

Revised Universal Soil Loss Equation Version 2

(RUSLE2)

HANDBOOK

Prepared by the USDA RUSLE Development Team:

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WELCOME TO RUSLE

Version 2 of the Revised Universal Soil Loss Equation (**RUSLE2**) estimates soil loss from rill and interrill (sheet and rill) erosion caused by rainfall and its associated overland flow. **RUSLE2** uses six factors for climatic erosivity, soil erodibility, slope length, slope steepness, cover-management, and support practices to compute soil loss.

RUSLE2 is a powerful tool for conservation planning, inventorying erosion rates over large areas, and estimating sediment production that might become sediment yield in watersheds. It can be used on cropland, pastureland, rangeland, disturbed forestland, construction sites, mined land, reclaimed land, landfills, military lands, and other areas where surface overland flow occurs because rainfall is greater than infiltration.

ABOUT VERSIONS OF RUSLE

This Handbook provides guidelines for users of **RUSLE 2**. RUSLE versions 1.05 and 1.06 are also widely used. If you are using a version of RUSLE1, we recommend that you switch to **RUSLE2**. **RUSLE2** uses a modern graphical user interface instead of the text-based interface of RUSLE1 with many new features including global change of units between US customary and SI units, which makes **RUSLE2** far easier to use than RUSLE1 where SI units are preferred. The interface allows values for individual variable to be graphed, units changed, and number of significant digits to be changed. Also, **RUSLE2** is much more powerful than RUSLE1, has improved computational procedures, and provides far more output useful for conservation planning than does RUSLE1. Much of the data in RUSLE1 data files is directly transferable to the **RUSLE2** database using procedures included in **RUSLE2**.

ABOUT THE HANDBOOK

This Handbook describes **RUSLE2**, its factors, selection of input values to compute its factor values, and application of **RUSLE2**. The TABLE OF CONTENTS lists the topics covered by the User's Guide.

RUSLE2 is a straight forward, easily used computer program that is best learned by using it. As you become familiar with the operation of the program, we encourage you to thoroughly read the Handbook on **RUSLE2**.

Like all other hydrologic models, **RUSLE2** has its limitations and its proper approach for selecting input values and interpreting computed values. Before you begin to apply **RUSLE2** to your own problems, you should become well acquainted with **RUSLE2** and its factors.

This Handbook provides instructions for application of **RUSLE2**. This guide is not complete, but it should be sufficient for most applications. Additional information is available in the **RUSLE2** program itself on the **HELP** screens. Agriculture Handbook No. 703 (AH703), entitled "Predicting Soil Erosion by Water - A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE)," is the reference manual for RUSLE1¹. This handbook

¹Renard, K. G., G. R. Foster, G. A. Weesies, D. K. McCool, and D. C. Yoder, coordinators. 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation

provides detailed information on the mathematical equations used in **RUSLE1**, input parameters, input values, and how to obtain them, and how to interpret output. **AH703** contains many tables and figures, some of which are referenced in this User's Guide, that are helpful in using **RUSLE2**. Many of the equations in **RUSLE2** have been changed from those used in **RUSLE1**, but the general approach is the same in both **RUSLE1** and **RUSLE2**. A document similar to **AH703** will be prepared to describe equations, procedures, and core data for **RUSLE2**.

Customer Support

The USDA-Natural Resources Conservation Service (NRCS) is the major user of **RUSLE2** and has developed much expertise and specialized database information for application of **RUSLE2**. Contact your NRCS state agronomist to obtain additional databases, information, and assistance on **RUSLE2**.

The USDA-Agricultural Research Service (ARS) is the lead research agency that developed **RUSLE2**. Much of the scientific information in **AH703** provides general background on **RUSLE2**. Further information on the scientific development of **RUSLE2** can be obtained from Dr. George Foster (address below). Information on the modeling and computer structure of **RUSLE2** itself, its interface, and database can be obtained from Dr. Daniel Yoder (address below).

To ensure consistent application of **RUSLE2** across geographical and political boundaries, NRCS personnel are encouraged to contact their technical specialist with **RUSLE2** responsibility. That individual will work with the Cooperating Scientist for Erosion and Sedimentation, Glenn Weesies, to obtain information and assistance with application of **RUSLE2**.

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(RUSLE). U. S. Department of Agriculture, Agriculture Handbook No. 703, 404 pp.

ABOUT RUSLE2

The structure of the revised universal soil loss equation **RUSLE2** is based on the Universal Soil Loss Equation (USLE), which is given by:

$$A = R K L S C P$$

where **A** = average annual soil loss from rill and interrill erosion caused by rainfall and its associated overland flow (tons ac⁻¹ yr⁻¹), **R** = the factor for climatic erosivity, **K** = the factor for soil erodibility measured under a standard condition, **L** = the factor for slope length, **S** = the factor for slope steepness, **C** = the factor for cover-management, and **P** = the factor for support practices. A value for soil loss **A** is computed by selecting values for each factor and multiplying them.

These factors represent the effect of climate, soil, topography, and land use on rill and interrill erosion. By assigning values to these factors based on site-specific conditions, the USLE computes soil loss for specific sites, and it can be used to guide conservation planning tailored to individual field sites.

RUSLE1 was a revision and update of the Universal Soil Loss Equation (USLE), which has been widely used since the early 1960s. The first version of the USLE was described in Agriculture Handbook No. 282, published in 1965. The second major version of the USLE was described in Agriculture Handbook No. 537, published in 1978. RUSLE1 is the third version of the USLE, and it is described in Agriculture Handbook No. 703, published in 1998 by the U.S. Department of Agriculture, Washington, D.C. RUSLE1 retained the equation structure of the USLE, but each factor was either updated with recent data, or new relationships were derived based on modern erosion theory and data.

The major fundamental difference between **RUSLE2** and the USLE and RUSLE1 is in the method used to solve governing equations. Mathematical approximations were used in the USLE and RUSLE1 to integrate time varying equations that underlie the erosivity, topographic, erodibility, cover-management, and supporting practices factors. These approximations were used to produce a simple, powerful, method to compute soil loss that could be used in a “paper version” form in field offices. RUSLE1 was also available in a computer program.

RUSLE2 uses a much more detailed and proper mathematical approach to integrate the underlying governing equations, which makes **RUSLE2** more powerful and accurate for many conditions than either the USLE or RUSLE1. The increased complexity of the mathematical procedures used in **RUSLE2** requires that **RUSLE2** be used as a computer program rather than in a paper version. If a paper version of **RUSLE2** is to be used, its values should be based on computations using **RUSLE2** rather than continuing to use RUSLE1. An appendix to this User Guide describes differences between the USLE, RUSLE1, and **RUSLE2**.

RUSLE2 uses a hybrid approach that combines empirically derived equations with those derived from theory for erosion processes to estimate rates of rill and interrill erosion. The underlying structure of **RUSLE2** uses empirical indices for the major factors that affect rill and interrill erosion. The governing equations for these indices are derived both from an analysis of empirical

data and from modern theory for erosion processes and mechanics. More than 10,000 plot-years of data from natural runoff plots and an estimated equivalent 2,000 plot-years of rainfall simulator data were used in the derivation and validation of **RUSLE2**. It is an exceptionally well-validated erosion prediction technology that has been proven by more than four decades of use of its predecessors, the USLE and **RUSLE1**. Modern theory on erosion processes of detachment, transport, and deposition of soil particles by raindrop impact and surface runoff was used to derive several of the **RUSLE2** relationships where the necessary equations could not be derived from empirical data.

A strength of **RUSLE2** is that it has been developed by a group of experienced and nationally recognized erosion scientists and conservationists. Data needed to develop and validate **RUSLE2** were not complete in all cases, which necessitated using judgement of both scientists and users of the equation to fill gaps. In addition, **AH703** and publications on various **RUSLE** components have been reviewed by peer scientists in a process typical of the reporting of rigorous research results. Erosion scientists and NRCS technical specialists have made many runs with **RUSLE2** to ensure that it works well for every imaginable condition where **RUSLE2** will be applied. The scientific documentation for **RUSLE2** will be peer reviewed according to USDA standard procedures. Thus **RUSLE2** can be used with full confidence that the equation meets high scientific standards.

RUSLE2 is to be used as a guide to conservation planning rather than as a precise estimator of soil loss. It represents the main trends demonstrated in field data, but the accuracy of **RUSLE2** estimates varies depending on the magnitude of the soil loss, land use, and other factors. Uncertainty in **RUSLE2** estimates is discussed in a later section. While **RUSLE2** is based on modern erosion science and includes numerous features never before used in applied erosion prediction technology, it is not designed for research purposes.

Numerous erosion variables are computed by **RUSLE2** depending on how the landscape is represented for a **RUSLE2** computation. The basic application is to a hillslope profile defined as the path from where overland flow originates to where it enters a major flow concentration. **RUSLE2** can consider the effect of conditions varying along the hillslope profile, including those related to steepness, soil, and cover-management conditions. In addition to computing rill and interrill erosion on the eroding portions of hillslopes, it also computes the deposition that occurs on hillslope segments induced by changes in topography and cover-management conditions. The main erosion variables computed by **RUSLE2** are sediment yield from the hillslope profile, total sediment detached on the hillslope profile, soil loss from eroding portions of the hillslope profile, and a conservation planning soil loss that takes in account amount and location of deposition on the hillslope profile. **RUSLE2** also computes erosion and deposition rates along a hillslope profiles. The sediment yield computed by **RUSLE2** is not necessarily the sediment yield from a field or watershed unless the end of the hillslope profile happens to end at the field or watershed boundary.

Several important terms are used with **RUSLE** to describe the erosion process. In the mid-1940's, W. D. Ellison defined erosion as, "... a process of detachment and transport of soil particles." Detachment is the removal of soil particles from the soil mass and is expressed in units like tons ac⁻¹. Once soil particles are removed from the soil mass, these particles are referred to as sediment. The movement of sediment downslope is sediment transport, and a measure of

sediment transport is sediment load. Sediment load is expressed in units like lbs./(ft width of slope)⁻¹. The sediment load at the end of the hillslope profile is defined as sediment yield.

Sediment load on a hillslope profile increases with distance downslope where detachment is occurring. That is, detachment adds to the sediment load. Conversely at locations where runoff is slowed like at the toe of concave slopes or by strips of dense vegetation, deposition occurs, transfers sediment from the sediment load to the soil mass. That is, deposition removes sediment from the sediment load, and sediment accumulates on the soil surface. Deposition is a selective and sorting process. When deposition occurs on a portion of a landscape, coarse sediment is deposited in the depositional area and fine sediment remains in the sediment load that is transported downslope. The size of the particles in the sediment load downslope from the depositional area is finer than the particles in the sediment load upslope from the depositional area and finer than the particles in the soil where the sediment was originally produced by detachment. Sediment yield from a landscape experiencing deposition is enriched in fines in relation to sediment from a similar area not experiencing deposition.

RUSLE2 computes values for the size of sediment classes and the distribution of the sediment among classes based on soil texture and the degree that deposition has reduced the sediment load.

RUSLE2 computes deposition using equations for transport capacity and deposition mechanics as a function of runoff hydraulics and sediment characteristics and how these variables change along a hillslope profile. For example, **RUSLE2** takes in account how the sediment load becomes progressively finer as deposition occurs along a concave slope.

Two types of deposition, remote and local, occur. Remote deposition is that deposition that occurs some distance away from the origin of the sediment. Deposition on the toe of a concave slope, on the upper side of vegetative strips, and in terrace channels is an example of remote deposition. Local deposition is where sediment is deposited very near, within several inches, of where it was detached. Deposition in micro-depressions and in low gradient furrows is an example of local deposition. The difference between detachment and local deposition is called net detachment. Full credit for soil saved is taken in **RUSLE2** for local deposition, but the credit given to remote deposition as soil saved depends on the location of the deposition. Sediment deposited at the end of a hillslope profile is given very little credit as soil saved.

RUSLE2 computes soil loss as the amount of net amount of sediment produced on a segment of the hillslope profile divided by the length of the segment. Typical units are tons ac⁻¹. **RUSLE2** also computes sediment load (delivery) at locations along the hillslope profile at ends of segments. These values as computed as sediment load at a given location divided by the slope length to that location. Typical units are tons ac⁻¹.

RUSLE2 is principally used to estimate the rate that erosion is removing soil from critical parts of the landscape and to guide the choice of conservation practices to control erosion to a “soil loss tolerance” level. Soil loss tolerance is the average erosion rate that can occur with little or no long-term degradation of the soil. Soil loss tolerance, or **T**, values have been assigned by the NRCS to major soils in the US. Typical values of **T** range from 3 to 5 tons ac⁻¹ yr⁻¹ with some values as low as 1 ton ac⁻¹ yr⁻¹ for lands where the soil is very fragile.

In a typical application, **RUSLE2** computes soil loss values based on site-specific values for the main variables that affect rill and interrill erosion based. These values are related to climatic

erosivity at the location, erodibility of the soil based on soil survey information, length and steepness of the hillslope profile representing the critical portion of the site, and land use. If the computed soil loss is less than the **T** value, control of rill and interrill erosion is assumed to be adequate. If computed soil loss exceeds the **T** value, rill and interrill erosion is considered to be excessive and improved erosion control is needed. Alternative conservation practices are proposed and evaluated with **RUSLE2**. Those practices that give estimated values of soil loss less than or equal to the **T** value are considered acceptable.

RUSLE2 can be used to estimate sediment yield from large watersheds by multiplying soil loss estimates by a sediment delivery ratio that depends primarily on watershed area. Sediment yield on a per unit area basis and sediment delivery ratios generally decrease as watershed size increases. **RUSLE2** is not a sediment yield equation but is an equation for sediment production by rill and interrill erosion on overland flow areas, which is a major source of sediment in many watersheds. In addition, erosion in concentrated flow areas (ephemeral gullies), classical gullies, stream channels, and mass movement of material into channels are other major sources of sediment that contribute to sediment yield but are not estimated by **RUSLE2**.

Sediment yield from most watersheds is often less than sediment production within the watershed. Thus, much sediment is deposited within a typical watershed. **RUSLE2**, in contrast to the USLE and **RUSLE1**, can estimate the deposition that occurs on the overland flow portion of the landscape. The amount of this deposition can be substantial on many hillslopes. If **RUSLE2** is being used to estimate sediment yield in watersheds, it should be applied to the eroding portion of the landscape to make a soil loss computation comparable to that produced by the USLE. Otherwise, a different set of sediment delivery ratio values from those used by the USLE would have to be used with **RUSLE2**.

General Use of the **RUSLE2 Program**

The **RUSLE2** program is simple and easy to use. Rill and interrill erosion at a specific site is a function of the weather, soils, topography, and land use at the location. Data for variables that represent these factors are stored in **RUSLE2** databases. **RUSLE2** is run by selecting database entries to represent site-specific conditions. **RUSLE2** then computes soil values using this information. Most of the input values needed to run **RUSLE2** are readily available in existing database files that are supplied with the program. If the necessary data are not available, the parameters used in **RUSLE2** are simple so that new values can be easily developed.

