CHAPTER SEVEN

Applications of RUSLE

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Benefits of Using RUSLE

What can RUSLE do for you? Numerous erosion-control and reclamation activities are integral parts of a thoroughly planned design that collectively contribute to the reduction of soil loss, but are not accounted for in the original Universal Soil Loss Equation (USLE). For years, permit applicants and erosion-control and reclamation specialists have encouraged concurrent reclamation, leaving the soil/spoil surface in a roughened state, using mulch or a temporary cover crop, contouring, and terracing, and establishing sustainable vegetation. These erosion-control measures have become standard operating procedures on many mined lands and construction sites resulting in long-term stabilized areas, reduced sediment basin clean-out costs, and reduced potential off-site impacts. With RUSLE the benefits of these and other erosion-control measures can be estimated and alternative reclamation plans can be readily compared. Other advantages of using RUSLE include: (1) assessment of alternative hillslope configurations (convex, uniform, concave, and complex), (2) obtaining erosion-control or erosion-reduction credit for the surface rock fragment covers that exists on many mine sites, and (3) analyses of the effects of straw mulch, random roughness, soil consolidation, sediment deposition, and changes through time due to mulch decomposition and deterioration of surface roughness due to rainfall.

The RUSLE program facilitates analyses associated with permitting and bond release through comparison of pre- and post-mining scenarios. Soil loss can be estimated with respect to the influence of plant growth, canopy development, residue cover, and below-ground root development as a function of time and geographical region. Decreases in random roughness through time, which decrease the resistance of disturbed soils to erosion, and increases in soil consolidation through time, which increase the resistance of disturbed soils to erosion, can be estimated using the RUSLE program.

RUSLE is a powerful program that is capable of predicting soil loss from fields or hillslopes that have been subjected to a full spectrum of land manipulation and reclamation activities. RUSLE can accommodate undisturbed soil, spoil, and soil-substitute (growth medium) material, percent rock cover, random surface roughness, mulches, vegetation types, and mechanical equipment effects on soil roughness, hillslope shape, and surface manipulation including contour furrows, terraces, and strips of close-growing vegetation and buffers.

Application Overview

The purpose of this chapter is to demonstrate how to use RUSLE. Several scenarios, including mining and construction cases, are provided as examples using RUSLE to account for the effectiveness of specific erosion-control measures. Alternative design scenarios illustrate: (1) embankment stabilization during highway construction, (2) hillslope reconstruction during back-filling and grading of reclaimed outslopes, highwalls, and ramps, (3) deposition on multi-segmented concave hillslopes, (4) establishment of terraces and contour furrows in conjunction with mechanical surface manipulation including deep ripping and disking during minesoil reconstruction, and (5) comparison of pre- and post-mining soil loss with emphasis on the effects of vegetation and soil consolidation. Scenarios were selected for various geographical areas including the southeastern U.S. for highway construction; the Appalachian coal region for outslope reconstruction; Lexington, KY for deposition and sediment-delivery estimations; the semi-arid U.S. for terracing, contour furrows, and mechanical surface manipulation; and the Mountain States for pre- and post-mining comparisons focusing on vegetation assessment. It should be noted that these examples do not provide a comprehensive assessment of an entire erosion-control or reclamation plan, but are intended to provide the user with an understanding of the capabilities of the RUSLE program and how to utilize it in specific situations.

RUSLE fundamentally is a DOS program. Users running the program as a DOS program, or as a DOS program within Windows 3.1 or Windows 95, should experience no difficulties. Users running RUSLE within Windows NT environment have experienced problems. The easiest solution to these problems is to use RUSLE on a computer with Windows 3.1 or Windows 95. Users attempting to run RUSLE on a computer with Windows NT may require expert assistance.

The five examples, with alternative design scenarios, provide the user of these Guidelines with step-by-step inputs and procedures. The examples constitute a sequence of lessons. The first example enables the user to learn the basic functions of RUSLE version 1.06. All inputs, and even key strokes, are given in a detailed format. The remaining four examples provide the user with additional and advanced capabilities. In subsequent examples, it is assumed that the user has acquired the skills explained in previous examples; therefore, only new concepts are introduced in the detailed step-by-step manner. The series of examples were developed to enable the user to gain knowledge comfortably about the extensive capabilities of the RUSLE program. Also, explanation and evaluation of outputs, given in each example, should provide the user with insights to the effectiveness of alternative design options. Finally the section entitled 'What the User Will Learn' helps the user rapidly find the section that gives detailed information on a specific topic.

Using RUSLE Software

Make a directory for RUSLE 1.06. Copy all files from the disk to the hard drive. Commands or input values to be entered are shown in brackets, [ ]. Also note that comprehensive HELP tables and information are always available by selecting the context-sensitive help key [F1].

Change the Directory to RUSLE 1.06, i.e. [CD\RUSLE 1.06].

Type [RUSLE] and then press [Enter] to execute the program.

The main program screen, as shown in **Figure 7-1**, appears.

```
             File        Exit        Help        Screen
+-------------------------------< RUSLE 1.06 >---------------------------------- +


             +---------------------------------------------+
                   program choice:  1
              ---------------------------------------------
               -->   1. RUSLE Soil Loss Prediction Table
                     2. R Factor
                     3. K Factor
                     4. LS Factor
                     5. C Factor
                     6. P Factor
                     7. Database Utilities (City, Veg., Op)
                     8. RUSLE Information and Maintenance
             +---------------------------------------------+


+---------------------------------< Esc exits >-------------------------------- +
Tab  Esc F1   F3   F9   End
FUNC esc help cont info last
```

Figure 7-1. Primary Program Option Screen

Select [1] RUSLE Soil Loss Prediction Table by pressing the [Enter] key.

Example 1: Fill Embankment Stabilization During Highway Construction

Problem Statement: An interstate highway is to be constructed near Charleston, South Carolina. An assessment of alternative fill-slope embankment stabilization scenarios is conducted using RUSLE.

Scenario 1 - no erosion control
Scenario 2 - two tons per acre straw mulch
Scenario 3 - broadcast seeding with tall fescue grass
Scenario 4 - rock mulch

What Will the User Learn?

This is an introductory problem that will first teach the RUSLE user how to install version 1.06. RUSLE version 1.06 has been developed to incorporate various mining- and construction-design options.

In Scenario 1 the user will learn how to create an input file, select a CITY code, enter inputs, progress through input screens, run the program, and save a file.

Scenario 2 shows the user how to recall a previously saved file and modify the file. The user is introduced to the time-varying option, long-term random roughness, number of years needed for soil consolidation, the field operations display, entering a basic sequence of field operations, (i.e. site disturbance and addition of crop residue), and ending a sequence of operations. Understanding the output is emphasized through display and discussion of half-month sub-factors. The user will gain insight into temporal residue decay, changes in previous land-use, and seasonal EI (R-factor) distributions.

Scenario 3 expands the user's knowledge of the vegetation display and provides additional field-operation capabilities. Result interpretation, illustrated by the half-month sub-factors values, is expanded to encompass canopy sub-factor changes due to establishment and growth of a grass cover. The interplay between mulch decomposition and grass growth is evident to the user from the half-month display. The relationships among mulch, grass growth, and temporal erosion potential is discussed.

The substitution of a rock cover, to stabilize a fill outslope, is illustrated in Scenario 4. The user's knowledge of the field-operations data base is enhanced through this scenario. Again, complete rock cover precludes post-reclamation land uses.

Design information:

Location - near Charleston, SC.

Soil - topsoil, sandy loam, K = 0.24 (from soil survey report).

Refer to county soil series publications obtained from the Natural Resources Conservation Service, NRCS (formerly Soil Conservation Service).

Grass - tall fescue.

Planting method - broadcast seeding.

Mulch - straw applied at 2 tons per acre. Held in place by netting.

Gradient - 4:1 (Horizontal : Vertical).

Vertical height of fill-slope is 28 ft.

A road berm is located above the fill -slope to direct road runoff to a protected downdrain.

Duration of assessment - 1 year.

Scenario 1 - Fill embankment stabilization during highway construction, no erosion control**.** Now we can begin to create a file for the first scenario.

The R factor is discussed in Chapter 2.

As displayed near the bottom of the screen, the function key F4 is used to call a factor.

[F4] to obtain a listing of the CITY codes.

Page down until the SC listings are displayed and then arrow down until Charleston, SC is highlighted. It is shown as CITY code 40001.

[Enter] to select the highlighted city.

The next screen shows an Average Annual R of 400. This is the R value for Charleston, SC. The relatively high value is due to the number and severity of storms that occur, on the average, in Charleston.

The LS factor is discussed in Chapter 4.

The embankment gradient is 25 % for the 4:1 fill-slope.

To enter this value, first go to the LS-factor routine [F4]. The LS-factor routine is now displayed.

Because this is a single uniform hillslope simply [Enter] [2] indicating that segment lengths are measured horizontally.

The program shows a soil texture of silt loam, which is the default. The actual soil texture is sandy loam for this example, which only can be entered on the K-factor screen. To select soil texture, move to the K-factor screen by pressing [F4].

The soil texture options are listed. Chose [3] to select sandy loam, the texture for the soil in this example. Additional entries are needed on the K-factor screen. We will make those entries later. Press [F3] to accept the sandy loam selection, and then [Esc] to return to the LS-factor screen.

Use the down arrow or [Enter] to move the cursor to the next entry for general land use. [8] [Enter] chooses "disturbed fill, topsoil, no rock cover," appropriate for this example.

Rock cover is a factor in determining general land use. A hillslope is assumed to have rock cover when the rock cover is greater than 35 percent for the purpose of choosing the land use.

The gradient % is [25]. [Enter].

The horizontal projection of hillslope length is [112] ft, (28 x 4).

[F3]. The calculated LS value is 4.74.

[Esc] [Esc] returns to the R-factor screen. The hillslope gradient has now been entered in the R-factor screen. [Enter].

The adjustment for ponding is only used where the soil is very rough or in ridges so that soil projects above the waterline during an intense storm. The adjustment for ponding is a function of hillslope gradient and the 10-year storm EI, which is contained in the CITY file for each location. For flat hillslopes, high-intensity rainfall events create ponded conditions. The ponded water dissipates the energy of the raindrop impact. For this situation, the R value over-predicts soil loss. An adjustment corrects the R-factor for these conditions. The flatter the hillslope and the higher the 10-year storm EI, the greater the R value correction.

Because the soil surface for this fill embankment is smooth, adjustment for pondage should be entered, [2], [Enter]. As the results show, the adjustment for pondage has no effect on this steep hillslope.

R-factor information has now been completed. [F3]. [Esc]. [Esc]. [Enter] or [right arrow] to proceed to the K factor.

The K factor is discussed in Chapter 3.

Even though the K value is known for this example, (i.e. 0.24), the K screen must be executed. [F4]. [Enter] to select Option 1 and [Enter] to move to the estimated K section of the seasonally variable K-factor screen.

Execution of the K screen is necessary to compute the time-variable K and to activate key variables such as hydrologic soil group that will be needed in the P-factor computations. [0.24] [Enter].

The percent rock cover is "0" so accept the default value of zero, [Enter].

The default value of 7 years to consolidation is also accepted, [Enter].

The hydrologic soil group for a sandy loam, on a fill-slope constructed by a dozer, should be relatively compacted such that infiltration is reduced. Thus, either a 3 or 4 would be applicable.

Select [3]. [Enter].

