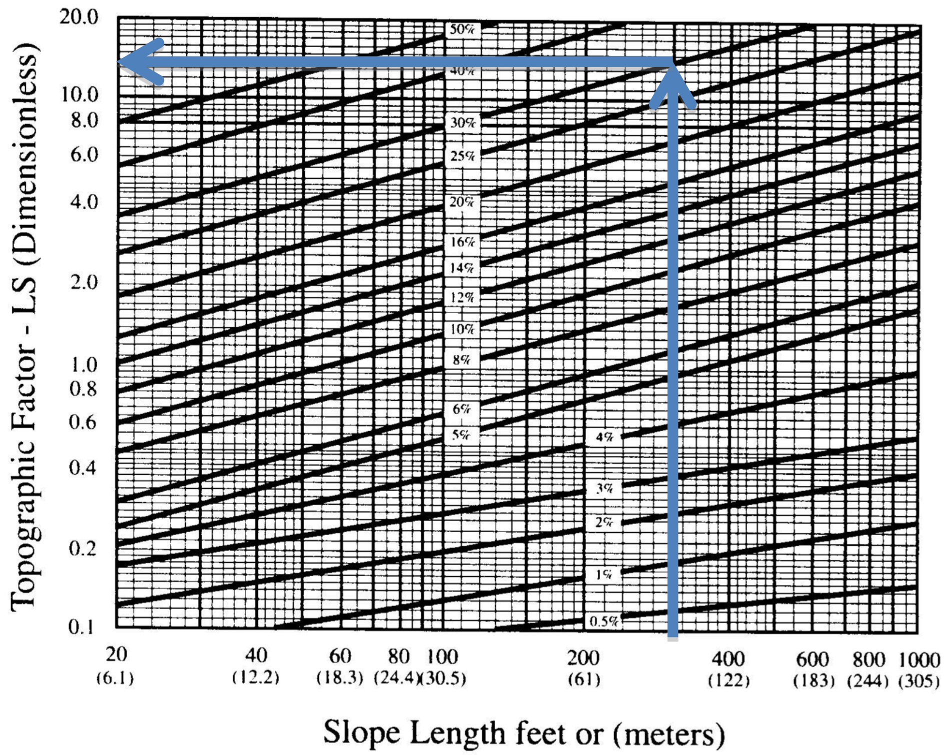
K (Soil Erodibility Factor) from Table 1
Based on soil type: silt loam & silty clay loam, subsoil
Note that whether soil is mollic or non-mollic is not relevant in this case
K = 0.43 tons/acre

LS (Topographic Factor) from Figure 2
Slope length in this example is 300 feet and Slope is 30%
Read Figure 2 as shown in the diagram below.
LS = 14

C (Cover & Management Factor) from Table 2
For the first part of this exercise assume the baseline, which is "Bare Soil"
C = 1

P (Erosion Control Practice) from Table 3
For the first part of this exercise assume the baseline, which is "No Erosion Control Practice"
P = 1

To Find LS:



CALCULATIONS:

Baseline Case:
E = 50 x 0.43 x 14 x 1 x 1 = 301.00 tons/acre-year

If the site were covered with 3.0 tons per acre of straw mulch, the soil loss would be:
E = 50 x 0.43 x 14 x 0.03 x 1 = 9.03 tons/acre-year

If the site were contoured, extrapolating the values for 25 percent land slope, the soil loss would be:
E = 50 x 0.43 x 14 x 1 x 0.9 = 270.90 tons/acre-year

FIGURE 3

Example of a sediment- and erosion-control plan for a commercial development. (Adapted from Braxton Williams, Soil Conservation Service)