Erosivity (**R** factor) values for locations where a particular user will apply **RUSLE** are in a database file in the **RUSLE** computer program or in AH703, Figures 2-1 through 2-5. **RUSLE2** also uses values for the bimonthly distribution of the erosivity, which are available in AH703. Values used by **RUSLE2** for average monthly temperatures and precipitation are available in the **RUSLE2** data files supplied with the program or can be obtained from readily available weather records.

Soil erodibility (**K** factor) values are selected from soil survey information available in field offices of the USDA-Natural Resources Conservation Service (NRCS). The particular site is located on a soil survey map, and the erodibility of the soil-mapping unit at the site is identified

and entered into the **RUSLE2** program. If values are not available, they can be calculated using the Soil Erodibility Nomograph in the **RUSLE2** program.

Slope length, steepness, and other topographic values are determined from an on-site visit or from other topographic information such as highly detailed contouring maps. These values are entered directly in the **RUSLE** program.

Land use is the simple most important factor that determines rill and interrill erosion. The typical objective in conservation planning is to use **RUSLE2** as a guide in choosing a land use practice that controls erosion to an acceptable rate. The effect of land use in **RUSLE2** is considered in the terms of management practices along with supporting practices like contouring that is added to the basic management practice.

Management practices refer to such things as the tillage, cropping, vegetation, and erosion control materials that are applied to the hillslope. A database file for a management practice in **RUSLE2** involves a set of dates with corresponding operations, vegetations, and residues. A typical management file for a “conventional” cropping system for corn is illustrated in Table ??.

Numerous management files are include in the management database that comes with the **RUSLE2** program. When **RUSLE2**, the user selects an existing management file, or a new one is created to represent the particular field condition. In almost all cases, an existing management file can be used, but if a new one is created, it is saved for use in other similar applications.

Operations are discrete events that change properties of live vegetation, residue, and/or the soil that affect rill and interrill erosion. Examples of operations include tillage, planting, harvesting, grazing, burning, frost, ripping, and blading. Certain information used to describe operations is stored in operation files that are contained in a **RUSLE2** operations database that comes with the **RUSLE2** program. Operations are selected from the operation database to describe management practices. If an operation is not available in the operations database, one can be created and stored in the database for later reuse.

Vegetation is one of the most important factors that affect erosion. Certain operations like those associated with planters and drills that seed crops call a vegetation file that represents live vegetation that is being considered in the application of **RUSLE2**. Just like for operations, vegetation files are developed for the various vegetations that are encountered in **RUSLE2** applications. Several vegetations are in the vegetation database that comes with **RUSLE2**. If the necessary file is not available in the **RUSLE2** database, a new vegetation file can be created and added to the database.

Ground cover produced by crop residue and plant litter is the single factor having the greatest effect on erosion. Plant residue is the vegetative material left after live vegetation is killed. Such operations as shredding and tillage convert standing residue to flat residue and to buried residue. **RUSLE2** also track both live and dead roots. Each vegetation produces residue. Residue data files are included in the residue database provided with **RUSLE2**. A residue file is assigned to each vegetation file, and additional residue files can be created and saved in the **RUSLE2** database.

Residue data files are also used to describe mulch and manufactured materials applied to construction sites to control erosion.

RUSLE2 comes with an incomplete database, which is intended primarily to illustrate typical information in the database rather than to serve as a working database. A much more complete RUSLE2 database is available from the NRCS state office, which can usually be obtained by contacting the NRCS State Agronomist.

BASIC OPERATION OF RUSLE2

The purpose of this User's Guide is primarily to describe individual RUSLE2 factors and to provide guidance on how to choose values used by RUSLE2. However, that information is best described by having the RUSLE2 program open and moving through the program as various topics are discussed. The following information is a general overview. Other documents should be consulted to provide details on the mechanics of the RUSLE2 program.

When RUSLE2 is initially started, the opening screen requires two selections. The first choice is to choose from objects for worksheet, hillslope profile, climate, storm erosivity, soil, management, operation, vegetation, and residue. The worksheet and hillslope profile objects are used to make erosion computations. The other objects are used to place information in the RUSLE2 database.

Worksheet

The worksheet object is used to carry out computations for multiple management practices on a single hillslope profile or carry out computations for multiple hillslope profiles. Individual worksheets and the information in them can be saved with a name for the worksheet chosen by the user.

Hillslope profile

The hillslope profile object is used to compute erosion for a single hillslope profile. Hillslope profiles and the information associated with them can be saved with a name chosen by the user. A single hillslope profile can be viewed as the erosion computation for a specific overland flow path at a particular location on a particular landscape with a particular land use or possible land use. Thus the information associated with a profile includes location, soil, topography, management, and supporting practices.

Climate

The climate object describes the weather information for the site. The information in this object includes data on annual erosivity, 10 yr EI storm, average monthly temperature, and average monthly precipitation. Information is cataloged in the database according to names of locations.

Storm erosivity

Storm erosivity varies through the year depending on location. The information in the storm erosivity object describes how erosivity varies during the year as a function of zones or regions. Information is cataloged in the database according to a zone number.

Soil

The soil object includes information on soil erodibility, soil texture, hydrologic soil group, and rock cover. Also, this object includes the soil erodibility to compute a value for the soil

erodibility factor if one is not available. Information is cataloged in the database according to a soil name, which could be a soil-mapping unit from an NRCS soil survey.

Management

The management object contains information on management practices. Each practice typically includes a list of dates and the operations, vegetations, and applied materials like mulch and manure associated with each date. Information is cataloged in the database according to a management name chosen by the user.

Operation

The operation object contains the information used to describe operations. A key component of the information used to describe an operation is processes including begin growth, kill vegetation, flatten standing residue, disturb surface, remove surface cover, and remove live biomass. Information is cataloged in the database according to an operation name chosen by the user.

Vegetation

The vegetation object contains the information used to describe live vegetation. This information includes a name for the residue to associate with the vegetation and data on yield, the relationship of above ground biomass to yield, how the vegetation slow runoff, and temporally varying values on root biomass, canopy cover, fall height, and live ground cover. Information is cataloged in the database according to a vegetation name chosen by the user.

Residue

The residue object contains the information used to describe residue. This information includes data related to the rate that the residue decomposes on and in the soil and the amount of mass that covers a particular portion of the soil surface. Information is cataloged in the database according to a residue name assigned by the user.

Template

The other choice is a template that controls the amount of information that RUSLE2 displays. Templates are customized for particular applications, where increasing amounts of information is displayed. Also, the templates can be customized to use terminology that is common to a particular organization or discipline.

Chose the NRCS Field Office (beginners) template and the profile object when you first begin to use RUSLE2. This template shows the steps of using RUSLE2. Simply follow the steps to compute a soil loss value. Try changing some of the inputs and notice the change in the computed soil loss value.

Now, switch to the NRCS Field Office (summary) template. To switch to that template, use the icon on the toolbar. Move the cursor to the load template icon on the tool bar and click. Select the summary template.

This template uses a set of folders for soil, topography, and management that are opened to enter values. Not only are these folders included input, they also contain output directly associated with the variable represented by the folder. The output in these folders becomes especially important when the hillslope profile is divided into segments.

Tool bar

The tool bar across the top of the screen contains icons that give immediate access to RUSLE2 functions and databases. The functions of these icons are described in other documents.

Menu

Similar to the icon bar, the menu bar gives immediate access to certain RUSLE2 functions. The file menu is especially important because it allows choice among alternative databases and to import data from RUSLE1. The other very important menu choice is the help item.

Special RUSLE2 interface features

RUSLE2 is driven by a tremendously powerful interface and uses certain conventions.

Variables in RUSLE2 have several attributes including a name, values, units, and significant digits. RUSLE2 has the capability of working with these attributes. To gain access to these capabilities, place the cursor over the variable name and right click on the mouse, which displays a list of actions that can be taken for that variable. For example, the variable can be graphed, units can be changed, and the number of digits displayed can be changed. Certain names can be changed. These changes can be saved in the template being used.

RUSLE2 operates on a top down principle. No more information is displayed than is needed to accomplish the task at hand. For example, to compute a soil loss, all that is required of the user is to choose a location, a soil, slope length and steepness, a management, and supporting practices, as can be done with the beginners template.

Far more information is involved in the soil loss computation that is seen by the user, but this information can be seen by “drilling down.” The upside down triangle to the right of the field on a variable means that a list of items for the variable is available from the user chooses a particular one. Click on the upside down triangle displays the list.

The yellow folder to the left in the field of a variable means that information is behind the variable. The information can be displayed by clicking on the folder.

Hillslope profile layers

Some of the templates display a hillslope profile schematic with three layers. The upper layer represents management, the middle layer represents soil, and the lower layer represents topography.

Adding segments

Segments along the slope for soil, topography, and management can be created in two ways. One way is to “cut” the slope into segment by clicking on the “add break” button and moving the scissors to the layer and location along the slope where a “cut” (segment) is to be made. Open up the corresponding folder and select information for management, soil, and steepness for each segment. This approach can be used to create hillslope profiles with convex, concave, and complex shapes; different soils along the slope; and strip cropping, buffer strips, and filter strips.

Click on the “erase button” to remove a segment break. Move the eraser to the break that is to be removed and click.

The second way of adding segments is to use the “+” button to create a new segment. The entry in the above the new segment is copied into the new segment. Change the entry in the new segment to the desired value. The “-“ button removes segment. Select the segment that is to be removed as a row would be selected in a spreadsheet, and click on the “-“ button.

CLIMATE OBJECT

Open the Climate Object for a particular location. The window for the Climate Object includes several areas. The area in the upper right is for entering basic erosivity values. The area just below this group is for the Northwest Wheat and Range Region where erosivity values must be adjusted for the highly erosive conditions during the winter. A single selection needs to be made for varying soil erodibility during the year. The bottom part of the window involves three folders labeled monthly, daily, and info.

R Values

The erosivity of rainfall varies greatly by location. For example, erosivity in central Mississippi is about 10 times that in western North Dakota. The **R** factor represents these differences in erosivity among locations. Values for **R** computed from weather records were used to produce the maps shown in Agricultural Handbook No. 703, Figures 2-1 through 2-5. Be careful in using **R**-values computed for a specific location. Values from **R** maps are preferred in the eastern U. S. because the **R** maps have been drawn to smooth unimportant variations. However, in mountainous areas, values of **R** can vary greatly over a relatively short distance because of the effect of elevation on rainfall, and values for the **R** map may not be accurate for a specific location if selected from a map without sufficient detail.

Special consideration is given to cropland in the Northwestern Wheat and Range Region (NWRR)², adjacent areas with similar climate, and the mountainous areas of the western U.S. Erosion from rainfall and/or snowmelt on thawing cropland soils in the NWRR is much greater than expected based on standard **R**-values. Therefore, equivalent **R**-values, **R_{eq}**, were developed for applying **RUSLE2** to cropland in the NWRR. Maps of these **R_{eq}** values are given in Agricultural Handbook No. 703, Figure 2-6 and 2-7. Use Agricultural Handbook No. 703, Figures 2-2, 2-3, and 2-4 to select **R** values when applying **RUSLE2** to land uses other than cropland in this region.

These special values can be used in **RUSLE2** by answering Yes to the question **In Req area?** By answering **Yes**, **RUSLE2** computes an equivalent R-value from monthly precipitation values. **Req** values are much larger than those computed from rainfall data using standard procedures.

²The Northwest Wheat and Range Region includes about 10 million acres of non-irrigated cropland in parts of eastern Washington, north central Oregon, northern Idaho, southeastern Idaho, southwestern Montana, western Wyoming, and northwestern Utah. Runoff and erosion processes in this area are dominated by winter events. Many of these events involve rainfall and/or snowmelt on thawing soils. The thawing soils remain quite wet above the frost layer and are highly erodible until the frost layer thaws allowing drainage and consolidation. The transient frost layer near the surface limits infiltration such that almost all rainfall and snowmelt runs off and creates a super-saturated moisture condition.

A special region in northwestern Colorado is assumed to have a combination of rainfall, runoff and soil characteristics between those in the NWRR and the eastern U.S. Another special region is in southeastern Utah and southwestern Colorado. The R_{eq} values for these special regions can be obtained from state agronomists in those states.

In the eastern U.S., a single location is usually sufficient for applying **RUSLE2** in a county. However, in large counties, especially in the mountainous regions of the western US, several locations within a county may be needed. As a guide, variations within 5 percent can be represented with a single **R**-value in a locale such as a county.

Erosivity varies greatly by elevation in mountainous areas. Since weather stations tend to be located in populated valleys, data may not be available for all locations where **RUSLE2** might be applied. The following is suggested when **RUSLE2** is applied where data are not available to directly compute an **R** value from weather records: The **R** value at the nearest location where **R** is known is multiplied by the ratio of non-snow annual precipitation at the location where **RUSLE2** is being applied to non-snow precipitation at a location where **R** is known. Rainfall data may not be available even to estimate annual precipitation in remote mountainous areas. Production level and type of vegetation can be used to estimate annual precipitation, which in turn can be used to estimate **R**-values.

Makeup of R

Erosivity for a single storm is the product of the storm's energy **E** and its maximum 30-minute intensity I_{30} for qualifying storms. Storms less than 0.5 inches are not included in the erosivity computations unless intensity exceeds 0.5 in hr^{-1} because these storms generally add little to the total **R** value. A value of **R** for a location is the average of EI_{30} values summed for each year of a 22-year record. Except for low intensity rainstorms, EI_{30} values are almost directly proportional to the product of storm amount and I_{30} . Thus, **R** is an indication of the two most important characteristics of a storm determining its erosivity: amount of rainfall and peak intensity sustained over an extended period.

The procedure used to compute EI_{30} and **R** from weather records is described in Agriculture Handbook No. 703.

Ten-Year Frequency Single Storm EI (EI_{30})₁₀ Values

The effectiveness of support practices like contouring and stripcropping is computed using the erosivity of the single storm having an erosivity value with a return frequency of once every ten years. Values for $(EI_{30})_{10}$ have also been computed by location from weather records and entered into a climate database by location. The same precautions for choosing **R**-values also apply to choosing $(EI_{30})_{10}$ values.

Variation of Erosivity During the Year

Erosivity varies during the year, more at some locations than at others. For example, erosivity is nearly uniform throughout the year at Memphis, Tennessee, while eighty percent of the erosivity occurs in the months of May, June, and July in North Dakota, a period when row crops are

especially susceptible to erosion because little cover is present. Therefore, on a relative basis, a crop like corn allows more erosion per unit **R** in North Dakota than in Tennessee.