The value selected for permeability is chosen to reflect the soil condition that would exist if the soil was maintained in continuous tillage for growing a crop like corn. The reason for this consideration is that K is defined for soil loss measured from the unit-plot condition, which is a continuous, clean-tilled fallow condition.

Soil series information is used primarily for review purposes because a great deal of information can be readily obtained from the National Resources Conservation Service (NRCS) based simply on the soil series. Such information includes soil texture, K values for undisturbed various soil horizons, permeability class, soil classification under USDA and NRCS methods, etc.

Because the soil series name is unknown for this example, [Enter].

As given in the problem statement the surface texture is a sandy loam, [3]. [Enter]. [F3]. The bi-monthly %EI and K values are now displayed. The K values are constant for the entire year because of climatic conditions at this location, which experiences a long freeze-free period. [Esc]. [Esc]. [Enter]. [Enter].

C and P factors are discussed in Chapters 5 and 6, respectively.

Because this is a smoothly-graded hillslope that was back-bladed by a dozer, and Charleston receives high intensity rainfall events, no credit can be taken for contour ridges left by a dozer tracking up and down the hillslope. Back-blading removed these small ridges.

Thus the C value and P value are entered as [1], [Enter], [1], [Enter].

The estimated average annual soil loss for Scenario 1 - no erosion control is 450 tons per ac/year. To put this in perspective 450 tons/ac/year is equivalent to approxi-mately a 2.5 inch loss of soil over the entire hillslope length.

Saving the created file:
[tab].
[arrow down to 2]. [Enter].
Type filename. [EX1SCNO1]. [Enter].
Type in a description of the scenario.
[6/10/97

Charleston, SC
Fill embankment stabilization during highway construction
Ex. 1, Scenario 1-no controls]
[F3].

Scenario 2 - Fill-embankment stabilization during highway construction, two tons per acre straw mulch.

The only difference between Scenarios 1 and 2 is the application of 2 tons per acre of straw mulch. Initial grading is assumed to be conducted March 1 and straw mulch with netting is placed that afternoon, with the mulch anchored to the soil surface.

The previous file can be reused so that data needed for the R , K, and LS factors do not have to be reentered. To accomplish this:

[arrow down to the next line] on the Soil Loss and Sediment Yield Computation Worksheet.
[tab].
Select loadfile [Enter].
[Arrow down] to highlight "EX1SCNO1". [Enter].
The factor values from the first scenario are now listed on the second line.
[Arrow] to the C factor. [F4].
The time-varying option will be illustrated.
[Highlight it] and [Enter].
The Charleston CITY code is displayed. [Enter].
The default for adjusting soil moisture is highlighted and a dialog box appears.
[Enter].

Use the default of zero because no rock fragments are present on the soil surface. The effect of rock fragments will be illustrated later in Example 4. [Enter].

The land use has already been specified on the LS-factor screen as being disturbed land with fill topsoil, with no rock cover. This information can be used by RUSLE to automatically select a b value.

To select this option, which is the preferred option, [1], [Enter].

As an alternative, a b value can be selected based on the information in the RUSLE help screens or from information in Chapter 5. The RUSLE help screen can be reached by pressing the F1 key with the cursor at the point where the b value is entered.

Because this is a single disturbance [0] and not a crop rotation, [Enter].

The final long-term roughness defaults to 0.24 inches, but will be changed to 0.15 inches because that is the roughness left by the blade fill material operation, which is smoother than the default.

If the initial roughness left by an operation is greater than 0.24 inches, a final roughness is chosen that represents the long-term roughness of the surface after the surface has been smoothed by rainfall assuming the surface is not disturbed again. [0.15] [Enter].

The number of years to consolidation is used to reduce the erosion potential of the site as soil aggregates develop. Research has shown that soil that has been disturbed and then is left undisturbed becomes less erodible through time. The consolidation effect ranges from 4 to 20 years and averages 7 years for the Eastern U.S. but may be considerably longer in the Western U.S.

Accept the default value of [7] because the site is located in the Eastern U.S. [Enter].

A dialog box listing grasses, crops, etc. now appears. [Arrow down] to "no vegetation" and highlight it. [Enter]. [F3]. [F3]. Refer to **Figure 7-2**.

```
              File        Exit        Help        Screen
+  ------------------< Time-varying C: general inputs 1.06 >---------------------+
                            city code: 40001  CHARLESTON            SC
   adjust for soil moistured depletion: 1
    % surface covered by rock fagments: 0
  surface cover function; B  value code: 1     landuse shown in LS:   8
            number of years in rotation: 0
           long term rand +---------------------------+      #   Veg.
                  # years |     alfalfa, spring seed  |   +--------------------+
                          |     bermudagrass; coastal |   | 1 no vegetation    |
                          |     bromegrass seedling   |   +--------------------+
                          |     corn; 125 bu          |
                          |     grama    1st yr       |
                          |     grama    2nd yr       |
                          |     grama    3rd yr       |
                          |  -  > no vegetation       |
                          |     orchardgrass; seed yr |
                          |     Red clover: spr seed  |
                          |     sorghum               |
                          +---------------------------+

+-------------------------<F3 When don enter Veg. Names >----------------------- +
Tab  Esc F1  F2  F3  F4  F8  F9  F10  Ins  Del  PgUp  PgDn  Home  End
FUNC esc help clr cont call dupe info desc ins del pgup pgdn lst last
```

Figure 7-2. Vegetation Inputs

Field operations are now displayed. [Enter].

The question about senescence is not applicable for this example so select the default answer of [no]. [Enter].

Enter the beginning date of the first operation. [3/1/1]. [Enter]. The sequence is Month/Day/Year with year one being the first year. A two-digit year can also be used (e.g. 98)

Another dialog box appears that lists equipment such as disk, chisels, blade cut matl (dozer blading a cut), drills, harrows, and rippers as well as additions of other crop residue, e.g. straw mulch and rock mulch.

Prior to adding mulch we must disturb the soil. [blade fill matl] is selected. [Enter]. [Enter].

The next operation is the addition of 2 tons/ac straw mulch. [3/1/1]. [Enter]. Highlight "add straw mulch". [Enter]. [Enter].

Input the quantity of mulch addition in lbs/ac. The amount entered for the mulch should reflect the mulch remaining if some is blown away by the wind. In this example, netting is used to retain the mulch in place. Also, the mulch is assumed to be well anchored to minimize runoff flowing between the soil and mulch and to minimize mulch movement by runoff.

[4000]. [Enter]. [Enter]. [F3]. We will assume that there is no additional operations, so "no operation" [Enter]
We are now finished with the data entry [F3].

Display options are now listed. Highlight number [1]. [Enter]. [Esc], and then highlight number [2] to display Rotational C (by vegetation) and Operational C tables, respectively, as shown in **Figure 7-3**.

```
      File        Exit        Help        Screen
+------------------< C Factor: results by veg. types 1.06 >--------------------- +
|                                                                                |
|                                                                   veg. C       |
|   veg.                       start date     end date     %EI       factor      |
| ------------------------------------------------------------------------------ |
|  no vegetation              3/1/1          3/1/2       100.0      0.159        |
| --------------------------------------------- Rotation C Factor = 0.159 ----- |
       File        Exit        Help        Screen
+------------------< C Factor: results by operations 1.06 >--------------------- +
|  veg. # 1/1: no vegetation        prev. veg.: no vegetation                    |
|                       % res. cover    op.          date                         |
| ---operation------------after op.----date---------next op.-----SLR-----%EI----- |
|  blade fill matl           0       3/1/1         3/1/1       0        0.0      |
|  add straw mulch           91      3/1/1         3/1/2       0.159  100.0      |
+---------- Rotation C Factor = 0.159 -------- Veg. C Factor = 0.159 ----------- +
```

Figure 7-3. Results by Vegetation and by Operations

Highlight number [3] to display half-month sub-factors, **Figure 7-4**.

```
     File        Exit        Help        Screen
+------------------< C Factor: 15-day SLR subfactors 1.06 >--------------------- +
|                      % res.                                                     |
|                      cover  plu  *  cc  *  sc  *  sr  *  sm  =  slr    %EI     |
 -------------------------------------------------------------------------------
*********** BEGINNING/END OF ROTATION *** Rotation C Factor = 0.159 ***********
  3/1/1         no vegetation        blade fill matl
  3/1/1         no vegetation        add straw mulch
  3/1 - 3/15/1         90     1         1       0.066  1.06   1      0.07       1.0
  3/16 - 3/31/1        89     0.999  1       0.069  1.06   1      0.073      2.0
  4/1 - 4/15/1         87     0.997  1       0.072  1.06   1      0.076      2.0
  4/16 - 4/30/1        85     0.994  1       0.076  1.06   1      0.08       2.0
  5/1 - 5/15/1         83     0.991  1       0.08   1.06   1      0.084      3.0
  5/16 - 5/31/1        80     0.988  1       0.086  1.06   1      0.09       3.0
  6/1 - 6/15/1         77     0.984  1       0.096  1.06   1      0.1        5.0
  6/16 - 6/30/1        73     0.979  1       0.106  1.06   1      0.11       9.0
  7/1 - 7/15/1         69     0.975  1       0.119  1.06   1      0.123     11.0
  7/16 - 7/31/1        64     0.97    1       0.134  1.06   1      0.138     12.0
  8/1 - 8/15/1         60     0.965  1       0.151  1.06   1      0.155     11.0
  8/16 - 8/31/1        56     0.96    1       0.171  1.06   1      0.174      9.0
  9/1 - 9/15/1         52     0.955  1       0.192  1.06   1      0.194      9.0
  9/16 - 9/30/1        48     0.95    1       0.213  1.06   1      0.214      6.0
  10/1 - 10/15/1       45     0.945  1       0.232  1.06   1      0.232      3.0
  10/16 - 10/31/1      43     0.94    1       0.248  1.06   1      0.247      3.0
  11/1 - 11/15/1       41     0.935  1       0.261  1.06   1      0.258      2.0
  11/16 - 11/30/1      40     0.929  1       0.273  1.06   1      0.269      1.0
  12/1 - 12/15/1       38     0.924  1       0.285  1.06   1      0.279      1.0
  12/16 - 12/31/1      37     0.919  1       0.297  1.06   1      0.289      1.0
  1/1 - 1/15/2         36     0.913  1       0.308  1.06   1      0.298      1.0
  1/16 - 1/31/2        35     0.908  1       0.32   1.06   1      0.308      1.0
  2/1 - 2/15/2         33     0.903  1       0.333  1.06   1      0.318      1.0
  2/16 - 2/28/2        32     0.897  1       0.345  1.06   1      0.328      1.0
*********** BEGINNING/END OF ROTATION *** Rotation C Factor = 0.159 ***********
```

Figure 7-4. Results by 15-day Period

What can be learned from **Figure 7-4**? The time increments are given in 15-day intervals. The percent residue cover decreases from 90% to 32% during the year. This is not a C sub-factor, and is simply listed to provide information.

The prior land use (PLU), C sub-factor accounts for soil consolidation, i.e., the soil becomes less erodible through time. On 3/1/1 C-PLU is initialized at a value of "1" because the soil was disturbed during fill-slope construction.

Other construction situations can exist. If the soil is scraped or cut without loosening the remaining soil, and the cut is below the root zone, (which is the most likely case), then a consolidation sub-factor (PLU) value of 0.45 should apply. For the fill-slope situation, sub-factor PLU reduces to 0.897 after one year of consolidation.

The RUSLE program allows the creation of a specific operational file for various operation scenarios. If only the vegetation and the near surface soil is cut, most of the roots would remain to help bind the soil. A construction operation could be created to begin the sequence of operations with the roots remaining in the soil. In this case PLU would include the effects of roots and the effect of consolidation, thus the PLU value would be less than 0.45.

The canopy sub-factor (CC) value is 1.0 because no vegetation is present that forms a canopy to intercept rainfall and reduce its erosivity.

The surface cover sub-factor, (SC), is the predominant mechanism of soil-loss reduction. On 3/1/1 SC was initiated at a value of 0.066, and through time the mulch became less effective because of decomposition. For example, the SC value increased to 0.096, 0.19, and 0.28 for 6/1/1, 9/1/1, and 12/1/1, respectively. After a full year, the mulch effectiveness was reduced to a SC value of 0.34.

The value of the surface roughness sub-factor (SR) is 1.06, (which means that the smooth surface left by the grading is six percent more erodible than the base condition of the unit-plot condition in RUSLE that is assigned a value of 1.0, as previously described).

The other information that can be found in **Figure 7-4** is the % EI that occurs throughout the year for Charleston, SC. Historically the most erosive storm period is from 6/16 through 9/15, which accounts for 61 % of the total average erosion. The Fall and Winter seasons have a very small erosion potential, suggesting preferable times for site disturbance. The overall rotational C value is 0.16. Thus, the mulch provided substantial soil protection.

[Esc] to return to the prior screen where the option for C factor output is chosen.

Highlight "Operational C". [Enter]. The overall C-factor is 0.16.

[Esc] [Esc] [Esc] [Esc] to return to the Soil Loss and Sediment Yield Computation Worksheet.

Although RUSLE displays several decimal places in the output, these decimal places are not always significant. Generally the number of significant decimal places that should be reported is two, which is the way that the decimal places are reported in this chapter, even though RUSLE screens show additional places.

As can be seen, the C value of 0.16 has been calculated and entered. The total estimated average annual soil loss has been reduced from 450 to 72 tons/ac/year, comparing Scenarios 1 and 2, respectively.

Saving the created file:
[tab].

[arrow down to 2]. [Enter].
Type filename. [EX1SCNO2]. [Enter].
Type in description of the scenario.
[6/11/97 Charleston, SC
Fill embankment stabilization during highway construction
Ex. 1, Scenario 2- 2 tons/ac
straw mulch. 1 yr simulation]
[F3].

Scenario 3 - Fill embankment stabilization during highway construction, broadcast seeding of tall fescue grass followed by 2 tons per acre straw mulch.

We expand on Scenario 2 by adding the broadcast seeding of tall fescue grass which also begins the growth cycle on March 1 followed by the placement of mulch and netting.

To use the previous file:
Arrow down to the next line on the computation worksheet.
[tab]
Select [loadfile] [Enter]
Arrow down to highlight "EX1SCNO2" [Enter].
The factors are now listed on the third line.
Arrow to the C factor. [F4].

We will follow the same sequence of steps as in Scenario 2; only the new changes will be discussed herein.

Move the cursor to the area where vegetation is entered.
"No vegetation" will be highlighted.
[F6] will display the list of vegetation choices.
Use the arrow key to move the cursor so that "tall fescue, 1st year" is highlighted.
[F3]. [F3]. [F3].

The field operations screen is now displayed.
[Enter] until the 3/1/1 date for the "add mulch operation" is highlighted
[ins] key
[3/1/1] [Enter]
From the dialog box select "broadcast planter" . [Enter]
The input C factor figure is shown in **Figure 7-5**.

The sequence of operations is important. The seed is planted before the mulch is applied. If the add mulch operation precedes the planting operation, the planter buries a portion of the mulch, resulting in less cover and more erosion than when the planting occurs before adding mulch. Also, some of the seed will rest on the mulch so that the expected vegetation cover may not be realized.

[F3].
Highlight "Rotational C". [Enter].
Highlight "Operational C". [Enter]. Refer to **Figure 7-6**. [Esc]
Highlight "Half-Month Sub-factor Values". [Enter]. Refer to **Figure 7-7**.

```
             File        Exit        Help        Screen
+---------------------< Time-varying C: operations 1.06 >---------------------- +

   1/1   veg.: tall fescue, 1st yr_   senescence code :1
  -Date-------Field Operation-------Res. Add  (#/A)----New Growth Set-----------
 3/1/1          blade fill matl
 3/1/1          broadcast planter
 3/1/1          add straw mulch        4000
+------------------------<F3 when Questions Answered >------------------------- +
Tab  Esc F1  F2  F3  F4  F8  F9  F10  Ins  Del  PgUp  PgDn  Home  End
FUNC esc help clr cont call dupe info desc ins del pgup pgdn 1st last
```

Figure 7-5. C-factor Inputs

```
       File        Exit        Help        Screen
+------------------< C Factor: results by veg. types 1.06 >--------------------- +

                                                                 veg. C
   veg.                        start date     end date     %EI       factor
 -------------------------------------------------------------------------------
  tall fescue, 1st yr          3/1/1          3/1/2       100.0      0.009
 ------------------------------------------------ Rotation C Factor = 0.009 ------

+------------------< C Factor: results by operations 1.06 >--------------------+

  veg. # 1/1: tall fescue, 1st yr        prev. veg.: tall fescue, 1st yr
                    % res. cover    op.           date
 ---operation------------after op.----date---------next op.-----SLR-----%EI------
  blade fill matl          0        3/1/1          3/1/1       0         0.0
  broadcast planter        0        3/1/1          3/1/1       0         0.0
  add straw mulch          91       3/1/1          3/1/2       0.009  100.0
 ---------- Rotation C Factor = 0.009 -------- Veg. C Factor = 0.009 ------------


+------------------------< Esc Returns to C Result Menu >---------------------- +
Tab  Esc F1   F3   F9   PgUp PgDn Home End
FUNC esc help cont info pgup pgdn 1st  last
```

Figure 7-6. Results by Vegetation Operations

So what is the effect of the planting and establishing of a grass cover along with the 2 tons/ac straw mulch on the erosion rate:

1. The percent residue cover decreases from 90 % to 32 %, as it did in the previous scenario.

2. The prior land use (PLU) factor changes from 1.00 to 0.33 during the year reflecting the effect of root biomass and consolidation of the soil on soil loss.

3. The canopy sub-factor (CC) decreases from 1.00 to 0.11 to account for the development of the grass cover, which is established by 6/1 as shown by a sub-factor CC of 0.11.

4. The surface cover sub-factor (SC) is initiated at 0.066 and increases the same as in Scenario 2.

5. The surface roughness sub-factor (SR) is 1.056, essentially the same as in Scenario 2.

The overall C factor is 0.009.

```
      File        Exit        Help        Screen
+------------------< C Factor: 15-day SLR subfactors 1.06 >--------------------- +
                         % res.
                         cover  plu  *  cc  *  sc  *  sr  *  sm  =  slr    %EI
 ---------------------------------------------------------------------------------
 *********** BEGINNING/END OF ROTATION *** Rotation C Factor = 0.009 ***********
   3/1/1        tall fescue, 1st yr  blade fill matl
   3/1/1        tall fescue, 1st yr  broadcast planter
   3/1/1        tall fescue, 1st yr  add straw mulch
   3/1 - 3/15/1         90     0.954  0.908  0.066  1.056  1      0.061     1.0
   3/16 - 3/31/1        89     0.857  0.644  0.069  1.056  1      0.04      2.0
   4/1 - 4/15/1         87     0.754  0.4    0.072  1.056  1      0.023     2.0
   4/16 - 4/30/1        85     0.63   0.254  0.076  1.056  1      0.013     2.0
   5/1 - 5/15/1         83     0.514  0.182  0.08   1.056  1      0.008     3.0
   5/16 - 5/31/1        80     0.414  0.129  0.086  1.056  1      0.005     3.0
   6/1 - 6/15/1         77     0.38   0.109  0.096  1.056  1      0.004     5.0
   6/16 - 6/30/1        73     0.378  0.109  0.106  1.056  1      0.005     9.0
   7/1 - 7/15/1         69     0.375  0.109  0.119  1.056  1      0.005    11.0
   7/16 - 7/31/1        64     0.373  0.109  0.134  1.056  1      0.006    12.0
   8/1 - 8/15/1         60     0.37   0.109  0.151  1.056  1      0.006    11.0
   8/16 - 8/31/1        56     0.368  0.109  0.171  1.056  1      0.007     9.0
   9/1 - 9/15/1         52     0.365  0.109  0.192  1.056  1      0.008     9.0
   9/16 - 9/30/1        48     0.363  0.109  0.213  1.056  1      0.009     6.0
   10/1 - 10/15/1       45     0.36   0.109  0.232  1.056  1      0.01      3.0
   10/16 - 10/31/1      43     0.357  0.109  0.248  1.056  1      0.01      3.0
   11/1 - 11/15/1       41     0.354  0.109  0.261  1.056  1      0.011     2.0
   11/16 - 11/30/1      40     0.352  0.109  0.273  1.056  1      0.011     1.0
   12/1 - 12/15/1       38     0.349  0.109  0.285  1.056  1      0.011     1.0
   12/16 - 12/31/1      37     0.346  0.109  0.297  1.056  1      0.012     1.0
   1/1 - 1/15/2         36     0.343  0.109  0.308  1.056  1      0.012     1.0
   1/16 - 1/31/2        35     0.34   0.109  0.32   1.056  1      0.013     1.0
   2/1 - 2/15/2         33     0.337  0.109  0.333  1.056  1      0.013     1.0
   2/16 - 2/28/2        32     0.334  0.109  0.345  1.056  1      0.013     1.0
 *********** BEGINNING/END OF ROTATION *** Rotation C Factor = 0.009 ***********
```

Figure 7-7. Results by 15-day Period

We can see in the Soil Loss Ratio (SLR) column in Scenario 3 that as the mulch is decomposing, the grass is becoming established and the combination of these two factors results in the low estimated soil loss. The grass growth during the highest erosion-potential period of 6/1 through 9/15 is especially critical in reducing estimated soil loss.

The estimated soil loss is 4.0 ton/ac/year. This is a major reduction in soil loss from the 72 tons/ac/year estimated for the straw mulch alone. The results reflect our expectations and experience that grass planted at the right time of year and protected by anchored mulch will readily become established, protecting the surface from erosion, and protecting the contractor from potential costs of re-treating a portion or the entire job. The contractor's vulnerability to potentially detrimental off-site impacts is likewise reduced by proper planning and implementation of erosion controls.

[Esc] from program and save as [EX1SCNO3].

Scenario 4 - Fill embankment stabilization during highway construction using rock mulch.

We will again modify the file used in Scenario 2 by substituting rock mulch for straw mulch.

Follow the previously detailed procedure to load file EX1SCNO2.
Proceed to the C factor and highlight "% surface cover by rock fragment".

We could use this field to enter a value for the rock cover, but that would be an improper use of this field. This entry is used to designate coverage of rock fragments on soils that also include rock fragments in the profile. It is not used to enter rock added as a mulch. Leave this entry at zero.

However, the land use designation will need to be changed to show disturbed land, topsoil fill, with rock cover.

Use the arrow keys to place the cursor on the land-use designator.
[F4] to reach the LS screen where the land use can be changed.
[12] [Enter] to select the land use of "disturbed land, topsoil fill, rock cover".
[F3] to compute a new LS value with the new land use.
[Esc] to return to the C-factor screen.