One way to reduce soil loss is to choose a crop that provides cover during the year when rainfall is most erosive. Growing wheat in North Dakota rather than corn can significantly reduce soil loss because wheat provides cover during the time of maximum erosivity. Making sure that a construction site is covered when erosivity is greatest is an objective in controlling erosion on construction sites.

Soil erodibility varies during the year as a function of temperature and precipitation. Erosion is greater when the period of peak erodibility corresponds with the time of peak erosivity.

This variation in erosion with time as erosivity and other factors vary is taken into account in RUSLE2 by considering conditions on each day of the year, based on average annual conditions for that day.

Distributions of erosivity have been computed at many locations, and distributions have been assigned by zones. The location of the zones, zone numbers, and values for an erosivity distribution for each zone are given in Agriculture Handbook No. 703. The values for the distribution for each zone have been included in the RUSLE2 database. The distribution assigned to a location is selected by selecting the zone that includes a particular location.

The R_{eq} distribution should be used in the freeze-thaw influenced area of the NWRR and adjacent areas, identified in RUSLE2 as an Req area. First answer **Yes** for the **Req area** question and answer **Yes** to the **Req distribution** question. Then choose the **req** erosivity distribution for a location within the Req region.

A special erosivity distribution is needed in southeastern Utah and southwestern Colorado because a significant portion of the erosivity comes from both the Northwest Wheat and Range Region condition and from standard rainfall erosivity characteristic common to the eastern U.S. In these and similar areas, the **R**-value and the distribution of erosivity during the year is weighted based on the relative contribution of each type of erosivity to the overall erosivity.

At first, the R_{eq} effect may appear to apply to areas beyond the NWRR where frozen soils and runoff from snowmelt occurs, such as the northern tier of states in the U.S. However, that region does not experience the repeated freezing and thawing throughout the winter that is characteristic of the NWRR, and the freezing and thawing and runoff on thawing soils is limited to about one month. Research at Morris, Minnesota showed that only about seven percent of the annual erosion at that location is associated with erosion during the spring thaw. The soil is much more susceptible to erosion during this period, but that increased erosion is considered in the variable soil erodibility factor **K** for all areas of the US except for the Req region where the req distribution accounts for the variation of soil erodibility.

Similarly, the R_{eq} effect might apply in regions like the upper Mid-South and lower Midwest that experience repeated freezing and thawing events and where much rainfall routinely occurs during the winter. Even though repeated freezing and thawing is experienced, the soil is not super-saturated by a restricting frost layer a few inches below the soil surface like that in the NWRR.

Having a soil erodibility factor **K** that varies during the year takes into account that soil erosion is greater per unit erosivity during the winter in these regions than at other times.

The question **adjust for soil moisture** is answered **Yes** when RUSLE2 is applied to cropland in the **Req** region.

Weather Variables

Enter monthly values

In addition to weather data for erosivity, RUSLE2 uses data for the weather variable average monthly temperature and average monthly precipitation. These values, which are used to compute the temporal variation of the soil erodibility factor and decomposition of residue, are entered by clicking on the monthly folder tab.

Values for these variables are obtained from local weather records. However, values from a nearby location can generally be used in **RUSLE2** because variations in these values do not greatly affect results within a local region. In addition to these weather variables, elevation of the location is included in the climate database. Elevation is not currently used in **RUSLE2** but may be used in future versions of **RUSLE2** to estimate **R** and temperature for locations where weather data are not readily available.

Except in mountainous areas where weather variables can vary greatly over a relatively short distance, representative data have been chosen to represent monthly temperature and rainfall using multiple stations, covering perhaps as many as five counties or more. Microclimate effects at particular weather stations can produce data that differ significantly from data typical of the region. For example, temperature at major metropolitan airports can be greater than temperature on farmland away from the local-climatic influence of the airport. Therefore, data from adjacent weather stations should be examined, and perhaps used to obtain an average for the location.

RUSLE2 uses the monthly precipitation values to compute the value for average annual precipitation at a location.

Display daily values

Click on the Daily folder tab to display the average annual daily values used by RUSLE2. The daily values for EI (erosivity) are computed by linear interpolation from the values used to describe the EI distribution curves. The values for daily temperature and precipitation are computed from the monthly values using a linear interpolation approach. The daily values, especially precipitation, may not appear to be as smooth as expected. The reason is that is the linear interpolation preserves the monthly mean value. Smooth values cannot be developed while preserving monthly means, which was considered to be a priority in RUSLE2.

Enter notes

Click on the **Info** folder tab to open an area where notes can be entered.

Vary Soil Erodibility

The question of vary soil erodibility should be answered **Yes** for all areas except for the Req area. RUSLE2 computes a monthly value for soil erodibility based on monthly precipitation and

monthly temperature. Daily values are computed for soil erodibility using the same interpolation approach used to compute daily precipitation and temperature values.

The relationships used to vary soil erodibility are meant to apply to the western US in addition to the eastern US. However, the data used to derive the equations use to compute a temporally varying soil erodibility were derived from data collected in the eastern US with none of the data being from the western US. The judgment of the RUSLE2 Development Team is that the relationships used to vary soil erodibility for the eastern US should also be used in the western US, except for Req areas. However, you can turn off this computation by selecting No so that RUSLE2 uses a constant value for soil erodibility throughout the year.

Adjust in Erosivity for Low Slopes

Runoff plots on low slopes and reduces the erosivity of rainfall. As slope steepness increases, less ponding occurs and has a decreased effect on erosivity. Also, the degree that ponding decreases erosivity depends on rainfall characteristics. The effect of ponding is assumed to be greatest in high intensity and large rainfall events. Thus, the effect of ponding is greatest in eastern coastal areas where large, intense rainfall most frequently occurs. The 10 yr EI storm along with slope steepness is used in RUSLE2 to compute the reduction in erosivity by ponding.

SOIL OBJECT

Open the Soil Object for a particular soil. The Soil Object window is divided into two major parts where basic data are entered and a folder area where supplemental information can be entered and computed values can be displayed.

Soil Erodibility (**K**) Factor

Soils vary in their susceptibility to erosion. The soil erodibility factor **K** is a measure of erodibility for a standard condition. This standard condition is the unit plot, which is an erosion plot 72.6 ft long on a 9 percent slope, maintained in continuous fallow, tilled up and down hill periodically to control weeds and break crusts that form on the surface of the soil. The plots are plowed, disked, and cultivated in much the same as for a row crop of corn or soybeans except that no crop is grown on the unit plot. Values of **K** are determined by fitting the equation:

$$A_u = EI_{30} K$$

to the erosion and rainfall data measured at the unit plot. The variable A_u is the soil loss measured for individual storms and EI_{30} is the erosivity of the storms that produced the respective soil loss values.

What K Represents

The soil erodibility factor **K** represents susceptibility of soil to erosion, transportability of the sediment, and the amount and rate of runoff given a particular rainfall input, as measured under the standard unit plot condition. Fine textured soils high in clay have low **K** values, about 0.05 to 0.15, because they are resistant to detachment.³ Coarse textured soils, such as sandy soils, have

³ The R and K factors have units. In this guide R has the units of hundreds of (ft tons ac⁻¹ yr⁻¹ in hr⁻¹). The corresponding units on K are

low **K** values, about 0.05 to 0.2, because of low runoff even though these soils are easily detached. Medium textured soils, such as the silt loam soils, have moderate **K** values, about 0.25 to 0.45, because they are moderately susceptible to detachment and they produce moderate runoff. Soils having a high silt content are especially susceptible to erosion and have high **K** values. They are easily detached and they tend to crust and produce large amounts and rates of runoff. Values of **K** for these soils typically exceed 0.45 and can be as large as 0.65.

Organic matter in the soil reduces soil erodibility because it produces compounds that bind soil particles together and reduce the susceptibility of the soil to detachment by raindrop impact and surface runoff. Also, organic matter increases aggregation in the soil that increases infiltration and reduces runoff and thus erosion.

Permeability of the soil profile affects **K** because it affects runoff. Like organic matter, permeability and infiltration that affect runoff can be changed by plant growth and management. These cover-management effects are considered in the **C** factor.

Soil structure affects **K** because it affects detachment and infiltration. Soil mineralogy has a significant effect on **K** for some soils, including subsoils, soils located in the upper Midwest, and volcanic soils.

Selection of K Values

The main source of **K** values is the USDA-Natural Resources Conservation Service (NRCS). Other federal agencies publish **K** values including the USDA-Forest Service for soils typical of forest lands, the USDI-Bureau of Land Management for soils typical of rangelands, and the USDI-Office of Surface Mines for soils typical of surface mining.

The **K** values published by NRCS are based on classes. The width of these classes indicates the uncertainty associated with the **K** value for each class. For example, if a **K** value is 0.28 and the next highest **K** value is 0.32 and the next lowest **K** value is 0.24, the width of the class is 0.04. The uncertainty in **K** is therefore ± 0.02 , which provides an indication of the certainty in the **RUSLE2** soil loss estimate.

Values for **K** are not available for all soils. For those soils for which a **K** value is not available, a **K** value can be estimated using the soil erodibility nomograph in AH-703, "Predicting Soil Erosion by Water - A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (**RUSLE**)". The **RUSLE2** computer program includes the soil erodibility nomograph in the **K** factor component, which can be accessed by opening the folder named Monograph Info.

The nomograph was obtained by an empirical analysis of soil erosion data collected in the central Midwest. While the nomograph seems to broadly apply to cropped surface soils, it should be not be extrapolated beyond the curves shown on the nomograph. For example, a value for organic matter greater than four percent is not recommended or allowed in **RUSLE2**. The definitions and variable descriptions used in the nomograph must be carefully followed.

The soil erodibility nomograph must not be used to adjust for practices that increase organic matter in the soil. That effect is considered in the cover-management equations used in RUSLE2. The organic matter that should be used in the nomograph is the “inherent” organic matter in the soil. Soil erodibility is determined from erosion measured on the unit plots that have been maintained in continuous fallow for an extended period, preferably of about 10 years.

Agricultural Handbook No. 703 provides other guides to estimate **K** when data are insufficient to use the nomograph or no alternative way is available for estimating **K**. This curve represents a summary of all erosion data available for estimating **K** values.

Values for **K** have been determined for several “benchmark” soils from experimental erosion data. Values for **K** can be estimated for other soils by comparing properties of the soil for which a **K** value is desired against properties of soils having known **K** values. Soil scientists with NRCS or universities can assist with these comparisons. These benchmark soils and their **K** values are listed in Agriculture Handbook No. 703.

Soil Erodibility Influenced by Organic Matter Increases

Organic matter in a soil is affected by management practices such as adding animal manure, plowing under “green” manure, and improved residue management. Plant growth and management practices affect the susceptibility of the soil to detachment and its infiltration rate, both of which affect erosion. These effects are considered in **RUSLE2** but not in the **K** factor; instead these effects are considered in the cover-management factor **C**.⁴

An adjustment in **K** to account for increases in organic matter is a double accounting for the effect of cropping and management on organic matter and is a misuse. The erodibility factor **K** is a measure of soil erodibility obtained under the standard unit plot conditions where the effects of management have been largely eliminated.

Special Soils

The soil erodibility nomograph does not apply to soils of volcanic origin, organic soils such as peat, subsoils, Oxisols, low activity clay soils, calcareous soils, and soils high in mica. Refer to Agriculture Handbook No. 703 for estimating **K** values for these special soils.

Rock Fragments

Rock fragments can have a major effect on soil erosion. Rock fragments on the surface act as surface cover and reduce soil loss like other surface cover such as crop residue and plant litter. Rocks in the soil can reduce permeability and increase runoff, which increases erosion.

⁴ Considering the effect of organic matter in **K** seems logical because the **K** factor includes a variable for organic matter. **RUSLE** is an empirical, index-based equation based on a certain set of definition of variables rather than being a process-based approach. The variables in **RUSLE** could have been defined in many different ways, but once set as they were in **RUSLE**, definitions must be carefully followed. Adjusting **K** to account for the effect of cropping and management on organic matter is inconsistent with **RUSLE** definitions.

Unless stone has been purposefully added to the soil surface, rock fragments are normally considered to be a part of the soil. Only the effect of rock fragments within the soil profile are considered in the **RUSLE2 K** factor. Soil survey information usually describes the extent of rock fragments in the soil profile.

The soil erodibility nomograph is based on soil fines, particles smaller than 2 mm (sand-sized and smaller). The effect of rock in the soil profile is considered by adjusting the permeability class in the soil erodibility nomograph. Generally rock fragments in the soil profile decrease infiltration. The guide for changing the permeability class is that if the percentage of rock fragments by weight in the soil profile is less than 25 percent, no adjustment is made. If the rock fragment percentage is greater than 25 percent but less than 60 percent, a one step change in the permeability class is made to a less permeable class. If the percentage of rock fragments exceeds 60 percent, a one or two-step change in the permeability class can be made. Refer to Agriculture Handbook No. 703 for additional discussion on the effect of rock in the soil profile.

Rocks on the surface are treated as surface cover, and the corresponding effects are considered in the cover-management equations. Values for rock cover are entered in the **K** factor component of the **RUSLE2** program. The reason that rock fragments on the surface are considered in the **C** factor and rock fragments in the soil profile are considered in the **K** factor is to be consistent with **RUSLE2** definitions and to ensure that the mathematical relationships for the effects of surface cover are correctly solved.

When using **K** values from NRCS soil survey information, determine if **K** values have already been adjusted for rock fragments, especially for surface rock. Use **K** values for the fine earth fraction (**K_f**) that are unadjusted for the effect of surface rock fragments in **RUSLE2**. A **K** value adjusted for rock within the profile can be used directly in **RUSLE2**.

Restricting Layers

Soils having a restricting layer that increases runoff should be assigned a higher **K** value than similar soils without restricting layers. The adjustment is based on the degree that the restricting layer affects runoff. The permeability class in the soil erodibility nomograph is adjusted to reflect the increased runoff.

(Add information from OSM manual)

Enter a Value for Erodibility

Once a value has been determined for erodibility, it is entered for erodibility in the soil object window. **RUSLE2** can also use the nomograph to compute an erodibility factor values. Direct entry of an erodibility value bypasses **RUSLE2** making any computation of an erodibility value. However, **RUSLE2** will use the nomograph or the equations to compute erodibility for volcanic soils and automatically place that value in the field for erodibility.

Place the cursor on the variable name erodibility and right click, which open a menu for the variable. Move the cursor to the line calculate from in the menu and select nomograph to have the nomograph compute an erodibility value and place in the erodibility field. Make sure that you open the nomograph folder and enter the appropriate values for the nomograph.

Temporal Variability in K

Soil erodibility varies during a year. Erodibility tends to be high early in the spring during and immediately following thawing, and during periods when the soil tends to be wetter than at other periods. Values for **K** tend to be low in the fall, partially because the soil is drier than at other times. **RUSLE2** computes **K** values that vary by month and then uses a linear interpolation procedure to compute daily values. The monthly values of **K** are computed using equations that are a function of monthly precipitation and monthly temperature.

The equations used to compute the temporally variable erodibility were derived from erosion data collected in the eastern US. The procedure used in **RUSLE2** for computing temporally varying erodibility values should also be used in the western US, except in Req areas. However, a constant erodibility value that does not vary during the year can be used in **RUSLE2** by answering No to the question **Vary erodibility with climate** in the Climate Object.

Other Input Data Associated With Soil Object

Information on soil texture is entered in one of two ways in the **Soil Object**. The first way is to select a soil texture, which is used by **RUSLE2** to compute the distribution of sand, silt, and clay in the soil. The values used for this distribution is from the midpoint of the textural class in the textural triangle.

The second way to enter textural information is to open the Particle Sizes folder and enter actual values for the distributions of sand, silt, and clay in the soil. **RUSLE2** will then assign a textural class using the textural triangle. The values entered for the sand, silt, and clay distribution will be used in **RUSLE2** if entered directly in the Particle Size folder.

A hydrologic soil group designation is also entered in the **Soil Object**. The hydrologic soil designation is used in **RUSLE2** to compute how support practices affect runoff and thus erosion. Hydrologic soil group designations are available in NRCS soil survey information and from other federal agencies involved in management of soil resources.

Rock fragments on the soil surface reduce erosion just like any other cover when percent cover is considered. If rock fragments are present on the soil surface are present, enter the portion of the soil surface covered by rock fragments. The way to obtain an estimate for rock fragment cover is to visit the field site. The best time to measure rock fragment is after a substantial rain that washes away soil so that the rock fragments are most easily detected so that their cover can be measured. Rocks often cannot be easily detected after tillage. Also, if rock cover varies through the year, use a value that represents the one fourth of the year when erosion is likely to be greatest.

Do not use an erodibility factor value that has been adjusted for surface rock fragment cover.

RUSLE2 requires a value for the soil to “consolidate” after tillage. Soil is more than twice as erodible following tillage than after an extended time after the tillage where no mechanical disturbance of the soil has occurred. Seven years is normally assumed in the eastern US for the soil to “consolidate.” Longer times are assumed for the western US, especially for very coarse textured soils.

Answer **Yes** to the question **Calc(ulate) consol time from ppt(preciptiation)** to have **RUSLE2** compute a consolidation time. If the question is answered Yes, **RUSLE2** uses amount of annual to compute consolidation time. Consolidation time increases up to 25 years as annual precipitation decreases. Having **RUSLE2** compute a consolidation time is preferred.

Adding Notes

Open the Info folder to add notes on a particular Soil Object.

Soil Loss Tolerance

A value is entered for soil loss tolerance. This value is currently not used in **RUSLE2**.

Detached Soil Particles

The folder detached soil particles shows the sediment particle distribution that **RUSLE2** computes for values input for soil texture. This information on sediment characteristics is used by **RUSLE2** to compute deposition and how deposition changes the characteristics of the sediment.

TOPOGRAPHY REPRESENTATION

Topography is represented in **RUSLE2** by entering information for location of slope segments and the steepness of each segment. As many segments are entered as necessary to describe the slope shape. The simplest representation a uniform slope with a particular length and steepness.

Slope Length and Steepness Effects

The slope length factor **L** computes the effect of slope length on erosion and the slope steepness factor **S** computes the effect of slope steepness on erosion. Values for both **L** and **S** equal 1 for the unit plot conditions of 72.6 ft length and 9 percent steepness. Values of **L** and **S** are relative and represent how erodible the particular slope length and steepness is relative to the 72.6 ft long, 9 percent steep unit plot. Thus some values of **L** and **S** are less than 1, and some values are greater than 1.

What L and S Represent

The erosion computed by **RUSLE2** is composed of two components, rill erosion that is caused by surface runoff concentrated in small, usually parallel channels, and interrill erosion that is caused by raindrop impact on the space between the rills. The actual slope length associated with an interrill area is half of the spacing between the rills, whereas the slope length for rill erosion is the entire slope length. The slope length for rill erosion is used in **RUSLE2** to avoid having to specify a rill spacing. **RUSLE2** considers a weighting between the two types of erosion.

Because detachment on an interrill area is by raindrop impact, soil loss from interrill areas is independent of position on the slope. Therefore, if soil loss is entirely produced by interrill erosion, the **L** factor equals 1 for all slope lengths.

Because detachment associated with rill erosion is produced by flow, rill erosion increases with distance downslope as runoff rate increases along a slope. In general, this relationship is nearly linear such that if soil loss is entirely produced by rill erosion, the **L** factor would increase linearly with slope length.

The equation $L = (\text{L}/72.6)^n$ is used to define the **L** factor where L = slope length in ft and 72.6 is the length of the unit plot in ft. The slope length exponent **n** for interrill erosion is 0 while it is 1 for rill erosion.

Since both interrill erosion and rill erosion contribute to total soil loss, the slope length effect is between the extremes of all interrill erosion and all rill erosion. That is, the effective slope length exponent **n** lies between 0 and 1. Conditions such as steep slopes produce more rill erosion than interrill erosion, and therefore the **L** factor has a larger exponent and more effect than on flat slopes where interrill erosion is greater than rill erosion. Also, conditions that produce increased runoff have an increased slope length effect because of increased rill erosion relative to interrill erosion. The **L** factor is affected by cropping-management systems because surface cover reduces rill erosion more than interrill erosion.

The slope length exponent **n** in RUSLE2 is a function of the ratio of rill to interrill erosion. Those variables such as slope steepness that increase rill also increase the slope length exponent. Ground cover affects rill differently than interrill erosion, and thus the slope length exponent is a function of the percent ground cover because the ratio of rill to interrill erosion varies the percent ground cover varies. Rill erosion is decreased more by soil consolidation than is interrill and thus the slope length exponent is a function of the degree of soil consolidation. Soil quality is indicated in RUSLE2 by the amount of soil biomass affects infiltration and the susceptibility of the soil to rill erosion, and thus the slope length exponent in RUSLE2 is a function of amount of biomass in the soil including buried residue and live and dead roots. Some soils are naturally more susceptible to rill erosion than to interrill, which is a function of soil texture in RUSLE2, and in turn the slope length exponent is a function of the ratio of rill erodibility to interrill erodibility.

In summary, the slope length exponent in RUSLE2 is a function of land use as reflected by basic measures in ground cover, degree of soil consolidation, and amount of soil biomass, as well as varying from day to day as these variable vary day to day.

A special case is rill erosion of the thaw-weakened soils of the NWRR where the single, constant value is used for the slope length exponent.

The **S** factor describes the effect of slope steepness on soil loss. Steepness has a greater effect on rill erosion than on interrill erosion. Also, the slope steepness relationship also depends on soil, cover, and management conditions. In contrast to rill erosion, a variable relationship like that for the **L** factor was not developed for the **S** factor. The **S** factor is a linear relationship with a break at a 9 percent steepness. The **S** factor relationship for the NWRR is a special case.

Horizontal vs. Along the Slope Measurement of Slope Length

The slope length used in the **RUSLE2** computations is a horizontal measure, but either a horizontal or an “along-the-slope” measure of slope length can be entered in the **RUSLE2** computer program. Measuring slope length along the slope is easier in the field than measuring horizontal slope length. Slope length measured from maps is a horizontal measure. The difference in the two measurements is small for slope steepness less than 20 percent. Horizontal or “along-the-slope” measurement of slope length is selected in RUSLE2 by placing the cursor on the slope length variable name and clicking the right mouse button to display a menu where the choice can be made.

Nonuniform Slopes

Most hillslope profiles are assumed to be uniform when using RUSLE2 in conservation planning. However, RUSLE2 applies equally well to nonuniform slopes. Most conservation planning, the emphasis has been on the controlling erosion on the eroding portion of the slope to an acceptable level. The typical slope length was the distance from the origin of overland flow to the point that deposition began to occur on slopes with concave sections that decreased to a slope steepness sufficiently flat to cause deposition.

A major advancement of RUSLE2 is that the slope length can be defined as the distance from the origin of overland flow to the point that the overland flow enters a major concentrated flow channel. RUSLE2 computes both erosion and deposition along the hillslope profile. RUSLE2 provides an estimate of sediment yield from the slope length, the amount and location of deposition, the location and rate of erosion, the total amount of detachment on the slope, and a conservation planning soil loss that gives partial credit for deposition considering the amount and location of the deposition.

Topographically nonuniform hillslope profiles are ones where slope steepness changes along the slope length. RUSLE2 can define any slope shape by dividing the slope into as many segments as necessary to describe the field slope. However, some rules can be given that should be observed in describing nonuniform slopes. Three segments are usually adequate for defining convex slope sections, but at least twice as many segments are needed on concave slope sections where deposition occurs. If RUSLE2 is being used to estimate sediment yield from a hillslope profile, extra care should be given to describing slope steepness on the lower 1/5 of the slope for a concave section at the end of the hillslope profile.

Constructing a concave slope hillslope profile nicely illustrates the capability of RUSLE2 for computing erosion and deposition along a nonuniform slope. Open the topography folder and graph the soil loss values for the segments.

Influence of Upslope Areas

In some applications, **RUSLE2** is applied to a field downslope from an upslope area that is very different from the field. The irregular slope procedure that divides the slope into segments can be used to estimate soil loss on the field, but an adjustment for slope length may be needed. If runoff production on the upslope area is less than that on the field, the slope length at the upper

edge of the field should be shortened. An example is an undisturbed forest on the upslope area where the slope length begins at the upper edge of the field because no runoff is assumed to occur from the undisturbed forest. If the upslope area is pasture and only produces half the runoff that the field produces, the slope length at the upper edge of the field should be one half the distance of the slope length across the pasture area.

Conversely, if the upslope area produces more runoff than does the field, the slope length at the upper edge of the field should be greater than the actual distance in proportion to the differences in runoff potential for the two areas.

Selection of Landscape Profiles

RUSLE2 computes average soil loss for the selected landscape profile. Many landscape profiles exist in a field, and thus a user has to choose one or more profiles for the **RUSLE2** computation. In conservation planning, the slope profile representing a significant portion of the field having the most severe erosion is often chosen. This profile is usually in the steep areas of the field.

If an average soil loss estimate is needed for the field, soil loss is computed for several profiles, and the individual soil loss values are weighted according to the portion of the field represented by each profile to obtain an average soil loss value for the field. Average field values are needed when estimating sediment yield for the field or when estimating the soil loss reduction for an entire field. The worksheet object in **RUSLE2** directly carries out these computations.

An average soil loss computed with **RUSLE2** for the field is not sediment yield from the field but is an estimate of the total sediment production on the field by rill and interrill erosion. Sediment yield from a field can be much less than the average soil loss for the field if much deposition occurs. If much ephemeral gully erosion occurs, sediment yield can be much greater than the sheet and rill erosion estimated by **RUSLE2**. Ephemeral gully erosion is not included in the **RUSLE** estimate.

*Applications of **RUSLE** to Fields and Watersheds*

Some applications of **RUSLE2** require an estimate of average soil loss or distribution of soil loss within a field or watershed. Depending on the application, one of three approaches may be used.

The first approach involves mapping major soil units within the watershed and assigning slope length and steepness values to representative profiles for these units. If cover, such as on rangelands, depends highly on changes of soil and aspect within these units, the units should be subdivided further. The soil loss computed for each profile is weighted according to the area represented by that profile.

The second approach involves laying a grid across the watershed. A **RUSLE2** landscape profile is determined for each intersection point on the grid, and the soil loss is computed for each profile.

The third approach involves computing soil loss at each grid intersection point rather than computing soil loss for the profile passing through the grid point. The procedure for computing soil loss for a point in **RUSLE2** is to determine the hillslope profile down to the point. A segment 1 ft long is set up at the end of the hillslope profile, so that **RUSLE2** computes soil loss or deposition on this short segment, which is essentially the same as that for a mathematical point.

RUSLE2 is sometimes used in watershed analyses to estimate sediment yield. To apply **RUSLE** in this application requires that consideration be given to the likelihood of deposition of sediment between its source and the outlet of the watershed. The sediment that is deposited on hillslope profiles where overland flow occurs can be computed with **RUSLE2**. Also, other sources of sediment such as ephemeral gully erosion and channel erosion must be considered, as well as the likelihood of deposition of sediment from these sources. A critical factor in the amount of sediment delivered from a watershed is the transport capacity of the runoff and channel flow along the transport path of the sediment.

Determining Slope Length

The standard definition of slope length is the distance from the origin of overland flow along its flow path to the location of either concentrated flow or deposition. In most applications, **RUSLE2** is used to estimate soil loss from the eroding (sediment producing) portions of the slope. In those cases, the slope length ends at the upper edge of an area of remote deposition, like at the toe of a concave slope.

Sometimes these features are not readily apparent, and as a result, different users determine different slope lengths for the same landscape profile. Fortunately, computed soil loss values are not especially sensitive to slope length, and differences in slope length of 10 percent are not important on most slopes, especially flat landscapes where errors in slope length can be as high as 50 percent and still have minimal effect on soil loss estimated by **RUSLE2**.

Slope lengths are best determined by visiting the site, pacing out flow paths, and making measurements directly on the ground. Contour maps having intervals greater than 2-ft should be used cautiously, if at all, to determine slope lengths. Slope length values are generally over-estimated when contour maps are used to determine slope length.

Slope lengths on many landscapes generally are less than 200 ft., and usually do not exceed 400 ft. Slope lengths longer than 1000 ft should not be used in **RUSLE2** because the reliability of **RUSLE2** at these long slope lengths is questionable, and flow becomes concentrated on most landscapes before such lengths are reached.

In contrast to slope length being limited to a maximum of 1000 ft, no minimum slope length exists. A slope length as short as 1 ft can be used in **RUSLE2**. Correspondingly, the maximum slope steepness that can be entered in **RUSLE2** is 100%.

Location of deposition is often apparent on cropland immediately after a rainstorm. The main areas of deposition that end the slope length for the eroding slope sections are depositional areas on concave slopes. Deposition in row middles and in depressions like those left by tillage are not slope ending depositional areas.

Determining the location of upper edge of depositional area is not necessary for **RUSLE2** because **RUSLE2** can compute the location of deposition. However, the traditional slope length can be used in **RUSLE2**.

An approach to use when no signs of deposition are present is to visualize where deposition occurs. The location and steepness where deposition begins depend on slope curvature. For example, no slope-ending deposition occurs on uniform slopes, and if a slope changes from 4

percent to 2 percent, most likely the 2 percent area would not be a slope-ending depositional area. However, if the steepness upslope from the 2 percent area is 6 percent or more, the 2 percent area is most likely a slope-ending depositional area. If the upslope area is as steep as 10 percent, the slope-ending area may be as steep as 3 percent. The slope-ending depositional area on a concave slope is usually below where the slope begins to flatten. That is, unless the slope flattens significantly, deposition does not occur.