The entries on the C-factor screen are now complete,

[F3] to move to the next C-factor screen to change operations to "add rock mulch" rather than straw mulch.
Use the arrow keys or [Enter] to reach and highlight add straw mulch. .
[F6] to obtain the list of field operations.
Arrow up to display add rock mulch.
Let s see the assumed values for this operation. [F4].
Select Option 1 to add/edit/delete operations from the OPERATIONS Database Set.
[Enter].

The field operation is "add rock mulch" and the assumptions are shown on the displayed screen (**Figure 7-8**). The effect of adding rock mulch is 4, which is simply other residue added to the site. At 90% surface cover, 200,000 lbs/acre were added.

```
      File        Exit        Help        Screen
+--------------< Create/Edit Site Operation Database Set 1.06 >----------------- +
                operation: add rock mulch______
   Effect #1:4 %sur 100  Dsr 0      Dsu 0      #/A@30%:0  60%:15000090%:200000
   Effect #2:1
   Effect #3:1
   Effect #4:1
   Effect #5:1

                      +-------------------------------------------------+
                        1. no effect
                        2. soil surface disturbed
                        3. current vegetation residue added to surface
                        4. other residue added to the site
                        5. residue removed from site
                        6. current vegetation harvested
                        7. vegetation growth begins
                        8. current vegetation is killed                 .
                        9. call in a new vegetation growth set
                      +-------------------------------------------------+



+--------------------< F7 Saves, Esc Returns to OP Main Menu >------------------- +
Tab  Esc F1   F2  F6   F7   F9   F10  Ins Del
FUNC esc help clr list save info desc ins del
```

Figure 7-8. Field Operation Data Base

One of the advantages of using rock is that it naturally conforms to the soil surface and provides greater protection than does a mulch like straw that tends to bridge low areas where runoff can concentrate and cause rill erosion beneath the mulch. However, rock mulch precludes post-reclamation land use.

[Esc] [Esc] [Esc] to return to the field operations screen.
Arrow to the right.
[200,000]. [Enter]. [F3].

View the half-month sub-factor values, as shown in **Figure 7-9**.

The surface cover C sub-factor has been reduced to 0.055, and remains constant throughout the year because the rock mulch does not decompose like the straw mulch.

Return to the Soil Loss and Sediment Yield Computation Worksheet

```
+-----------------< C Factor: 15-day SLR subfactors 1.06 >-------------------- +
                      % res.
                      cover  plu  *  cc  *  sc  *  sr  *  sm  =  slr    %EI
 -------------------------------------------------------------------------------
 *********** BEGINNING/END OF ROTATION *** Rotation C Factor = 0.055 ***********
   3/1/1        no vegetation       blade fill matl
   3/1/1        no vegetation       add rock mulch
   3/1 - 3/15/1        83     1      1      0.054  1.06   1      0.057     1.0
   3/16 - 3/31/1       83     0.999  1      0.054  1.06   1      0.057     2.0
   4/1 - 4/15/1        83     0.997  1      0.054  1.06   1      0.057     2.0
   4/16 - 4/30/1       83     0.994  1      0.054  1.06   1      0.057     2.0
   5/1 - 5/15/1        83     0.992  1      0.054  1.06   1      0.056     3.0
   5/16 - 5/31/1       83     0.989  1      0.054  1.06   1      0.056     3.0
   6/1 - 6/15/1        83     0.985  1      0.054  1.06   1      0.056     5.0
   6/16 - 6/30/1       83     0.981  1      0.054  1.06   1      0.056     9.0
   7/1 - 7/15/1        83     0.978  1      0.054  1.06   1      0.056    11.0
   7/16 - 7/31/1       83     0.974  1      0.054  1.06   1      0.055    12.0
   8/1 - 8/15/1        83     0.969  1      0.054  1.06   1      0.055    11.0
   8/16 - 8/31/1       83     0.965  1      0.054  1.06   1      0.055     9.0
   9/1 - 9/15/1        83     0.961  1      0.054  1.06   1      0.055     9.0
   9/16 - 9/30/1       83     0.956  1      0.054  1.06   1      0.054     6.0
   10/1 - 10/15/1      83     0.951  1      0.054  1.06   1      0.054     3.0
   10/16 - 10/31/1     83     0.946  1      0.054  1.06   1      0.054     3.0
   11/1 - 11/15/1      83     0.941  1      0.054  1.06   1      0.054     2.0
   11/16 - 11/30/1     83     0.936  1      0.054  1.06   1      0.053     1.0
   12/1 - 12/15/1      83     0.931  1      0.054  1.06   1      0.053     1.0
   12/16 - 12/31/1     83     0.926  1      0.054  1.06   1      0.053     1.0
   1/1 - 1/15/2        83     0.921  1      0.054  1.06   1      0.052     1.0
   1/16 - 1/31/2       83     0.916  1      0.054  1.06   1      0.052     1.0
   2/1 - 2/15/2        83     0.91   1      0.054  1.06   1      0.052     1.0
   2/16 - 2/28/2       83     0.905  1      0.054  1.06   1      0.052     1.0
 *********** BEGINNING/END OF ROTATION *** Rotation C Factor = 0.055 ***********
```

Figure 7-9. Results by 15-day Period The estimated soil loss, based on a C value of 0.055, is 26 tons/ac/year. Thus, 80% rock cover reduced soil loss much more than the straw mulch, but not as much as the straw mulch and grass combined, which illustrates the value of vegetation for controlling soil erosion.

Example 2: Reclaimed Outslope Reconstruction

Problem Statement: An Appalachian coal mine must reconstruct an outslope. Four alternative hillslope-profile configurations are considered: (1) uniform, (2) concave, (3) convex, and (4) complex. The alternative configurations are shown in Figure 7-10. An assessment of the alternative outslope configurations uses the RUSLE program.

Scenario 1 - Uniform hillslope.
Scenario 2 - Concave hillslope.
Scenario 3 - Convex hillslope.
Scenario 4 - Complex hillslope.

What Will the User Learn?

The RUSLE capability demonstrated through Example 2 is the ability to input and evaluate the hillslope-profile configurations of uniform, concave, convex, and complex. In Scenario 1 the user learns how to calculate the K value based on inputs of the soil-particle size percentages. The user will learn to account for the effect of percent rock fragments and the effect of specifying a roughened soil-surface condition. A method to estimate surface roughness is illustrated. Scenarios 2, 3, and 4 illustrate inputs and results interpretations for concave, convex, and complex hillslope configurations, respectively.

Design information

Location - Eastern Kentucky.

Soil-substitute material: From a particle size analysis; % silt and very fine sand = 28, % sand minus very fine sand = 64, % clay = 8, and from an organic material analysis the % organic material (non-coal) = 1.2. % sand = 67, % silt = 25, and % clay = 8, i.e. a sandy loam.

Hillslope-profile configurations -

(1) uniform 35 %, and 400 ft,

(2) concave 44 %, 250 ft and 20 %, 150 ft,

(3) convex 31.4 %, 350 ft and 60 % 50 ft, and

(4) complex 60 %, 150 ft, 13.3 %, 150 ft and 30 %, 100 ft.

Refer to Figure 7-10.

A terrace is located above the highwall to divert storm water away from the outslope. Thus no runoff will enter from above the highwall on to the hillslope.

Regraded Slope Shape	Segment 1			Segment 2			Segment 3		
	Slope (%)	Horizontal Distance (ft)	Vertical Drop (ft)	Slope (%)	Horizontal Distance (ft)	Vertical Drop (ft)	Slope (%)	Horizontal Distance (ft)	Vertical Drop (ft)
Uniform	3.5	400	140						
Concave	44	250	110	20	150	30			
Convex	31.4	350	109.9	60	50	30			
Complex	60	150	90	13.3	150	19.95	30	100	30

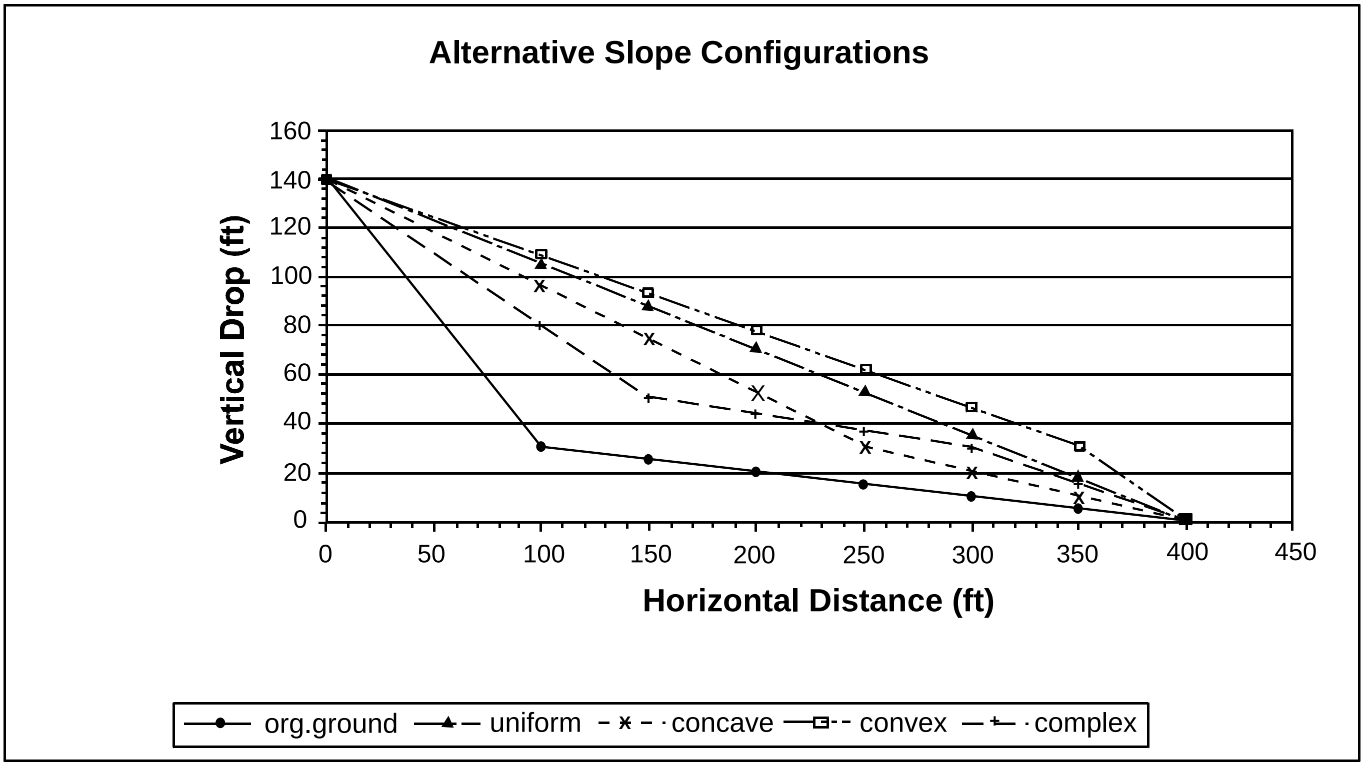

Fig 7-10. Alternative Hillslope Configurations

Scenario 1 - Uniform reclaimed outslope configuration.

Start a new file on the Soil Loss and Sediment Yield Computation Worksheet screen.

At the R factor. [F4].
Select [Charleston, WV] as the best climate station
[F4] to transfer to the LS value.
[1] hillslope segment,
[2] measured horizontally,
[3] sandy loam soil texture entered through the K-factor screen, and
[10] a land use of disturbed fill, subsoil, no rock cover is entered.