The following examples illustrate a rule of thumb for estimating where deposition might occur.

Assume a concave slope that decreases from 18 percent steepness at the upper end to 2 percent steepness at the lower end. The average steepness is 10 percent and one half of the average steepness is 5 percent. Deposition begins at the location where the slope has flattened to a steepness of 5 percent, which would be about 20 percent of the way up the slope.

For the second example, assume a concave slope that decreases from 4 percent at the upper end to 2 percent at the lower end. The average steepness is 3 percent and one half of the average steepness is 1.5 percent. Since the steepness at the lower end is greater than the steepness where deposition would occur, no deposition is assumed to occur on this slope.

This rule illustrates that the key factor in determining whether deposition occurs on a slope is not the steepness at the lower end, but the relative decrease in slope steepness. The type of deposition identified by this rule of thumb is remote deposition that occurs at the toe of concave slopes. It does not identify local deposition such as that in furrows on a low grade or in depressions left by tillage or similar operations. The concave portions of the slope--not the entire slope--are used in applying this rule.

Deposition is usually considered to end the traditional slope length. However, there is a case where slope length does not end when computing soil loss on the lower portion of the slope. An example is a relatively flat but outward sloping area in the middle of the hillslope. The middle area is sufficiently flat to cause deposition. If the runoff continues across the middle area as overland flow uniformly distributed across slope, a slope length reaching to the top of the slope should be used to compute soil loss on the lowest segment. An advantage of RUSLE2 is that it can be applied to the entire hillslope by describing hillslope profile. RUSLE2 computes erosion on the upper portion of the slope, deposition on the midsection, and erosion on the lower eroding portion of the slope. The basic assumption is that runoff flows down the entire slope as overland flow and that runoff on the lower section originated at the upper end of the hillslope. RUSLE2 can easily be applied to this hillslope if diversions are placed at various places on the hillslope to intercept runoff and change slope lengths.

Terraces need careful consideration when choosing a slope length. If the terraces are gradient type nearly on the contour, the terraces usually shorten the slope length according to the terrace interval. Such is not always the case with parallel terraces. A variety of slope lengths exist for parallel terraces. In fact, if the terraces are widely spaced, the addition of terraces may not shorten the slope length. Of the range of slope lengths that can exist for parallel terraces, choose the maximum value for use in **RUSLE2**.

The slope length in the **RUSLE2** computer program can be explicitly linked to terrace spacing or treated independently. The slope length entered in the **LS** factor should reflect terrace spacing. Slope length is often not directly linked to terrace spacing, especially for parallel terraces.

Determining if a channel is a concentrated flow channel that ends a **RUSLE2** slope length can be difficult. If the channels on the hillslope are parallel, these channels are considered to be rills regardless of depth, and the erosion in them is estimated by **RUSLE2**. One exception is where a single channel parallel to many rills collects runoff from an upslope area that would ordinarily have been distributed among several rills. Channels that collect the flow from several rills are generally considered to be slope ending concentrated flow channels.

Contouring redirects surface runoff from a direct downslope path to a path following the tillage marks around the slope. The **RUSLE2** procedure for determining slope length for these types of conditions is to visualize the downslope flow path as if the ridges do not redirect the flow.

Additional guidance is given in AH703 on selecting slope length.

Cover-Management (C) Factor

The cover-management factor **C** represents the effect of plants, ground cover, soil biomass, and soil disturbing activities on erosion. Fundamentally, erosion is a function of erosivity of the erosive agents relative to the erodibility of the soil. The **C** factor is related to both erosivity and erodibility. For example, plant canopy reduces the erosivity of raindrop impact and surface cover reduces the erosivity of both raindrop impact and surface runoff. The presence of roots and incorporated residue in the soil reduces the erodibility of the soil. Soil disturbing activities loosen the soil and increase its erodibility, while roughness left by soil disturbing activities reduces the erosivity of raindrop impact and runoff by creating small ponds that cushion raindrops and slow surface flow. The combination of erosivity and erodibility effects in the **C** factor demonstrates that **RUSLE2** is an index-based method of estimating soil loss rather than having terms specifically for erosion processes.

RUSLE2 uses a subfactor method to compute values for soil loss ratio, which is the ratio of soil loss at any given time in a cover-management practice to soil loss from the unit plot. Soil loss ratios vary with time as canopy, ground cover, roughness, ridge height, soil biomass, consolidation⁵ and antecedent soil moisture change each day.

RUSLE2 uses data files for management, operations, vegetation, and residue to describe how cover-management practices affect soil loss. Before discussing construction and use of these data files, the basic variables used to represent the effect of cover-management.

⁵ Consolidation refers to how the erodibility of a soil decreases with time after a soil disturbing activity. It does not solely refer to how the bulk density of the soil increases with time after a tillage operation. Some of the erodibility reduction is from an increase in bulk density, but wetting and drying of the soil from the cementing of particles cause the remainder.

Critical Variables affecting the C Factor

Soil, environment, and management affect characteristics of vegetation important to erosion. Some of the management effects such as planting, crop development through time, harvesting, and residue management are directly considered by **RUSLE2**. Other effects like yield that are affected by fertility management and soil are not internally represented by **RUSLE2**, which does not use a crop growth model to generate vegetative characteristics that are a function of soil and environmental conditions.

A data file used in **RUSLE2** to describe vegetation is for a specific type of vegetation such as a crop with a particular length of growing season. Environment and management affect yield. A yield value can be entered in **RUSLE2** and **RUSLE2** adjusts values in the vegetation data file to reflect such effects.

Canopy

Canopy is vegetative cover above the soil surface that intercepts raindrops but does not contact the surface runoff. The portion of the **above ground plant biomass** touching the soil surface is treated as **live ground cover**. The two characteristics of canopy used by **RUSLE2** are **canopy cover**, which is percent of the surface covered by canopy and **fall height**, which is the effective height in the canopy from which water drops fall. Open spaces within the outside perimeter of a plant are counted as open space and not as area covered by canopy.

Water drops falling from canopy generally do not have the erosivity of raindrops not intercepted by canopy. Effective fall height varies with the stage of maturity and the architecture of the plants. If the leaves and branches of the plant are concentrated in the lower part of the canopy, fall height is near the bottom of the canopy. If most of the leaves and branches of the plant are concentrated in the upper portion of the canopy, the effective fall height is one half to two thirds of the distance from the bottom to the top of the canopy. **RUSLE2** includes equations that can be used to estimate fall height. This procedure is described in the section on the Vegetation Object.

Water intercepted by the canopy reforms drops that fall from the plant leaves and branches. Some of the drops will be intercepted again by low-lying canopy. The lowest “average” height from which drops fall before finally impacting the ground is the height that needs to be considered in selecting an effective fall height. If an understory exists, the effective fall height is often determined much more by the understory than by the overstory.

Where multiple types of plants having different canopy characteristics are grown together, consideration must be given to overlapping canopy in determining an effective fall height. An example of this condition is interseeding of legumes in small grain on cropland.

RUSLE2 does not directly vary the plant characteristics that are a function of population or row spacing even though the effect of these variables is considered in **RUSLE2**. If canopy characteristics vary significantly between crop varieties or management practices, a vegetation file must be constructed to reflect each significant difference. Values for canopy and other plant characteristics for selected crops are available in Agricultural Handbook No. 703.

RUSLE2 does not “grow” vegetation as a plant model would grow vegetation. The user describes vegetative growth by entering values in the vegetation data file as plant variables like canopy evolve through time.

During the growth period, canopy cover increases. As plants approach maturity, some types of vegetation lose canopy by natural processes, like soybeans, or by defoliation, like cotton, where a loss of canopy is associated with biomass falling to the soil surface. In other crops, canopy can be lost by the leaves drooping without biomass falling to the soil surface.

The other way that canopy is lost is by operations that remove live biomass or remove residue after the vegetation has been killed. Operations like harvest, shredding, grazing, and burning are events that significantly canopy cover.

Ground Cover

Ground cover is material in contact with the soil surface that intercepts raindrops and slows surface runoff. The total percent of the surface covered is the characteristic used by **RUSLE2** to compute how ground cover affects erosion. Ground cover includes all cover that is present, including rock fragments, portions of live vegetation in contact with the soil, cryptogams, and plant residue. The only minimum size requirement for material to be counted as surface cover is that it either be of sufficient size or attached to the surface such that it is not removed by runoff. If rock is present on the surface, the **RUSLE2** program takes into account the overlap of rock by residue. A value for rock cover is entered in the **K** factor component of the **RUSLE2** program.

RUSLE2 considers residue added by senescence and by harvest-type operations. It also considers residue, manure, and other materials added to the soil surface specifically for the purpose of controlling erosion.

Although **RUSLE2** uses percent cover to compute the effect of ground cover on soil loss, residue accounting in **RUSLE** is by mass. The mass of residue is computed as a linear function of yield. The mass of above ground biomass at any point during the plant growth cycle is computed as a function of canopy cover. Loss of residue by decomposition is computed on a mass basis, and loss of residue by burial by a tillage operation can be computed on a mass basis. Mass of residue on the surface is converted to percent area basis to make the soil loss computations to display for assisting in conservation planning.

Values shown in Agricultural Handbook No. 703, Tables 5-1, 5-2, and 5-3, are typical values used in **RUSLE2** for “core conditions”. Values appropriate for crops grown in a particular region may vary from the values shown in these tables. Adjustments can be made to these values to reflect regional differences but not differences between varieties within a region for example.⁶

⁶RUSLE uses several parameters where values reported in the literature for them vary over a wide range. We have chosen values to represent typical conditions, and these values have been used in the calibration and validation of RUSLE. Depending on the situation, soil loss can vary over a wide range for the range of values reported in the literature for a variable. Since RUSLE is intended to represent main effects, the user should give priority to values given in the RUSLE User’s Manual to avoid inconsistency in soil loss values computed by RUSLE. Other agencies and organizations, such as the USDA-Natural Resources Conservation Service,

Mass of residue on the surface is converted to percent cover using curves in Agricultural Handbook No. 703 and relationships in the **residue** database in the **RUSLE2** computer program. The relationship of percent cover to mass of cover is highly variable, even for the same location. The values represent “best overall” values based on a literature survey. These values can be changed to reflect local conditions.

Some of the variability in the relationship of percent cover to mass directly results from variations in the distribution of plant components including stems, leaves, pods, and chaff. For example, the proportion of stems in southern grown soybeans seems quite different from that for soybeans grown in the Midwest. As a result, a given mass of residue from soybeans grown in the Midwest gives more cover than the same amount of soybeans grown in the South.

Part of the variability is also attributed to time of year of sampling. For example, a higher percentage of leaves relative to stems exists soon after harvest than in the spring because of differences in decomposition rate between the rapidly decaying leaves and the slowly decaying stems. This effect can be seen as an interaction with yield.

Residue measurements vary greatly, even when made under research conditions. The values given by **RUSLE2** represent, long-term average values, and therefore a difference between what **RUSLE2** shows and what is measured in the field is not surprising. Measurements need to be made over several years, at a minimum of three years, where a range of yield and weather conditions have occurred.

Another source of variability is in measurement itself. A minimum of 10 observations in a field is needed to obtain an accurate estimate of residue remaining after an operation. When residue cover is below 20 percent, the error in the measurement of residue increases dramatically. Another problem is non-uniform distribution of residue in strips because of harvest, tillage, water flow, or insects. If strips are narrow and cover in them is heavy, large errors can occur in the measurement. **RUSLE2** assumes that the residue is uniformly distributed over the surface.

The time that residue measurements are made can have a great effect on variability. For example, many small pieces of leaves are present immediately after harvest that provide much cover with little mass. However, over a few weeks, much of this fine material can either be lost by wind, runoff, or decomposition. Measurement of residue immediately after it has been incorporated after harvest can give very different results than would be measured when the same tillage operation is performed in the spring after the fines have disappeared and mainly stems are left.

Another potential source of error is in the conversion of cover to mass. When the residue cover is less than about 75 percentage, an estimate of cover can be accurately converted to an estimate of residue mass. However, at high percent of cover like 90 to 100 percent, an estimate of mass from a measure of cover can easily be in error by as much as a factor of two.

in individual states, may use values developed according to their organization's policy. These values should be checked against the values in the **RUSLE User's Manual**.

Therefore, use great care when measuring residue cover in the field and comparing these values to **RUSLE2**. Similarly, use great care when selecting a value for residue left by an implement for use in **RUSLE2**.

Residue on the soil surface disappears by decomposition and by operations such as tillage that incorporates residue. Above ground biomass as residue is in two pools, standing residue and flat residue. Another pool of residue is residue in the soil. Burial of residue by operation goes through three steps. The first step is to flatten standing residue. The second step is to bury flat residue. The third step is to resurface buried residue. The amount of residue on the soil surface after an operation is the net effect of these steps. Ratios based on mass are used in **RUSLE2** to describe each of these steps. These ratios vary according to adjustment of the implement, speed of operation, soil moisture, and other factors. The user can develop customized “implements” for particular conditions. Some chisel plows incorporate 70 percent of the residue while other chisel plows incorporate only 30 percent of the residue.

The amount of standing residue that is flattened is described by a flattening ratio that depends on the type of residue and characteristics of the operation. For example, the flattening ratio for wheat stubble is lower for a tandem disk than for corn stalks because of differences in resistance to flattening between wheat and corn stubble for a tandem disk. The same relationship between residue types does not exist for all implements because of differences in the flattening mechanisms.

The amount of residue that is buried is described by a burial ratio that depends on type of residue and characteristics of the implement. Geometric properties of the residue along with its toughness affect burial ratios. For example, the burial ratio for soybean residue is much larger for the small, fragile pieces common to soybeans than the large, tough pieces of woody debris.

The amount of residue left on the soil surface following a soil disturbing operation is a function of speed and depth of the operation. **RUSLE2** computes how changes in speed and depth affect the amount of residue left on the surface.

Loss of residue on the soil surface and in the soil by decomposition is computed using equations that are a function of average monthly air temperature and precipitation. The parameter values used in **RUSLE2** reflect differences in how rapidly residue from different crops decomposes. Leaves, stems, pods, and other components are lumped together rather than considered by component even though leaves decompose at a much faster rate than do stems. Consequently, decomposition parameter values can vary with region, which is reflected in differences between decomposition parameter values for soybeans for the Midwest and for the South and differences in decomposition values for wheat between the eastern U.S. and the Northwest Wheat and Range Region.

Although **RUSLE2** can use a decomposition coefficient for buried residue that is different from the one for surface residue, equal values are currently used in **RUSLE2** because insufficient research data are available to determine separate values.

The effect of ground cover on soil loss is computed in **RUSLE2** using the equation, $F_{sc} = \exp(-bM)$, where F_{sc} is the subfactor for the effect of surface cover and M is the percent surface cover, represents the relative effectiveness of surface cover for reducing soil loss. The variable b

represents effectiveness of surface cover, and it varies according to specific conditions. For example, under some conditions, a 50 percent surface cover can reduce soil loss by 95 percent, while in other cases the reduction is about 65 percent. RUSLE2 adjust values for the coefficient **b** to partially account for this variation in the effectiveness of surface cover. The adjustment is on the basis on the ratio of rill to interrill erosion because ground cover has a different effect on each type of erosion. The effect of ground cover is much greater on rill erosion than on interrill. The net effect is that the effective **b** values is greater for conditions where the potential for rill erosion in relation to interrill is increased. The largest **b** value is chosen to reflect conditions where surface cover has its greatest effectiveness.

Surface cover has much more effect on rill erosion than on interrill erosion for cover less than about 75 percent. Therefore, if most of the sediment being eroded from a bare soil is produced by rill erosion, adding surface cover will have much more of a relative reduction in soil loss than adding that same amount of surface cover to a bare soil where most of the sediment is being produced by interrill erosion. The ratio of interrill to rill erosion for the soil in a bare condition is used to select a value for **b**.

Infiltration, and conversely runoff, is sometimes related to surface cover. Infiltration may not be affected by adding cover to a freshly prepared, tilled surface, and thus adding cover has no affect on runoff. In contrast, infiltration on fields in no-till cropping typically increases with increases in surface cover with the result that runoff decreases as surface cover increases. Therefore, a given amount of surface cover reduces soil loss more on a no-till field than on the tilled site. A larger **b** value is selected for conditions like no-till where cover is expected to have a significant effect on infiltration and runoff. These effects are considered in RUSLE2 using variables such as soil consolidation, residue cover, and soil biomass because infiltration is related to these variables.

Conditions where rill erosion is low relative to interrill erosion for bare soil include flat and short slopes and where the soil is resistant to erosion by flow, which is usually the case where the soil is consolidated such as on pasturelands. Rill erosion relative to interrill erosion tends to be high on steep and long slopes where the soil is highly disturbed and where the soil is susceptible to erosion by flow. RUSLE2 computes a **b** value of about 0.05 for long term no-till cropping, especially where no-till significantly reduces runoff in contrast to a **b** value of about 0.035 for conventional tillage that involve much soil disturbance.

An important variable in **RUSLE2** is the fraction of residue left on the soil surface by tillage or other soil disturbing operations. Some operations like planters only disturb a portion of the surface. The value used for cover left on the surface by an operation is an average value for the total surface rather than a value for the area, such as a slot, that is disturbed. One reason for only using a single cover value is that values reported in the literature for slot-type operations like no-till planting are almost always for the entire surface. Another reason is that wind, insects, and runoff can redistribute cover on the surface.

Although non-uniformity affects the overall effectiveness of surface cover, sufficient research data are not available to recommend how to adjust **b** to account for spatial non-uniformity in surface cover.

When plotted as a function of surface cover at planting, soil loss computed by **RUSLE2** does not decrease as rapidly with increases in surface cover as does the surface cover subfactor. Conversely, when soil loss ratio values at the time of planting are plotted as a function of surface cover at planting, these values decrease more rapidly than does the surface cover subfactor. These soil loss ratios are similar to erosion data obtained from rainfall simulation experiments conducted shortly after planting. These differences must be considered when comparing information reported in the technical literature with values computed by **RUSLE2**.

Surface Roughness

Soil disturbing operations can leave two types of roughness on the surface, random and oriented. Random roughness is produced by depressions without any particular pattern to them. Depressions left by a moldboard plow are an example of random roughness. Random roughness ponds waters in the depressions and reduces the erosivity of the impacting raindrops. The velocity of surface runoff is also reduced, which reduces its erosivity. These reductions in erosivity reduce soil loss. The depressions also cause local deposition and store sediment, which reduces soil loss.

Different types of tillage operations produce different distributions of aggregate sizes. Soils and operations that leave large aggregate size promote increased infiltration and have increased resistance to detachment, which represent decreased erodibility. Roughness indicates the degree of cloddiness and the likelihood that the soil surface will seal, producing increased runoff. Also, fine particles are more susceptible to detachment than are large particles. Large aggregates also produce deep depressions that decrease erosivity.

Oriented roughness has a pattern. Ridges and furrows left by a lister are an example of oriented roughness. Oriented roughness (ridges) is important in **RUSLE2** in two ways. Ridges increase erosion by increasing detachment on the ridges by raindrop impact. This effect of ridges is considered in the cover-management effects computed by **RUSLE2**.

Ridges provide the effectiveness of contouring for reducing soil loss. Ridges are used in contouring to redirect runoff from a direct downslope path to a path around the slope where the gradient is much less than the steepness of the slope. This redirection of runoff reduces the erosivity of the flow. The effect of ridges on contouring is considered when **RUSLE2** computes the effect of supporting practices.

Random roughness and ridges diminish over time after they are created. Depressions fill with deposited sediment, raindrop impact on the soil peaks erodes them away smoothing the surface, and the soil subsides as it is wet by repeated rainfall. Ridges decay by similar processes. Random roughness and ridge height are reduced in **RUSLE2** as functions of both cumulative rainfall amount and cumulative erosivity adjusted for the effects of canopy and a ground cover effect to represent interrill erosion. The cumulative rainfall variable reflects how the soil subsides over time with repeated wetting, and the cumulative adjusted rainfall erosivity reflects how raindrop impact wears away the soil peaks and sediment accumulates in the depressions.

In **RUSLE2**, roughness and ridges are created by an **OPERATION**. Roughness values in Agricultural Handbook No. 703, Table 5-5 and in the **OPERATION** database in the **RUSLE2** computer program are for a base condition of a medium textured soil where large amounts of residue, like from a high production sod, corn, or wheat crop, are regularly incorporated into the

soil and the soil has a stable structure. The base values are adjusted for soil texture such that the roughness index used for a fine textured soil is greater than the base value and is smaller than the base value for a coarse textured soil. These values have been carefully chosen based on a literature survey to reflect differences in soil loss from different types of implements.

In research, values of random roughness are determined by measuring the micro-elevations of the soil surface by lowering pins to the soil surface or by using a laser to measure surface elevations. The resulting data are processed to determine the standard deviation of the elevations about the average elevation as a measure of surface roughness. Making such measurements and computations is impractical in field application of **RUSLE2**. If a tillage implement of interest is not listed in Agricultural Handbook No. 703, Table 5-5, or in the **OPERATION** database in the **RUSLE2** computer program, compare the roughness characteristics of your implement with a similar implement and make a selection on that basis.

The method of laying a roller chain across the surface and determining the extent that it is shortened from a “stretched-out” length is sometimes used to estimate roughness values. While this method is simple and easy to use, it should not be used to estimate roughness values for **RUSLE2**. A simple method that is an alternative to the chain method is to lay a 6-ft straight edge across the peaks of the roughness elements and measure the depth of the deepest depression, and use Figure C-10, Appendix C of Agricultural Handbook No. 703 to select a roughness value. Several measurements should be taken at the site. Also, the measurement should be taken so that only random roughness and not oriented roughness is being measured.

If field measurement of roughness is attempted, much care should be exercised. Roughness left by a particular implement can vary greatly with year, soil, cropping-management, speed of operation, and other factors. Making field measurements of roughness outside of a research setting to produce values to use in **RUSLE2** leads to great inconsistency in predicted soil loss and is strongly discouraged.

The roughness values shown in Agricultural Handbook No. 703, Table 5-5 represent values for an “excellent” soil condition. **RUSLE2** reduces these values for reduced amount of biomass in the soil. This reduction in roughness is supported by research data that show that the relative effectiveness of moldboard plowing is reduced when crop yield is low. The amount of live roots in a soil affects the roughness left by a tillage operation. This difference in roughness can be seen by comparing roughness in a grass strip with that in an adjacent field where both areas have been plowed. In considering the effect of biomass on roughness, keep in mind that the roughness subfactor effect in **RUSLE2** considers more than just the physical size of the roughness elements; it considers the effect of aggregate distribution and stability and their influence on infiltration and erodibility.

The rate that roughness is lost in **RUSLE2** is not a function of soil properties related to texture or soil management, but the effect of these variables on roughness at any particular point in time is partially taken into account by having the starting value be a function of soil texture and soil management as measured by soil biomass involved in the tillage operation that creates the roughness.

Initial values of ridge height are entirely a function of the operation that creates them. Also, the rate that ridge height decays is independent of soil texture and soil management. Input values in the Operation database can be adjusted to partially account for these effects.

Implements like moldboard plows and tandem disks disturb 100 percent of the surface. Other implements like no-till planters only disturb a portion of the surface. In contrast to surface cover where the value used for an implement reflects the cover condition for the overall area, the roughness value chosen for an implement is for the roughness of the area disturbed by the implement. **RUSLE2** uses the roughness of the surface before disturbance, the roughness of the disturbed portion, and the percent area disturbed to compute an equivalent roughness for the entire surface.

RUSLE2 considers two roughness values, one immediately after an operation, and a “long term” value. A roughness value of 0.25 inches should be used as a lower limit, long term value for most cropped fields. A roughness value of 0.25 inches is a relatively smooth condition and reflects the roughness that would be present in a field following a disk harrow operation after a year’s rainfall. A “long term” roughness can persist on pasture areas where bunch grass, local erosion, plant roots, and animals create roughness that remains on a continual basis. Livestock grazing on pasture or congregating in feeding and watering areas can create much roughness.

Soils that have been repeatedly tilled like with a rotary tiller to produce a smooth, finely pulverized seedbed for vegetables should be assigned an initial roughness less than 0.24 inches. In that case, the initial roughness is not reduced as a function of rainfall.

Prior Land Use

Present erosion is affected by prior land use. For example, land freshly plowed out of meadow is only about 25 percent as erodible as soil in continuous cultivation. Similarly, land following soybeans is about 40 percent more erodible than land following corn.

The effect of prior land use on soil loss is considered in cover-management effects in several ways. One way is the carryover of residue, an effect that disappears in time as residue decomposes. Another way is in roughness, which also disappears with time, following a soil disturbing operation in a prior land use. Also, soil disturbance loosens the soil and increases soil erodibility, but over time erodibility decreases as the soil “Consolidates.” In **RUSLE2**, this decrease in erodibility is generally assumed to occur over a seven-year period although different lengths of time can be used. When fully consolidated, **RUSLE2** computes a soil loss that is about 45 percent of that immediately after disturbance or when the soil is in continuous cultivation.

When a soil disturbance occurs, the consolidation subfactor is reset to begin to decay again with time. The consolidation subfactor is only reset on the portion of the soil that is disturbed such as the tilled strip with a no-till planter. The undisturbed portion continues to consolidate. However, only one consolidation value is tracked through time by **RUSLE2**, which computes an effective soil consolidation state based on the percent area disturbed and the degree of consolidation on the area not disturbed. An “effective point in time” on the consolidation time decay is reset to give the value of the consolidation subfactor after disturbance. This approach simplifies the computations in **RUSLE2** but captures the overall effect of consolidation as affected by spatially non-uniform disturbance.

Soil structure and organic material in the soil affect soil erodibility, and these effects carry over with a change in land use. Roots and incorporated residue provide organic matter that decompose and decrease erodibility. A change of land use usually causes a change in the amount of biomass in the soil. The amount from a prior land use decays, and the amount from the present land use accumulates until a new equilibrium condition develops. These effects of prior land use in **RUSLE2** are affected both by types of plants being grown and how the plants and soil are managed.

A part of the effect of prior land use is computed by relating the prior land use subfactor to the amount of biomass in the soil at any given time. Biomass in the soil is from three sources, “live” plant roots, “dead” roots, and residue buried by tillage. The effect of “killing a crop” by tillage or by application of a herbicide transfers the “live” root biomass to the residue pools of “dead” roots.

Decomposition of biomass in the soil is computed by the same equation used to compute decomposition of surface residue. Different coefficient values can be entered to compute decomposition of biomass on the surface at a different rate from that in the soil. However, the same value is currently recommended for all pools of biomass.

Erosion research has shown that incorporating organic materials into soil reduces soil erosion. This result has been demonstrated where animal manure, green manure, pine litter, tree leaves, and plant residue have been incorporated into the soil. The prior land use subfactor that is a function of amount of biomass in the soil captures the effect of addition of organic matter in the soil.

Another effect of tillage is to incorporate surface residue and litter into the soil and to redistribute existing biomass in the soil. When **RUSLE2** initially buries residue, it distributes the biomass in the soil based on the depth of the soil disturbance and the type of tillage. The inversion type of tillage places most of the residue greater than half the depth of tillage, whereas other types of tillage leave most of the residue in the upper half of the tillage depth, some closer to the surface than others.

Tillage also redistributes residue and buried roots in the soil. The inversion type of tillage “flips” biomass in the soil and tends to even out the distribution soil over time in the soil over time. Biomass tends to “filter down” with other types of tillage that do not invert the soil. For example, residue can be concentrated near the soil surface following the first tandem disk operation that buries residue. The next tandem disk operation can leave a fairly uniform distribution of biomass in the soil, but the third tandem disk operation can leave a concentration of biomass about tillage depth.

Also, the common idea is that rototillers uniformly distribute biomass in the soil. In fact, the first pass of a rototiller leaves most of the biomass near the soil surface. Subsequent passes move the biomass down into the soil so that a peak concentration of the biomass moves downward in the soil with repeated tillage operations. A common misconception is that biomass becomes uniform with repeated tillage operations. A somewhat uniform distribution does develop for implements like moldboard plows that invert the soil, but exactly the opposite occurs with non-inversion implements, which concentrates the biomass in the soil.

The relationships used in RUSLE2 are based on extensive research conducted by the USDA-Agricultural Research Service and the University of Minnesota.

An important feature in RUSLE2 is that it resurfaces buried residue, but not dead roots, depending on the characteristics of the implement, the depth of tillage, and the mass of buried residue in the tillage depth before the tillage. Also, the amount of residue that is resurfaced depends on the type of residue. Large, tough residue like corn stalks and woody debris is more likely to be resurfaced than fine, fragile residue like that for soybeans. The procedures used in RUSLE2 to resurface residue are based on research data collected by the USDA-Agricultural Research Service and The Ohio State University.

Organic matter accumulates in the upper layer of soils that are maintained in continuous no-till. To account for this effect, **RUSLE2** adds half of the decayed residue from the surface to the biomass in the upper two inches of soil. The effect of this biomass addition is to reduce soil erodibility under no-till conditions.

In **RUSLE2**, roots in the soil are assumed to have four major effects, which are to (1) mechanically hold the soil in place, (2) mechanically act as miniature grade control structures, (3) provide porosity that maintains infiltration where roots die and are sloughed by the plants, and (4) provide organic compounds that reduce soil erodibility as the roots decay. An indirect effect of roots is that they indicate evapotranspiration by vegetation, which increases infiltration, reduces runoff, and hence reduces erosion.