A gradient of [35] and length of [400] results in a LS = 17.9 and the equivalent slope = 35 % is the same as the actual hillslope steepness because the hillslope shape is uniform.

If the hillslope shape is nonuniform, the equivalent slope is not the same as the average steepness because the relationship between erosion and hillslope length is nonlinear.

[Esc]. returns you to the R-factor screen
R = 140.
No adjustment for ponding.

K-factor input:

Arrow to the K factor. [F4].
Select using the Soil Interpretation Record/ K Nomograph.
Arrow to estimated K. [F4].
% silt and very fine sand [28].
% clay [8]
% organic material [1.2].

Soil-structure code: The soil-substitute material is granular in structure and predominantly 1 to 2 mm, so select "fine granular". [2]

Soil structure can be determined by a soil scientist or other qualified scientist or engineer.

In the Appalachian region, soil-substitute material is expected to be slow to moderate in permeability. [4].

To define the permeability, a laboratory permeability analysis could be conducted using standard or modified Proctor compaction. Care should be taken to accurately mimic the in-field compaction. An alternative is to use a double-ring infiltrometer in the field. A difficulty in using this apparatus is obtaining a good seal along the infiltrometer walls and may require the use of kaolinite or bentonite clay for this purpose. Nevertheless, the permeability code represents the permeability of the soil profile.

Although additional specific information is gained through field and laboratory investigations, the RUSLE user is cautioned to balance the cost of gaining additional data with the anticipated increase in soil-loss estimation accuracy. The simplest way to determine this trade-off is to test the sensitivity of an input parameter with respect to output. For instance, to determine if it is worthwhile to invest time and money to conduct a field investigation of regraded soil-substitute permeability, the user should enter one higher and one lower permeability class to see how these changes affect the estimated K value. Of course, each of the input parameters need to be kept in perspective. Although we may be able to "fine tune" one parameter, the overall accuracy of the soil-loss estimate may be limited if some of the other parameters are input with lesser accuracy,

Refer to the Rock Fragments in the Profile section of Chapter 3 of these Guidelines or Chapter 3 of (Renard et al., 1997) for a detailed discussion of this variable.

Because the K value is anticipated to be greater than 0.15 no correction will be made to the K value. [1]. [F3].

A K value of 0.2 is calculated.
[Esc] to the Seasonally Variable K-factor screen. [Enter].
% rock cover. [20].

This is a sensitive parameter with respect to soil-loss estimations. A method to estimate percent rock cover is provided in Chapter 5.

For the number of years to consolidation, use the default value because no data exists for soil-substitute material, but such material should respond similarly to disturbed soils. [7]. [Enter]

Most soil-substitute materials in Appalachian coal fields are highly compacted and, depending on the mix of shale to sandstone, may weather rapidly which may further reduce permeability. Most soil-substitute material in these areas will be in hydrologic soil group 3 or 4. [3]. [Enter]

Entry of the soil series is for informational purposes, whereas the soil texture is used in the terrace P-factor computation. Leave soil series blank. Soil texture is based on the United States Department of Agriculture (USDA) soil textural classification system.

[3] for Sandy Loam. [F3]

The seasonally Variable K-Factor screen is now displayed showing an average annual K value of 0.19 as shown in **Figure 7-11**. Also listed are the maximum and minimum K values of 0.46 and 0.078, respectively. The maximum value occurs at the end of the annual freeze-thaw period which is April 2 for this area. The minimum value occurs on October 2, corresponding to a period when the soil is the driest and least likely to produce runoff. This is also at the end of the period of biological activities in the soil, which reduces soil loss.

The LS value has already been calculated and so proceed to the C factor. We need to account for the effect of percent rock fragment on the surface and the roughened state of the soil- substitute material on soil-loss rates

```
      File        Exit        Help        Screen
+------------------< Seasonally Variable K Factor 1.06 >---------------------- +
      city code: 48001   CHARLESTON          WV       estimated K: 0.2
  % rock cover: 20    # yrs to consolidate: 7    hyd. group: 3
  soil series:                    surface texture: sandy loam

   1/1-1/15        1.0      0.187          7/1-7/15         13.0       0.179
   1/16-1/31       1.0      0.215          7/16-7/31        11.0       0.155
   2/1-2/15        1.0      0.248          8/1-8/15          9.0       0.133
   2/16-2/28       1.0      0.284          8/16-8/31         8.0       0.115
   3/1-3/15        1.0      0.319          9/1-9/15          5.0       0.098
   3/16-3/31       1.0      0.365          9/16-9/30         5.0       0.085
   4/1-4/15        2.0      0.435          10/1-10/15        2.0       0.082
   4/16-4/30       3.0      0.376          10/16-10/31       2.0       0.094
   5/1-5/15        4.0      0.325          11/1-11/15        1.0       0.108
   5/16-5/31       5.0      0.281          11/16-11/30       1.0       0.124
   6/1-6/15        8.0      0.24           12/1-12/15        1.0       0.142
   6/16-6/30      13.0      0.207          12/16-12/31       1.0       0.162
                                                                       -----
    EI DIST.: 111        FREEZE-FREE DAYS: 193    AVERAGE ANNUAL K:    0.189
     R VALUE: 140    Kmin = 0.078 on 10/2    Kmax = 0.461 on 4/2
+---------------------------------< Esc exits >-------------------------------- +
Tab  Esc F1   F2  F3   F4   F6   F9
FUNC esc help clr cont call list info
```

Figure 7-11. Seasonally Variable K Factor

[F4].
Highlight the time-invariant method to explore this method. [Enter].
Vegetation data will be entered directly. [3]. [Enter].

The values for the effective root mass, % canopy cover, and average fall height are set to zero because no vegetation is present.

The roughness value for the field condition is a moderately sensitive parameter that accounts for the roughened condition of a ground surface on soil-loss rates. A rough surface provides opportunities for runoff to pond and subsequently infiltrate, and provides numerous deposition sites. All of these effects reduce soil loss. A method to estimate random roughness in the field is detailed in Chapter 3. Refer to **Figure 7-12** which shows the relationship between the random roughness factor, and the range in elevation in inches. For example, the surface-elevation range for the soil-substitute material on this outslope will be 6 to 9 inches based on previous measurements of similar areas.

Select 7.5 inches and from **Figure 7-12**, a random roughness value of 1.6 is estimated. [1.6]. [Enter].

Yes, there has been mechanical disturbance. [2]. [Enter].
Number of years needed for consolidation. Use the default value of 7.
Number of years since last disturbance.
Because this outslope will be further reclaimed for Phase II bond release in about 1 year enter [1].

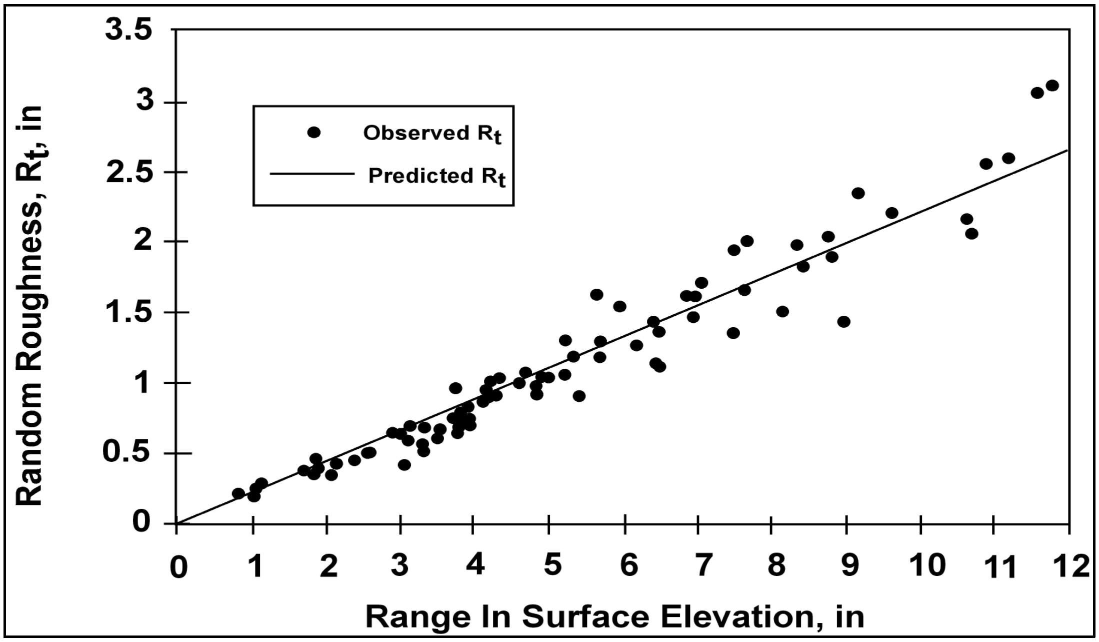

Figure 7-12. Relation between the range in surface elevation and random roughness

Note that this option for the C factor gives an estimate of the C value at the time since the last disturbance (e.g. 1 year), rather than an average for the period since consolidation. Because the spoil has been graded and left untreated for a period of one year, using "zero" or "one year" will compute a C value for the time immediately following grading. When seeding is completed to start Phase II bond release, the time since disturbance is reset, and time zero begins following the seeding operation. However, some consideration must be given to operations where only a portion of the surface is disturbed. For those situations, a separate RUSLE calculation should be made and the time should not be set to zero, but rather a proportional adjustment between 0 and 7 years, or the appropriate total number of years for soil consolidation, based on the percent of land disturbance.

The next three cover values have been previously entered in the K-factor input section.

The surface-cover function; b-value code is [1] to allow the program to automatically compute a b value. [F3]

A C value of 0.22 is calculated.

This value differs from the value that would be estimated for the C factor using the original USLE. Thus, one of the distinct advantages of using RUSLE is obtaining a C value that accounts for both surface rock-fragment cover and surface roughness.

The P factor has two options: (1) one for frequently disturbed land, and (2) one for infrequently disturbed land. The option for infrequently disturbed land is used for conditions such as pasture and rangelands where infrequent disturbance generally is for renovation of the vegetation. Use the option for frequently disturbed land for mining, construction, and reclaimed lands when the time since the last disturbance is less than the time to consolidation.

A P value of 1 is entered for this example after returning to the Soil Loss and Sediment Yield Computation Worksheet. [1].

The estimated soil loss is 100 tons/ac/year for the uniform reclaimed outslope configuration.

Save the file as EX2SCNO1.

Scenario 2 - Concave reclaimed outslope configuration.

The only change is with the LS factor:

Load the saved file and proceed as follows for the LS factor.
[2] hillslope segments and [1] varying in length are the input changes.
Segment 1 gradient [44], length [250] ft.
Segment 2 gradient [20], length [150] ft.
Resultant LS = 15.0, Equivalent LS-factor gradient is 29.3%. The actual overall gradient is 35 %.

Because of the concave hillslope-profile configuration the equivalent uniform LS gradient is reduced to 29.3%. That is to say that a 29.3 % hillslope, which is 400 ft in length, will result in a LS value of 15.0. Refer to **Figure 7-13**.

Note that a LS value is given for each hillslope segment. The LS value of a given hillslope segment depends, in part, upon the hillslope length above that segment but the LS value does not depend upon the rate of erosion upslope.

The estimated soil loss is 86 tons/ac/year.