The input value for live roots is the mass of roots in the upper four inches. RUSLE2 uses this value to estimate a total mass of roots over a fixed rooting depth of ?? inches. While a fixed rooting depth is unrealistic, this simplification works in RUSLE2 to capture the main effect of roots on soil loss. RUSLE2 assumes a distribution of roots in the soil over the rooting depth. Live roots are assumed to be mainly concentrated at about a 2 to 4 inch depth with decreasing values toward the soil surface and toward the rooting depth. Dead roots are redistributed in the soil by tillage.

The same root distribution is assumed for all types of vegetation, which was based on an extensive review of research data. This assumption seems appropriate for agronomic crops like corn, soybeans, and wheat. It may not be appropriate for vegetable crops where rooting depth is less. Some adjustment may need to be made in the root biomass values entered in RUSLE2 keeping in mind that the fine roots are the most important roots in the soil erosion process.

Remember, the intent of RUSLE2 is to capture the main effects of roots on soil erosion, not to be a model of roots as they actually occur in the field.

These effects of roots should be considered when root biomass values are selected. In most cases, only fibrous roots and not large taproots are represented in the root biomass values. Examples where these considerations are important include vegetable crops of carrots and sweet potatoes and range and disturbed forest lands with woody vegetation.

Values for root biomass for selected field crops, grasses and legumes are given in Agricultural Handbook No. 703, Tables 5-2 and 5-3. Based on empirical data, **RUSLE2** considers the

effectiveness of both live and dead (decaying) roots for controlling erosion to be different from the effectiveness of buried residue.

RUSLE2 describes the effect of manure additions to soil by considering how much biomass is incorporated and how much is left on the surface. The solids of the material left on the surface are treated as ground cover subject to decay. The organic material incorporated is treated like incorporation of crop residue and is subject to decay. Knifing manure into the soil is treating as a soil disturbance that is described in the same way that a tillage operation is described.

When manure is placed directly into the soil by injection (knifing), the manure is placed in the lower one half of the depth of surface disturbance used to inject the manure. The concentration of the manure is zero at one half the depth, maximum at three quarters depth, and zero at the depth of the disturbance. Subsequent tillage operations can bring some of the manure to the soil surface depending on the nature of the subsequent tillage operations.

Manure can be added to the surface and later be incorporated with an operation like a tandem disk. Four types of animal manure have been identified and are grouped according to their relative rates of decay. A group having a fast decomposition rates includes poultry litter and municipal sewage; one having a moderate rate includes beef, swine and dairy lagoon wastes; one having a moderately slow rate includes beef, swine and dairy manure from open lots or buildings; and one having a slow decomposition rate includes straw and newspaper bedding.

Manure is treated as a residue in **RUSLE2**, and values for the properties for manure are entered in the residue database.

Cropping-management practices can also be used to build organic matter in the soil and reduce soil erosion. **RUSLE2 is fully capable of describing how these practices affect erosion, an effect that is captured in the cover-management effects, not in the K factor. Adjustment of the K factor is a double accounting that produces incorrect results.**

Soil Moisture

In the Northwestern Wheat and Range Region and similar areas, the amount of soil moisture from a prior crop affects erosion during the present crop. If soil moisture is very low entering the present period, runoff and erosion will be very low. This subfactor is intended only for dryland cropping in the NWRR.

Cover-Management Systems

A cover-management system is described in **RUSLE2** by selecting operations, vegetations, and dates needed to define the system or practice. The best way to describe management systems in **RUSLE2** is to open a management object (window) and follow through the entries in the following steps.

SELECT A MANAGEMENT SYSTEM

To compute a soil loss estimate, a management system is selected. In addition to selecting the management system from the management database, values have to be entered for the additional variables of is this a rotation, length of rotation, and management alignment offset.

Answering Yes to the question is this a rotation causes RUSLE2 to proceed through the list of operations in the selected management system and continuously cycle through the list. The length of rotation is the number of years in the cycle before the first operation is repeated. A rotation can be 1 year or multiple years. A rotation can be a single crop grown in repeated years, such as continuous corn. It can be a multiple year rotation. A cycle of corn and soybeans is a two-year rotation. A cycle of corn, soybeans, and wheat is a three rotation.

Multiple crops can be grown in a single year. In a one-year rotation, planting and harvest need not be in the same year. The length of rotation is the duration in time between the beginning and end of the rotation, not the number of calendar years involved.

Operations need not occur in every year of the rotation. For example, corn could be grown in one year and the land left idle with absolutely no operation in the second year. The length of this rotation is two years. This system is a corn-fallow rotation.

RUSLE2 scans the list of dates in the management system and chooses a length of rotation. This value should be checked to make sure that it is correct. For example, in the corn-fallow system, RUSLE2 would choose 1 yr for the length of rotation when the correct length is 2 yr. The correct value of two years can be entered to override the 1 yr value determined by RUSLE2.

However, entering a no operation operation in the list of operations with a date in the second year of the rotation will cause RUSLE2 to properly determine the length of rotation.

The entry for management alignment offset is used to describe rotational strip cropping, which is discussed in a later section.

The question is this a rotation is answer nowhere the management practice is not a rotation, like on a construction site or a reclaimed mine. RUSLE2 starts with the first operation and runs for as many years as necessary to move the dates in the management object. When RUSLE2 is applied with a no-rotation, the proper initial conditions must be set up using the operations on the first day. Unless a soil disturbing operation is specified, RUSLE2 assumes the soil is fully consolidated. To create a “loose” soil, use a soil disturbing operation on the first day that creates the desired roughness. Also, the slope may have vegetation on the first day. Use an operation with begin growth and a corresponding data file to create the desired vegetation conditions.

Sometimes RUSLE2 will need to run for a time to create a particular condition. Specify the necessary dates in the management object. For example, the time of interest may be in the third year after the initial condition. Use an appropriate operation on the desired calendar date with year 1 as the year. Then the next date can be the same calendar date with year 3 as the date. Use the “no operation” operation to have RUSLE2 display the desired information without affecting the erosion computations.

MANAGEMENT OBJECT

1. **Open a management object** for a particular management. Open a management similar to the one being created. Often editing an existing management file is easier than

creating a new one. Immediately save the management under a new name that will be used for the management about to be created.

2. **Enter a value for the long-term natural roughness.** The typical value used for tilled cropland is 0.25 inch, but the value is typically about 0.6 inches for permanent pasture and similar lands.
3. **Prepare a list of dates, operations, vegetations, and additional information as needed.** The main element of the management practice is the list of dates, operations, and vegetations. Additional information may be needed for special operations. The “+” and “-“ keys can be used to insert or delete individual lines. Also, the right mouse key can be used to edit including copying and pasting within the management practice or from other management practice stored in the management database.
4. **Enter the date for the first operation and select the operation that occurs on that date.** Multiple operations can be entered on the date. For example, multiple operations can be entered on the same date to represent the effects of complex implements like a harrow being towed behind a tandem disk.

Each operation that involves a disturb process (see the later section on Operations for detailed information on processes are used to describe operations) has a speed and depth input that can be changed in the management object. The default values for these variables are the recommended speed and depth values entered in the operation data file for the particular operation. These default values can be changed in the management object within the maximum and minimum limits specified in the data file for the particular operation.

5. **Enter the particular vegetation** for those operations that include a begin growth process. The default value displayed for yield in the management object is the base yield in the particular vegetation that was selected. If the default yield is not the desired yield, a different yield value can be entered and RUSLE2 will adjust values in the vegetation data for the new yield.

The vegetation data file selected must have a maximum canopy cover less than 100% in order for another yield can be substituted for the default yield.

The manage object displays a value for the amount of ground cover in units of both mass and percent cover from residue at certain points, such as at harvest. This residue amount can be changed to a different value if desired.

RUSLE2 adjusts retardance class as a function of yield. The user can change the retardance class in the management object if it seems that RUSLE2 did not make the desired selection.

6. **If necessary, select added material and amount.** Operations like that those add manure or mulch require selection of a residue from the residue database to represent the added material. This selection is made in the management object from the residue database. Also, a value for the mass (dry basis) added must be entered in the management object as well.

7. Enter notes. Open the Info folder and add notes that might include information such as the date of creation, who created the file, and special information that should be considered when the management file is used.

8. Save. Save the new management under the new name.

VEGETATION

The main purpose of the vegetation object (window) is to define characteristics that describe how vegetation affects soil loss for particular vegetation. Information used to describe a vegetation include identifying a residue to associate with the vegetation and entering values for yield, root biomass, canopy cover, fall height, and live ground cover. Also, data are entered that define the relations of yield to above ground biomass that becomes residue and the degree that the vegetation retards runoff.

Information that describes the residue assigned to the vegetation is entered in the residue object (screen). Information used to describe how residue affects soil loss include values that determine how rapidly the residue decomposes on the soil and buried in the soil, the percent ground cover that a given amount (mass) of flat residue gives, and a residue type related to the size and toughness of residue pieces that influence the amount of residue that is flattened, buried, and resurfaced by a particular operation.

The guidelines follow the steps used to enter information for a vegetation object.

Steps

1. **Open a vegetation file:** Open an existing vegetation file for a vegetation that is similar to the vegetation for which you are creating a new vegetation file. Immediately save this file using the name that you have chosen for the new vegetation file.
2. **Select a residue:** Select a residue from the lists of available residue objects to associate with this particular vegetation. The same residue object can be used for multiple vegetation objects. For example, several corn objects can be developed based on days to maturity. The same residue object can be used for these corn objects.

You will need to create a new residue object if an acceptable one doesn't exist. Refer to other instructions for creating residue objects.

3. Yield definition: Yield is only important in RUSLE2 because the amount of residue, root biomass, canopy, and green ground cover depend on yield. Defining yield involves entering a yield unit (e.g., bushel) and the dry weight of each unit. The input value for yield is the number of yield units. The unit used to define yield is entirely arbitrary. Typically a common measure of yield is used, but you can create your own unit.

4. **Yield-residue points:** The equation “residue mass = a + b * yield mass” is used to estimate the amount of residue at the time that the vegetation is killed by an operation.

Residue is defined as the vegetative material that could possibly end up on the soil surface by harvest, senescence, flattening, or falling over by natural causes. “Killing the vegetation” moves the live above ground biomass into the standing residue pool and the live root mass into the dead root mass pool.

Values for above ground biomass at two yield data points are entered and used by RUSLE2 to determine values for coefficients a and b. Each data point involves a value for yield and a value for the amount of above ground biomass at maximum canopy associated with that yield. The value entered for above ground biomass is the amount of biomass on a dry basis at maximum canopy rather than the amount of residue at “harvest.” Entering the value for the above ground biomass at maximum canopy rather than at “harvest” allows RUSLE2 to account for senescence.

The values to enter for these data points can be obtained in one of several ways. Residue-yield data may be available to either fit the equation to field data, or someone else may have fitted the equation to appropriate field data. Use a plot of the equation and read off the residue and yield values for two data points on the line and enter those values.

Be careful using research data because of it can vary greatly from study to study. Assemble as much data as possible and choose values that best represent the data as a whole.

If these data are not available, values for the two data points can be estimated from information in Appendix D of Agriculture Handbook (AH) 703 where values are given for residue to yield ratios for particular crops for yield over a range. Assume that the residue to yield ratio applies to the middle of the yield range. Assume the midpoint of the yield range and the residue to yield ratio for the first residue-yield data point. For the second data point, use the yield for the lower end of the yield range in AH703 and the residue-yield ratio times 1.1. For example, the value for the residue to ratio value for corn in AH703 is 1.0. The residue to yield ratio value that would be entered for 50 bu/ac, the lower end of the yield range in AH703, would be $1.0 \times 1.1 = 1.1$.

Another way is to estimate the amount of residue at maximum canopy for a given yield and use this value for the first yield point. For the second point, estimate the amount of above ground biomass at maximum canopy if yield is zero.

Remember, the purpose of these data points is to account for residue, not yield. Other than indicating values for other variables, yield is unimportant and accounting for biomass in grain is immaterial unless the biomass ends up on the soil surface as ground cover. Soybean grain doesn't end up on the soil surface, but pods around the grain do and should be counted as above ground biomass.

The information for these data points is entered on the “Describe Yield-Biomass Relationship” Object (window) by following the steps below.

a. Click on the “set” button to open the “Describe Yield-Biomass Relationship” object (window). The information for two data points is entered.

- a. **Enter the yield value for the first data point**, which should be the higher yield. The amount of above ground biomass for that yield can be entered in one of two

ways. One way is to enter the amount of above ground biomass for the yield and RUSLE2 will compute a biomass to yield ratio. The other way is to enter a biomass to yield ratio and RUSLE2 will compute a biomass amount.

- b. **Enter the values for the second data point.**
- c. **Click on apply or apply/close** button when values for both data points have been entered.

5. **Retardance:** Retardance describes how vegetation slows runoff. Retardance depends primarily on the type and density of vegetation. For vegetation that is grown in rows, retardance must be specified in the two directions of rows on the contour perpendicular to the flow and row up and downhill parallel to the flow.

No retardance is where the vegetation has little or no effect on runoff velocity. Very high retardance is highest level of retardance, which is how dense, sod forming grass affects runoff velocity. Select a retardance class between and including these two extremes based on how the vegetation slows the runoff considering both the type and density of the vegetation. Crops at a typical populations and density are listed with each retardance class as to guide the selection of a retardance class.

The selected row spacing along with the retardance class assigned for the vegetation grown in strips on the contour are used by RUSLE2 to internally assign a retardance class for the vegetation grown in up and downhill rows parallel with the flow. At one extreme, is vegetation grown on ridges where the vegetation has no effect on flow. Keep in mind that the row spacing selection is made for rows that are up and downhill. The other row spacing at the same extreme as vegetation on ridges is a very wide row such that the overall effect of the vegetation on flow is minimal. At the other extreme is random broadcast where the retardance is the same for both directions. A class for row spacing is selected between these extremes based on the fraction of the flow that is affected by the stems and leaves of the vegetation. For example, a narrow row spacing would be selected even though the vegetation is grown on ridges if the leaves touch the ground and slow the flow. The spacings wide, moderate, narrow, and very narrow refer generally to 30, 15, 7, and 3-inch row widths, respectively. Remember, the selection is to reflect the degree that vegetation slows the runoff, not a row spacing per se.

The retardance class used internally in RUSLE2 is adjusted as a function of stage of growth. Also, RUSLE2 adjusts the base retardance class as a function of yield. RUSLE2 uses values entered for two yield points to calibrate the equation used to make the adjustment as a function of yield. The following steps are used to enter these values.

- a. **Click on the “set” button** to open the “Describe Yield-Retardance Relationship” object (window). The information for two data points is entered.
- b. **Select a retardance class for a high yield.** Enter a yield value that is near the highest yield that this vegetation file will be used to describe. This yield need not be the same yield value used to describe the biomass-yield relationship. Select a retardance class for this high yield.