Save as EX2SCNO2.

```
      File        Exit        Help        Screen
+-----------------------------< LS Factor 1.06 >-------------------------------+
|                                                                              |
|   number of segments: 2          segment lengths are measured: 2            |
|         segments are: 1                                                      |
|         soil texture: sandy loam                                             |
|     general land use: 10                                                     |
 -------------------------------------------------------------------------------
|                           1         2                                        |
| Gradient (%) of Segment   44        20                                       |
| Length of Segment (ft)    250       150                                      |
| Segment LS               15.99     13.257                                    |
 -----+--------------------------------------------------------------+---------
|     | overall LS = 15; equiv. slope = 29.3 %; horiz. length = 400 ft|        |
|     +--------------------------------------------------------------+         |
|                                                                              |
+---------------------------------< Esc exits >--------------------------------+
Tab  Esc F1   F3   F9
FUNC esc help cont info
```

Figure 7-13. Hillslope Segment Input Screen for Concave Hillslope

Scenario 3 - Convex reclaimed outslope configuration

Re-load EX2SCNO2, then [Enter]
Segment 1 [31.4], [350]
Segment 2 [60], [50].
Resultant LS = 19.0, Equivalent LS-factor gradient is 37.3 % as shown in **Figure 7-14**.

The influence of the hillslope-segment sequence can be readily seen in this example. The long upper hillslope segment transfers runoff to the shorter and steeper lower hillslope segment, thereby significantly increasing the LS value of this portion of the convex hillslope.

The estimated soil loss is 110 tons/ac/year.

The soil loss from this convex hillslope is somewhat more than that from the uniform hillslope. However, the soil loss from the lower segment of the convex hillslope is much higher than from the similar lower segment for the uniform hillslope. The LS value for the lower 50 ft on the convex hillslope is 51.7, which is 74 percent greater than the 29.7 value for this equivalent segment on the uniform hillslope. Establishing and maintaining vegetation on the convex hillslope will be more difficult than on the uniform hillslope because of the much higher erosion rate on the lower segment of the convex hillslope than on the uniform hillslope. The LS value for the lower segment on the uniform hillslope was obtained by dividing the uniform hillslope into two segments, 350 and 50 ft in length, respectively.

Save as EX2SCNO3.

```
       File         Exit         Help         Screen
+------------------------------< LS Factor 1.06 >-------------------------------+
|                                                                                |
|   number of segments: 2          segment lengths are measured: 2              |
|         segments are: 1                                                        |
|         soil texture: sandy loam                                               |
|     general land use: 10                                                       |
 -------------------------------------------------------------------------------
                           1         2
 Gradient (%) of Segment   31.4      60
 Length of Segment (ft)    350       50
 Segment LS              14.354    51.653
 -----+---------------------------------------------------------------+---------
|     | overall LS = 19; equiv. slope = 37.3 %; horiz. length = 400 ft |         |
|     +---------------------------------------------------------------+          |
|                                                                                |
+----------------------------------< Esc exits >---------------------------------+
Tab  Esc F1   F3   F9
FUNC esc help cont info
```

Figure 7-14. Hillslope Segment Inputs Screen for Convex Hillslope

Scenario 4 - Complex reclaimed outslope configuration.

Proceed as before, then [enter]:
[3] for the number of segments
Segment 1 [60], [150]
Segment 2 [13.3], [150]
Segment 3 [30], [100].
Resultant LS = 13.4, Equivalent LS-factor gradient is 26.4 %.
The estimated soil loss is 77 tons/ac/year.
Save as EX2SCNO4.

The complex hillslope configuration reduces estimated soil loss to less than any of the other profile configurations.

So which is the best hillslope configuration?

To summarize, the uniform, concave, convex, and complex hillslope shapes resulted in estimated soil loss of 100, 86, 110, and 77 tons/ac/year, respectively. Based on these data the complex configuration is most desirable. An examination of **Figure 7-10**, shows that the complex shape nearly approximates the original ground surface, thus requiring the least amount of earthwork. This has major cost implications. Regrade earthwork often requires extensive hauling of spoil and bulldozer work. The haulage cost is the largest cost variable. Examining alternative hillslope configurations can help operators to realize both reduced rates of soil loss and savings in haulage and earthwork cost. There are major cost savings that can be achieved by the engineer or reclamation specialist through a complete analysis of alternative hillslope-profile configurations.

Example 3: Sediment Yield and Deposition Along a Hillslope

Problem Statement: The deposition potential for alternative hillslope-profile configurations are evaluated. Assessment is made of both the soil loss from a hillslope and the quantity of sediment that will be transported away from the bottom of the hillslope and transported downgradient. The soil-loss is important when we are concerned with retaining adequate soil on the hillslope for revegetation, and the quantity of soil transported downgradient is a concern with respect to potential off-site impacts, such as sediment discharge into a waterway or sediment-control structure, e.g. a sediment basin.

Scenario 1 - no erosion controls, a uniform hillslope of 5 %.
Scenario 2 - no erosion controls, a concave hillslope proceeding from 10 to 1 %.
Scenario 3 - no erosion controls, a convex hillslope proceeding from 1 to 10 %.

What Will the User Learn?

Sediment yield at the end of a hillslope can now be predicted with RUSLE version 1.06. This is a significant addition to the program's capabilities. The advantage of estimating the sediment yield is that off-site assessments can now be made. The quantity of sediment, on an average annual basis, that exits a hillslope can be determined and used to estimate the sediment-storage requirements for sediment-control structures.

Design information

Location - Lexington, KY

Soil - silty clay loam, B-horizon, % sand = 10, % silt = 55, % clay = 35, % silt + % very fine sand = 57, % sand - % very fine sand = 8, % organic material = 1.8.

Hillslope gradient and length - Scenario 1, ten 10 ft-segments all at 5%. Scenario 2 - a concave hillslope consisting of ten 10 ft-segments ranging from 10 % to 1 % in increments of 1 %. Scenario 3 - a convex hillslope consisting of ten 10 ft-segments ranging from 1 % to 10 % in increments of 1 %.

Duration of assessment - 1 year.

Scenario 1 - One hillslope segment at 5 % uniform gradient, 100 ft in length.

Select Lexington, KY from the CITY file. The R value is 165.

Proceed to the hillslope gradient. One hillslope segment measured horizontally, silty clay loam soil texture, disturbed fill of topsoil with no rock cover, 5 % gradient and 100 ft in length.
Resulting in a LS value of 0.65.

No adjustment for ponding.

K-factor inputs:

Use the nomograph. Other input values from the preceding design information are used.

The silty clay loam sublayer is expected to be blocky in structure and the soil permeability will be slow to very slow.

Select [6] very slow.
No significant rock fragments exist [1].
An approximate K value of 0.391 is estimated.
The % rock cover is [0].
Use the default of [7] years for consolidation
The hydrologic soil group is [4], highest runoff potential.
The soil-surface texture is [9], a silty clay loam.

From the Seasonally Variable K Factor it can be seen that K values range from 0.16 to 0.85.
The average K value is 0.37.

C and P values are entered as [1].

The estimated soil loss is 39 tons/ac/year.

Save as [EX3SCNO1].

Scenario 2 - Concave hillslope-profile configuration ranging from 10 % to 1 % in 1 % increments and 10 ft lengths.

Recall EX3SCNO1.
Start with the R factor and proceed to the "field slope" to alter the LS-factor calculations.
Enter [10] hillslope segments.
Horizontally measured.
Select equal hillslope-segment lengths, [2].
The uniform hillslope segment length is [10] ft.
Enter hillslope gradient from 10 % to 1 % in 1 % increments proceeding from the first to the tenth segment. To save time use the right arrow key to proceed from gradient to gradient.

The results are very useful. As the hillslope flattens the segment LS values change from 0.48, 0.58, 0.78, 0.82, 0.79, 0.72, 0.61, 0.48, 0.32, to 0.17, respectively. Refer to

Figure 7-15. It can be readily seen that although the uppermost gradient is the steepest (10 %), the LS value for this segment is only 0.48 and LS values increase to 0.82 at the fourth segment. The interplay among hillslope segments becomes evident in the LS values. As we proceed downgradient, the quantity of runoff increases, the transported sediment increases, and the hillslope flattens. The ability to transport sediment is a function of runoff and hillslope gradient. So as we proceed downslope, the quantity of runoff increases, which for a constant gradient, increases the erosivity of the runoff. For the concave hillslope profile, the gradient decreases downslope, which reduces the erosivity of the runoff. The interrelationship between runoff represented by distance and hillslope gradient determine LS values for each segment. At the final downslope hillslope segment, number 10, the LS value is lowest due to the flatter gradient. The highest soil loss occurs at Segment 4 where the LS value is 0.82.

```
      File        Exit        Help        Screen
+-----------------------------< LS Factor 1.06 >-------------------------------+

    number of segments: 10         segment lengths are measured: 2
          segments are: 2          uniform segment length (ft) : 10
          soil texture: silty clay loam
      general land use: 8
--------------------------------------------------------------------------------
                           1         2         3         4         5
  Gradient (%) of Segment   10        9         8         7         6
  Length of Segment (ft)    10        10        10        10        10
  Segment LS                0.484     0.584     0.782     0.817     0.792
 ---+------------------------------------------------------------------+--------
    | overall LS = 0.576; equiv. slope = 4.36 %; horiz. length = 100 ft|
 ---+------------------------------------------------------------------+--------
                            6         7         8         9         10
  Gradient (%) of Segment   5         4         3         2         1
  Length of Segment (ft)    10        10        10        10        10
  Segment LS                0.72      0.612     0.476     0.323     0.167
 -------------------------------------------------------------------------------

+---------------------------------< Esc exits >--------------------------------+
Tab  Esc F1   F3   F9
FUNC esc help cont info
```

Figure 7-15. LS Values by Hillslope-Profile Segment

Values for LS represent the potential for erosion. Deposition occurs on concave hillslopes where the gradient near the end of the hillslope is sufficiently flat. Deposition occurs when the transport capacity of the runoff becomes less than the sediment load produced by upslope erosion. This deposition is estimated within the P-factor.

How can this information be used?

The effect of hillslope shape on soil loss is evident from the above and now shape can be incorporated as a design factor using RUSLE 1.06. Where should a limited quantity of straw mulch or increased seeding be used? In the case of this concave hillslope and with respect to the LS factor, it is most effective when placed along Segments 3, 4, and 5.

The deposition that occurs on the toe of concave hillslopes can now be estimated using the RUSLE 1.06. To accomplish this proceed to the P-factor inputs.

Select "frequent-disturbance P factor", [1].
Select "contoured". [F4].
For the ridge-height use code [1] because no contours actually exist.
A [0] furrow grade is entered, but it has no effect on the computations because no ridges was specified. No ridges means that contouring gets no erosion-control credit.

The equivalent LS factor for a uniform hillslope was forwarded from the LS-factor calculation. Likewise the soil hydrologic class was forwarded.

The cover/management code of [6] is selected because this is a bare soil with minimal roughness.

Select [2] because a concave hillslope profile now exists. [F3]. [Esc]. [Esc]. [Enter] to proceed to the concave hillslope calculations. [F4].

The silty clay loam soil texture was forwarded and will be used to estimate depositional properties of the sediment.

Because we are modeling this scenario in a single timeframe an entry of 0 or 1 is appropriate, [0].

We will enter the location of the bottom of the strip as a % of hillslope length, [1]. Enter [10] strips.

The cover/roughness code is 6 throughout all hillslope segments.

Enter [10] and [10] for Strip 1.

The first 10 indicates that the lower edge of the most upgradient hillslope segment is located at a distance of 10 % from the top of the hillslope. The second 10 indicates that this upgradient segment has a 10 % gradient.

Continue entering 20, 30 ..., 100 for the second column and 9, 8, ...,1 for the % slope column as shown in **Figure 7-16**. [F3].

The conservation practice P sub-factor value is 0.84 and the sediment-delivery ratio value is 0.37. What does this mean? The P value of 0.84 is used to compute the soil loss when selecting practices to protect the soil resource against excessive degradation by erosion. The sediment delivery ratio (SDR) of 0.37 means that 63% of the sediment produced is trapped on the hillslope by deposition and that 37% of the sediment moves off the hillslope as sediment yield with the potential for downstream impact. The difference between the 0.84 P value for conservation planning and the 0.37 P value for sediment yield is that full credit is not taken for all of the deposition because most of the deposition occurs on the lower portion of the hillslope and does not benefit the upper portion of the hillslope.

Escape to the Soil Loss and Sediment Yield Computation Worksheet.

```
      File        Exit        Help        Screen
+-----------------------< P Strips & Concave 1.06 >---------------------------+
| specified soil texture: silty clay loam                                      |
|        number of years: 0    strip width specification code: 1               |
|    year:  +--< 1 >---+                                                       |
|  strips:  |    10    |                                                       |
|  strip 1  |  6 10  10|                                                       |
|  strip 2  |  6 20  9.0                                                       |
|  strip 3  |  6 30  8.0                                                       |
|  strip 4  |  6 40  7.0                                                       |
|  strip 5  |  6 50  6.0                                                       |
|  strip 6  |  6 60  5.0                                                       |
|  strip 7  |  6 70  4.0                                                       |
|  strip 8  |  6 80  3.  +--------------------------------+                    |
|  strip 9  |  6 90  2.  | horiz. slope length (ft): 100  |                    |
|  strip 10 |  6 100 1.  +--------------------------------+                    |
|  +----------------------------------------------------------------------+   |
|    veg. strip, concave slope sub. P = 0.841,  (sed. del. ratio = 0.368)      |
|                                                                              |
|    (press Esc to dismiss)                                                    |
|  +----------------------------------------------------------------------+   |
+--------------------------------< Esc exits >--------------------------------+
Tab  Esc F1   F9
FUNC esc help info
```

Figure 7-16. Input Screen for P-factor Strips

The estimated soil loss is 29 tons/ac/year which is less than the 39 tons/ac/year estimated for the uniform hillslope. The sediment yield is only 13 tons/ac/year; that is, only 13 tons/ac/year was transported beyond the lowest hillslope segment. This 13 tons/ac/year is calculated by multiplying $165 \times 0.36 \times 0.58 \times 1.00 \times 0.37$. Notice the P value of 0.84 is not used in the sediment-yield estimation.

Save as EX3SCNO2.

Scenario 3 - Convex hillslope - 1 % to 10% in 1 % increments of 10 ft each.

Follow the same sequence as in Scenario 2.
For the LS-factor the gradient % will increase from 1 to 10 %.

The resultant LS values continuously increase from 0.11 to 2.09 as we proceed from the uppermost to the lowest segment.

The C and P factor are both 1.

The result is an estimated soil loss and sediment yield of 54 tons/ac/year. This is nearly twice as high as the soil loss from the concave hillslope, namely 29 tons/ac/year. The sediment yields from the two hillslope configurations are 13 tons/ac/year for the concave hillslope and 54 tons/ac/year from the convex hillslope.

Save as EX3SCNO3.

RUSLE 1.06 is a powerful design tool enabling the estimation of off-site impacts resulting from alternative hillslope configurations.

Example 4: Terraces, Deep Ripping, and Contour Furrows.

Problem Statement: Steep and long hillslopes are created during spoil grading, during reclamation of selected box cuts, final pits, highwalls, and areas that blend into adjacent natural topography. After spoil grading is completed, supplemental plant-growth medium is placed and terraces constructed. Contour ripping with multi-shanked deep rippers spaced 3 feet apart, followed by the construction of contour furrows using a modified offset disk. The contour furrows will be 9 to 14 inches deep.

Scenario - 1 No erosion control measures.
Scenario - 2 Terraces.
Scenario - 3 Ripping, contour furrows, and terraces.

What Will the User Learn?

Scenario 1 of Example 4 introduces the user to the time invariant C factor. Terrace systems are examined in Scenario 2. P values for conservation planning, and for estimating the amount of sediment that leaves a terrace are contrasted in Scenario 2. In Scenario 3 the effects of contour furrows and deep ripping on soil-loss rates are demonstrated in conjunction with a system of terraces.

Design Information

Location - semi-arid southwestern U.S.

Supplemental plant-growth medium - sandy loam. Clay = 16 %, silt = 25 %, sand = 59 %, % silt and very fine sand = 31, % sand minus % very fine sand = 53, % organic material = 1.4.

Landform - uniform gradient hillslope at 20 %, hillslope length is 800 ft.

Deep Ripping

Contour furrows - spaced 3 ft apart along the contour and 10 inches in height.

Terraces - spaced 200 ft apart, 800 ft in length, placed on a 0.5 % gradient, and 4 ft in height.

Scenario 1 - No erosion control measures except a roughened surface.

Start from the Soil Loss and Sediment Yield Computation Worksheet screen.

R-factor inputs:

Albuquerque, NM, and no adjustment for ponding.

LS-factor inputs:

A single hillslope, measured on the horizontal,
sandy loam soil texture, disturbed fill, topsoil, no rock cover,
20 % gradient, and 800 ft in length.
The result is LS = 12.5.

K-factor inputs:

From a standard particle-size analysis, the nomograph inputs are silt and very fine sand = 31 % and clay = 16 %.
Percent organic material = 1.4.
Soil structure = very fine granular.
Permeability = slow to moderate.
Coarse fragment correction = 1.
The resultant K factor from the nomograph = 0.17.
Percent surface rock cover = 8.
Number of years to consolidate = 20. This value is computed by pressing F4.
Hydrologic soil group = 3.
Soil Series [leave blank].
Surface Texture is a sandy loam [3].

The K-factor does not change through time for locations in the Western U.S.

The time-invariant C factor will be used in this example. Even though the K factor does not vary with time in the Western U.S., either the time-invariant or time-variant C factor can be used to estimate the C value in either the Eastern or Western U.S. We will use the time-invariant option in this example.

C-factor inputs:

The C-factor information will be entered directly, [3],
No plant information will be applicable. The effective root mass, % canopy cover, and average fall height do not apply for bare soil conditions.
[Enter], [Enter], [Enter] to accept the default values of zero.

The roughness value is the result of rough grading using a large dozer with a wide span reclamation blade. From field observations, the range in surface roughness will be approximately 4 inches, which is the roughness immediately following the operation.

From **Figure** 7-12, the corresponding random-roughness value is [0.85].

Through time, rainfall and other processes wear down the surface so that surface roughness decreases. A roughness value appropriate for the conditions represented at the time since last disturbance is used. The site has been mechanically disturbed and the erosion computation is for the time immediately after the last disturbance.

Enter [0] to represent this time.
The surface rock % cover has been previously entered as 8%.
[Enter] [Enter] [Enter] to accept the transferred values.
The surface-cover function (b value) will be determined from the land use, together with the soil characteristics, hillslope gradient, and surface cover.
A C-factor value of 0.50 results as shown in **Figure 7-17**.
A P value of 1 will be used.
The resultant soil loss estimate is 27 tons/ac/year.

Save as EX4SCNO1.

```
              File        Exit        Help        Screen
+-------------------------< Time-invariant C 1.06 >-----------------------------+
|       where get vegetation information?: 3                                    |
|                                                                               |
|                                                                               |
|                                                                               |
|    effective root mass (lb/ac) in top 4": 0                                   |
|                              % canopy cover: 0                                 |
|                 average fall height (ft): 0        +-----------+               |
|   roughness (in) for the field condition: 0.85     | C = 0.504 |               |
|    has there been mechanical disturbance: 2        +-----------+               |
| # of years needed for soil consolidation: 20                                  |
|   number of years since last disturbance: 0                                   |
|  total % ground cover (rock and residue): 8                                   |
|      % surface covered by rock fragments: 8                                   |
|       % vegetative residue surface cover: 0                                   |
|   surface cover function; B-value choice: 1        landuse shown in LS: 8     |
|                                                                               |
| enter avg. annual values!                                                     |
+------------------------------< Esc to continue >------------------------------+
Tab  Esc F1   F3   F9
FUNC esc help cont info
```

Figure 7-17. Time Invariant C Factor Inputs

Scenario 2 - Terraces.

Two changes to file EX4SCNO1 will be necessary, one in the LS factor to reflect the change in hillslope length caused by the terraces and one in the P factor to reflect the effect of deposition in the terrace channels. With terraces located every 200 ft horizontally along the hillslope, the hillslope length is reduced from 800 to 200 ft. The effect of terraces on deposition is taken into account by the gradient along the terrace as entered through the P factor.

Start with the EX4SCNO1 file and go to the LS factor.
Change the hillslope length from 800 to 200.
The LS value changes from 12.5 to 5.27.

One major function of terraces is to reduce the hillslope length, thereby significantly reducing the LS value. The addition of terraces, with the shorter hillslope length, reduces the estimated soil loss to about 40 percent of the original rate.

Go to the P factor. Highlight "calculate frequent-disturbance P-Factor". [Enter].
Arrow to Terraced . [F4].
Enter a graded terrace, [2].

The screen message reminds the user that to use the terrace-design procedure the contouring sub-factor is first required to determine an estimate of runoff which is used, along with the soil texture and inter-terrace soil loss, to estimate sediment deposition along the terrace.

The contouring P sub-factor must be run to determine the contouring effect, if any. If no ridges are present that produce a contouring effect, the contouring P sub-factor still must be run to compute runoff values needed in the terrace sub-factor computations.

[Esc] and arrow to "contoured." [F4]
Ridge height code, [1], for no ridges.
Furrow grade, [0].
The equivalent slope has been transferred from the LS factor. [Enter].
The hydrologic soil group has likewise been transferred and will not be changed. [Enter].

Because no vegetal cover exists, and the roughness is minimum input, [6] will be used.
No strip cropping or concave hillslope configuration exists, [1].
[Esc] and arrow to "terraced." [F4]
[F3]

Terrace inputs:

This will be a graded terrace with an open outlet. [2]. [Enter].
The distance between terraces is 200 ft. [200]. [Enter].
The specified soil texture was originally input in the K factor as a sandy loam and this response appears at the input prompt. [Enter].
The gradient of the terrace is 0.5 %. [0.5]. [F3].

The estimated annual soil loss above the terrace is 11.4 tons/ac/year. [F3].

The resultant terraced P sub-factor is 0.84 and the sediment-delivery ratio is 0.14 as shown in **Figure 7-18**. If the major concern is soil loss from the hillslope surface, between terraces because of potential depletion of the soil as a productive growth medium, then the 0.84 P value is used. If we are concerned with potential off-site impacts of sediment-laden water decreasing water quality downstream, then the sediment delivery ratio should be entered as the P value.

Return to the Soil Loss and Sediment Yield Computation Worksheet.

The estimated soil loss has been reduced to 9.6 tons/ac/year and the sediment yield is 1.7 tons/ac/year.

```
       File        Exit        Help        Screen
+------------------------< P Factor - Terraced 1.06 >--------------------------+
|                               terrace type code: 2                           |
|         horizontal interval between terraces (ft): 200                       |
|                          specified soil texture: sandy loam                  |
|              graded outlet has a percent grade of: 0.5                       |
|     est. annual soil loss above the terrace (T/A): 11.4                      |
|                                                                              |
|                                                                              |
|                                                                              |
|             +-----------------------------------------------------------+    |
|             | Terraced P subfactor = 0.843  (sed. del. ratio = 0.145)   |    |
|             |                                                           |    |
|             | Takes credit for deposition as a benefit for soil saved.  |    |
|             | See help screen for additional information.               |    |
|             +-----------------------------------------------------------+    |
|                                                                              |
+-------------------------< F3 When Questions Answered >-----------------------+
Tab  Esc F1   F3   F9
FUNC esc help cont info
```

Figure 7-18. Terrace Input Screen and Result

The graded-terrace system was effective in reducing off-site sediment delivery from 27 to 1.7 tons/ac/year . This reduction occurred for two reasons. The terraces shortened the hillslope length from 800 ft to 200 ft, which reduced soil loss by about 60 percent. In addition, the terraces trapped about 86 percent of the sediment eroded from the inter-terrace area. Thus the graded terrace had an average annual sediment trap efficiency of 86 % (1-sediment delivery ratio). Through use of a terrace system, the off-site soil loss was decreased by an order of magnitude, 27 to 1.7 tons/ac/year, compared to the "no erosion controls" of Scenario 1.

Save as EX4SCNO2.

Scenario 3 - Ripping and contour furrows added to the inter-terrace areas of Scenario 2

The expected impact of deep ripping is to increase the infiltration rate until the openings become filled with rainsplashed soil and deposited sediment. Because this site is located in the semiarid southwest with low precipitation, such deposition may take many years. The contour furrows will also significantly increase ponding of runoff, thereby further increasing infiltration to provide the moisture needed to establish vegetation, and reducing the erosivity of runoff. Changes will be required in the C and P values.

The K-factor is adjusted in this case. The definition of K is based on the standard unit-plot condition, and the K value represents a single specific condition unaffected by management. Parameter values for estimating K are selected based on how the soil would behave through the long term if it were regularly tilled as an agricultural soil. Deep ripping is assumed to have a long-term effect on the soil that persists during the 20 years to consolidation. The effect of deep ripping on the K value is to change the permeability rating of the soil from "slow to moderate" to "moderate." The adjusted K value is now 0.14 rather than the original 0.16. The other change due to deep ripping is to assume that there is also a long-term effect on the hydrologic group for the soil, namely from group [3] to group [2].

C-factor inputs:

The field roughness value increases due to the ripping operation. Based on field observations from other sites, the range in surface elevation is 12 inches, resulting in a Random Roughness value of 2.5.
The time since last disturbance is set to [0] to represent soil loss immediately after the disturbance.
It is important to note here that the roughening effect of ripping is considered to be temporary for the C factor. The roughness disappears through time as the peaks are eroded by rainfall and surface flow and the depressions are filled with sediment.

Even though contour furrows decrease the flow path of runoff to just a few feet along a uniform hillslope, the hillslope length is selected as if the surface is smooth.

The C value changes from 0.50 in Scenario 2 to 0.17 as a result of the ripping.

P-factor inputs:

Select "calculate frequent-disturbance P factor".
Select contouring. [F4].
Because the ridge height is greater than 6 inches, select [6].
Furrow grade - The furrows are designed to be on a zero gradient, but some deviation can be expected. [0.5].
The cover/management roughness code at the time of disturbance is considered to be very rough [3].
Do not have vegetative strips or concave hillslope, [1].
No other changes are needed.

The P sub-factor for conservation planning with the terrace is 0.90 and the sediment-delivery ratio is 0.48. The overall P value for conservation planning is 0.21.

Be sure to recompute the terrace sub-factor after changes in other parts of RUSLE. The program does not automatically update this computation after a change in the contouring sub-factor.

Note that the sediment delivery ratio greatly increased with the change in the contouring. The reason for the increase in the sediment delivery ratio is that deposition only occurs in the terrace channel when the transport capacity of the flow is less than the sediment load arriving at the terrace channel. The addition of contouring reduced the sediment load much more than the transport capacity of the flow was reduced in the terrace channel. Sediment yield from a terrace channel where deposition is occurring is controlled by the transport capacity in the terrace channel.

Average annual soil loss is estimated to be 0.7 tons/ac/year.
The sediment-delivery ratio is 0.48 for the terrace system.
The sediment yield is 0.34 tons/ac/year based on 0.7 x 0.48

Comparing Scenarios 2 to 3 (i.e. the addition of contour furrow and deep ripping to the terrace design), there is about an order of magnitude reduction in soil loss, from 9.6 to 0.7 tons/ac/year. Sediment yield decreased from 1.7 to 0.3 tons/ac/year resulting in a 82% reduction in the transport of sediment to a stream channel or sediment-control structure.

Save as EX4SCNO3.

Example 5: Pre- and post-mining soil loss emphasizing effects of vegetation.

Problem Statement: Estimates of soil loss during pre-mining conditions are based on the undisturbed plant community. After mining and before phase III bond release, the disturbed surface will be in transition with respect to plant development and soil conditions, experiencing a reduction in initial soil-surface roughness, with deposition of soil along contours and terraces, and soil consolidation. Soil consolidation is a key factor in determining soil loss during the phase III bond-release period. The use of the RUSLE program is illustrated for pre-mining and post-mining soil-loss estimates.

Scenario 1 - Estimating pre-mining soil loss
Scenario 2 - Estimating soil loss at Phase III bond release

What Will the User Learn?

C-factor plant-community inputs for pre-mining conditions are emphasized in Scenario 1. Scenario 2 illustrates the method to evaluate an established plant community, 10 years after reclamation, for phase III bond release.

Design information

Location - Northern Mountain States

Soil - Soils used in this example are typical of many soils on ridgetops and upland sideslopes in the mountain states. Soils are deep (40 to 60 inches) and develop from colluvium and some alluvium derived from interbedded sandstone. Subsoils are generally clayey and have a weak structure. Permeability of this soil is moderate as is the available-water holding capacity. The example soil is a clay loam with a moderate medium subangular blocky structure. The percent sand, silt, and clay is 36, 32, and 32, respectively. The % silt and very fine sand = 37, % sand minus very fine sand = 31, percent organic material = 2.6.

Landform - hillslopes are generally convex to uniform. The pre-mining hillslope is slightly convex with an overall gradient of approximately 9.5 percent.

Vegetation - grasses, forbs, and scattered shrubs at an elevation of 7000 to 7600 ft. Pre-development vegetation consists of wheatgrass, serviceberry, sagebrush, chokecherry, snowberry, gambel oak, and various forbs. During reclamation the vegetal mix consists of grasses, forbs, and shrubs.

Scenario 1 - Pre-mining soil loss estimation

Start from the Soil Loss and Sediment Yield Computation Worksheet screen.

R-factor inputs:
Select Grand Junction, CO with no adjustment for ponding.

LS-factor inputs:

A convex hillslope measured on the horizontal, clay loam soil texture, with the land use as range, except coarse textured soil [5] is input.
Segment 1 - hillslope gradient 6 %, 370 ft in length
Segment 2 - hillslope gradient 12 %, 220 ft in length
LS = 1.45

K-factor inputs:

% silt and very fine sand = 37
% clay = 32
% organic material = 2.6
soil structure = blocky
permeability = moderate

no significant rock fragments within the soil matrix
Percent surface rock cover = 0.
15 years to consolidate in the Western United States
hydrologic soil group 3
soil texture, clay loam.
K = 0.214

C-factor inputs:

Information source will be a plant scientist in the reclamation department, the NRCS state agronomist, Bureau of Land Management (BLM) range scientist, or other qualified plant specialist.

Time-invariant.
Vegetation information from plant community and site potential, [1].
Plant community - chaparral, [10].
Annual site production potential - [700] lb/ac.
The effective root mass in top 4 inches - a value of 350 lbs/ac is derived from the plant community data within RUSLE.
Canopy cover - [85] %.

Average fall height -- There are essentially two kinds of vegetation. The tall mountain brush will be approximately 7 ft in height with an average fall height of approximately 4 ft.
The sagebrush is about 2 ft in height and the fall height is assumed to be about 12 inches. Because there is about a 50-50 mix of these two types of vegetation an average fall height of [2.5] ft will be used.
Roughness value for natural shrub is .8 and sagebrush is 1.1; so select [.95].
No previous mechanical disturbance, [1].
Total % ground cover (rock and residue) - leave at 0.
% surface covered by rock - [0]. (From the K factor).
% vegetative residue surface cover - [60].
The total % of ground cover is calculated within the program as 60 %.
Surface cover function - computed from the land use, [1].
The resultant C value is 0.012.

P-factor inputs:

Because no disturbance occurred prior to mining, a P factor of 1 is entered.
The estimated soil loss from this pre-development site is 0.04 tons/ac/year.

Save as file EX5SCNO1

Scenario 2 - Reclaimed Mined Land

This scenario estimates soil loss 10 years after initial reclamation. To be very conservative, terraces are assumed to be nonfunctional, contour furrows are non-functional, and the positive effect ripping and disking are not considered. This scenario focuses on the effectiveness of revegetation and soil consolidation.

Load EX5SCNO1

R-factor inputs:

No changes except for linked changes to the LS value.

Ls-factor inputs:

The reclamation landform will be slightly less convex than that of the pre-mining hillslope shape.

Segment 1 - 8 %, 340 ft.
Segment 2 - 10 %, 250 ft.
The LS value changed only slightly from 1.45 for the pre-mining condition to 1.43 for the post-mining condition.

K-factor inputs:

The only change is to the number of years to soil consolidation, which will be changed to [10].
Resultant K = 0.21 which is the same as the pre-mining condition.

C-factor inputs:

The proposed seed mix for reclamation is approximately 16 pure live seeds per square ft of grasses, predominantly wheatgrass, bluegrass, fescue and redtop, 15.5 pure live seeds per square ft consisting of a variety of forbs, and 12.6 pure live seeds per square ft of shrubs dominated by rabbitbrush, sagebrush, and bitterbrush.

During reclamation there is a plant community shift from chaparral to a Northern mixedgrass prairie with some chaparral-type vegetation.

Select [2], N mixedgrass prairie, because this will be the dominant vegetation type.

The annual site potential production of a reclaimed site is much greater (based on extensive measurements) than the natural condition so increase this parameter from 700 to [2000] lb/ac.

The effective root mass will also be increased by the RUSLE program to 3000 lb/ac.
The % canopy is approximately the same so leave at 85 %.
The average fall height will be reduced from 2.5 ft to 1.5 ft based on the reclaimed vegetation.
Roughness will be slightly higher than the natural state. Change from 0.95 to [1.0].

When the time of interest for the C factor is beyond the time required to reach consolidation, no mechanical disturbance option should be chosen; no, [1].

Because this area receives about 15 inches of precipitation per year and a portion of this is in snowfall the number of years for soil consolidation is [10] rather than the average of 7.

The total percent ground cover will be calculated by the program based on the next two inputs so enter [0].
The percent rock fragments will remain nearly equal, [0].
The % vegetative residue will increase to [80].
The resultant C value is 0.0008.
P-factor inputs:

Assign a [1] to the P factor.
The estimated soil loss is 0.0 tons/ac/year.

The results of both analyses suggests that no significant erosion will occur during the pre-mining period or 10 years after mine reclamation.