- c. **Select a retardance class for a low yield.** The first consideration is to determine if a **no retardance** class applies at a yield greater than zero. For example, a **no retardance** class is assigned at a corn yield of 100 bu/ac. If the answer is yes, then enter the highest yield where the **no retardance** class is to apply, keeping in mind that RUSLE2 will assume the **no retardance** class for a yield slightly above the value entered.

If the **no retardance** class occurs at a zero yield, such as for a sod forming grass, select **no** for the question. Enter the **no retardance** class for the retardance class at zero yield. The other possibility is that the retardance class at a zero yield is greater than the **no retardance** class. If so, enter the appropriate class for the retardance conditions at a zero yield.

6. Senescence: As plants like soybeans approach maturity, leaves fall from the plant to the ground, a process known as senescence. This loss of biomass from the canopy results in a corresponding increase in biomass in the flat residue. In most cases, only a fraction of the total above ground biomass of the vegetation is subject to senescence. An estimate of that fraction is entered for the above ground biomass for senescence, using an estimate is on the high side to account for the fact that most of the biomass that experiences senescence is leaves. The value of 0.6 seems to work well for crops like soybeans and cotton. A high value, perhaps up to 1.0 is appropriate for some grass-type vegetation.

RUSLE2 multiplies this fraction by the amount of biomass at maximum canopy to obtain the mass of the residue that will be added to the soil surface. The addition is distributed over time based on how the percent of canopy cover changes through time.

The fraction should be based on the amount of senescence that would occur if the plant were to reach “full” maturity. Make sure that the dates for the temporal vegetation variables, especially percent of canopy cover, extend beyond the date that the vegetation is killed. RUSLE2 estimates the amount of above ground biomass at the time that the vegetation is killed based on the date that the vegetation is killed relative to the date of maximum canopy and the dates in the percent canopy cover table.

Remember, the objective is to account for the material that experiences senescence rather than perfectly model senescence as a process.

Some plants lose percent canopy cover without canopy biomass falling to the soil surface. An example is corn where the leaves droop as the plant approaches maturity. For this and similar types of vegetation that lose canopy cover percent but not canopy mass before the vegetation is killed, enter a zero for the fraction of the above ground biomass that experiences senescence.

6. Moisture depletion rate: This variable is used only for the region of the US referred to as the Northwest Wheat and Range Region (NWR) and a few other similar areas in the Northwestern part of the US. This area includes the Palouse region. Ignore this input unless RUSLE2 is being applied to NWR. Recommended values will be provided at a later date.

7. Yield: The data for above ground biomass, root biomass, canopy cover, fall height, and live ground cover are a function of yield. Thus, a yield value must be entered using the yield units

defined above. If the yield is changed, then these other values must change as well. The program computes an amount of above ground biomass from the entered yield value and the data entered for the yield points that define the relationship between yield and above ground biomass.

Data files can be created for new yield values, or RUSLE2 will automatically change root biomass, canopy cover, fall height, and live ground cover as a function of yield by entering a yield value in the management object (screen). At this point, make sure that the proper yield value has been entered for the root biomass, canopy cover, fall height, and live ground cover entered in the table.

Also, make that a yield has been chosen that gives a maximum canopy less than 100% if this vegetation data file is to be used as a base file for adjusting for new yields.

8. Enter temporal values: Enter dates and corresponding values for root biomass, canopy cover, fall height, and live ground cover in the table to describe how these characteristics vary through time over the listed dates. The zero date corresponds to the calendar date that a “begin growth” process for an operation calls this particular vegetation.

RUSLE2 uses a single vegetation at a time. For example, RUSLE2 does not take information from a file one type of vegetation and combine it with information from the file for another vegetation to create a mixed plant community.

The information used by RUSLE2 to describe vegetative conditions at any point in time comes from a single file. Make the information in that file represents the composite conditions as they exist in the field.

In monocropping, a single plant type is growing at a time. Multiple plant types grow simultaneously on cropland with intercropping, pastureland, landfills, rangelands, and similar lands. A single value at a given point in time is used for each vegetative variable like canopy fall height regardless of the how many plant types are growing.

Dates

Dates in a vegetation file are specified in days since the “begin growth” command calls this particular vegetation. Dates are entered in one of two ways. The first approach is to chose dates that occur at a regular interval, such as 15 days. The 15-day interval was used in RUSLE1, and dates in RUSLE2 will be on a 15-day interval when data files are imported from RUSLE1.

In RUSLE2, the dates need not be on a fixed interval. RUSLE2 assumes a linear variation between data points regardless of the dates that are entered. If the vegetation doesn’t change over a time period, only dates at the beginning and end of the period need to be entered. If values for a variable vary linearly between two dates, only dates at the beginning and end of the linear time period need to be entered. Sufficient dates should be used in time periods where changes are nonlinear to give a good representation of the period. Dates can be less than 15 days apart.

The last date in the file for a vegetation should be later than the date of an operation that kills the vegetation. However, if the last date is less than the killing date, the values on the last date will continue to be used until the time that the vegetation is killed.

No time limit exists for the last date. The last date for a vegetation file in RUSLE1 was limited to a single year. In RUSLE2, the dates can go for as long as desired to represent the full duration of the vegetation, which can be multiple years.

Multiple files are sometimes used to represent certain conditions, like a hay crop where the vegetation is harvested and regrows.

These characteristics of RUSLE2 emphasize that RUSLE2 uses a descriptive procedure to set important parameter values that affect soil loss rather than using a plant model. The focus in creating and using vegetation files is to describe, not to model.

Root Biomass

For each date, enter a value for the root biomass in the upper four inches of soil. RUSLE2 uses these values to estimate root biomass values throughout the rooting depth. These values should be based primarily on the annual production of fine roots. Large taproots have little effect on soil loss.

Root biomass increases through time from zero on day zero for seeded annual crops, but the root biomass can be greater than zero on day zero for plants that are transplanted. On perennial vegetation, the variation of root biomass through time should be entered. Root sloughing, similar to above ground senescence, provides soil organic material that significantly affects soil loss. Entering a root biomass that does not vary through time causes RUSLE2 to miss this important organic matter pool and to overestimate soil loss.

In some cropping-management systems, one vegetation immediately follows another vegetation. An example is a forage crop where vegetation grows back following a hay harvest. This practice is represented using multiple vegetation files. The canopy cover and live ground cover values for day zero of the regrowth are selected to represent conditions left by the hay harvest. The canopy cover before harvest might be 100% and be 10% after harvest. In contrast, the harvest is not assumed to affect root biomass. Thus, the root biomass in the data file for the first vegetation should be the same at harvest as the root biomass for day zero in the data file for the second vegetation that regrows following harvest.

A critically important point is that RUSLE2 interprets any decrease in root biomass as root having died. The difference in root biomass is moved into the dead root biomass pool, which can have a significant effect on soil loss. This technique should be carefully considered when constructed data files for intercropping to ensure that dead root biomass is increased when the first crop is killed and the second crop continues to grow.

In a hay crop like alfalfa, the root biomass values should be the same before and after harvest. An intercropping practice is to seed a legume in small grain. When the small grain is harvested, the legume continues to grow. The root biomass at harvest of the small grain is reduced to a lower value. The small grain was killed by the harvest but the legume continues to grow. This decrease in root biomass is the amount of biomass that RUSLE2 transfers to the dead root biomass pool when the small grain is harvested.

A similar example is the emergence and growth of weeds in row crops in the Southern US.

Be careful in selecting root biomass values. Measuring root biomass is very difficult and time consuming. As a result, values in the literature vary over a huge range. Many data sources need to be reviewed. Consistency must be maintained between plant communities and the core data values assumed for RUSLE2. RUSLE2 has been calibrated using the core values, and if values are chosen that are not consistent with the core values used to calibrate RUSLE2, then RUSLE2 may give very erroneous results. Do not use root biomass values without checking them for consistency with RUSLE2 core values.

Canopy Cover Percent

Canopy cover is the portion of the soil surface covered by plant canopy. Canopy is defined as vegetative cover that is above the soil surface that only affects raindrop interception but not surface runoff. One way to estimate canopy cover is to first determine open space between plant rows and open space within the perimeter of the plant canopy and subtract this percent from 100. Canopy cover can be estimated from photographs for certain crops like corn where live vegetation does not touch the surface. A better approach for vegetation like that on pastureland where some of the live vegetation touches the ground is to lay out a transect and count the number of hits for canopy as well as dead and live ground cover.

Canopy Fall Height

Canopy fall height is the effective height from which intercepted rainfall falls from the plant canopy. This height is less than the height to the top of the canopy but greater than the height to the bottom of the canopy. Fall height is a function of these variables as well as the shape of the canopy and the density distribution of the canopy with height.

Some plant communities like grass growing under shrubs have two distinct canopies. If the under story is dense, it will be given main consideration in selecting a fall height.

Several procedures are available for selecting values for fall height. One approach is to observe plants in the field or photographs and assign values. Another approach is to use the transect approach where the height of the lower level at canopy at each point is measured. Fall height is the average of those values. A third approach is use estimation procedure in RUSLE2 that uses values to the top of the canopy, bottom of the canopy, shape of the canopy, and the height within the canopy where the densest part of the canopy is located.

To use on the RUSLE2 procedure, follow these steps:

a. Click on the fall height set button on the vegetation object (screen) to use the RUSLE2 procedure to estimate fall. This click opens the “adjust fall height” object (window).

The selections in the upper left portion of the new window are for information. They provide a visual representation of canopy shape and the density distribution within the canopy. If most of the canopy is concentrated near the bottom of the canopy, the overall effective fall height will be closer to the bottom of the canopy than to the top. If most of the canopy is near the top of the canopy, overall effective fall height is nearer to the top of the canopy than to the bottom of the canopy.

The dates entered in the main vegetation object (window) are copied into the adjust fall height object (window).

b. Enter heights to the top of the canopy and the bottom of the canopy for each date. RUSLE2 computes a fall height as each canopy height is entered that is based on the shape and density selection shown in the table on the right of the window.

c. Adjust for canopy and density in the table to the right by choosing the canopy shape and density distribution that best represents the vegetation. These selections change the fall heights according to the new shape and density selections. Notice that the change was made for all of the dates.

d. Adjust for different canopy shapes and densities through time. The table at the right is used to adjust fall heights as canopy shape and density changes through time. For example, in the beginning growth stage, the canopy shape for wheat is a triangle with the canopy density near the bottom. When the wheat is mature, the proper canopy shape is an inverted triangle, with the canopy density near the top of the plant.

Dates are entered to represent points in time where a new canopy shape or density distribution should be used. Enter the dates for the midpoint of the time periods to be represented by a particular shape and density distribution, and select the appropriate shape and density for that time period. RUSLE2 will compute a new fall height for those dates and interpolate fall heights for the other dates in the table to the left.

e. Apply the fall height values to the main vegetation file. Once the desired fall height values have been filled in the table on the fall height object (window), click on the Apply or the Apply/Close button to place the fall height values in the main vegetation table.

Live Ground Cover

Live ground cover is live vegetation that touches the soil surface that affects raindrop impact and surface runoff in the same way that ground cover like crop residue, plant litter, and applied mulch affect soil loss. That is, live ground cover is one form of ground cover. The percentage of the soil surface covered by live ground cover can be very high early in the plant growth stages and the vegetation is almost entirely composed of very low lying leaves. As the vegetation grows and stems develops, live ground cover can decrease, even to the point that no part of the plant, other than the stems, touch the soil surface to provide live ground cover. Entering a value for live ground cover is the way to reflect how basal area affects soil loss.

A value for live ground cover expressed as the portion of the total surface covered is entered for each date.

9. Develop a new growth chart: Type of vegetation and annual production level (yield) determine values for many of the vegetative variables that affect soil loss. The effect of these variables is handled in RUSLE2 in one of two ways.

One way is enter a yield value in the management object (screen) where a vegetation file is selected for the operation that has a “begin growth” process that calls the vegetation. Selecting a vegetation file accounts for the type of vegetation and yield can be accounted for by entering a yield value. Adjusting for yield in the management object (window) requires that the selected base vegetation file be for a yield where maximum canopy cover is less than 100%. RUSLE2 will adjust root biomass, canopy cover, fall height, and live ground cover using this “base” data file for the vegetation.

The other way is to create a data file for each yield level, which was the approach used in RUSLE1. The equations described in AH703 to adjust vegetation files for yields have been incorporated into RUSLE2 so that these adjustments do not have to be made by hand. To use this approach to account for yield means that the begin growth operation calls the vegetation with the desired yield.

To create a vegetation file with a new yield, follow these steps.

- a. Open an existing vegetation file for the particular type of vegetation.** Immediately save this file under the name that will be used for the new vegetation file that is about to be created.
- b. Click on the “set” button** “Develop a new growth chart based on yield” to open the “Develop new growth chart based on yield” object (window).
- c. Select a base file** for the given type of vegetation. This file will be adjusted by RUSLE2 to produce a vegetation file for the new yield.

The base data file must use a yield where the maximum canopy is less than 100%. The equations for the yield adjustments require that the maximum canopy in the “base” data file be less than 100% required for the yield adjustment procedure to work.

d. Enter the new yield. The first yield that is displayed is the yield for the “base” data file. Enter a value for the second (new) yield that is displayed. This yield can be greater or less than the base yield. When the value for the new yield is entered, the new values for root biomass, canopy cover, fall height, and live ground cover are shown in the new growth chart.

e. Apply new values. If the new growth values are satisfactory, click on the apply or the apply/close button to place the new values in the new data file previously saved for the new yield.

f. Save the newly created vegetated file under the new name.

RESIDUE OBJECT

The residue object describes properties of residue that are assigned to particular vegetations. It is also used to describe properties of materials added to the soil surface or placed in the soil. These materials include straw mulch, manufactured erosion control materials, manure, papermill waste,

and pine needles.

Plant residue is composed of a mixture of plant materials including leaves, stems, pods, seeds, and roots. The preferred way of treating residue would be treated each component individually, but approach was considered too complex for RUSLE2. Thus, values entered for residue variables are chosen to represent the main effect that residue has on soil loss. For example, leaves decompose very rapidly and only stems are left after a short time after harvest for a crop like soybeans in the southern US where fall temperature and rainfall are high. In contrast, soybean leaves persist longer in the upper Midwest US, and thus the leaves should be given greater consideration in selecting parameter values in the upper Midwest US than in the southern US.

Different residue files can be created for the same residue type can be created where different parameter values are used to represent such differences among location, soil types, management practice, and characteristics of the vegetation producing the residue.

The intent of RUSLE2 is to capture main effects, not all of the details from secondary effects. However, RUSLE2 frequently has the capability to be calibrated to local conditions.

The material placed in the soil should be subject to decomposition, but inert materials like rock can be placed on the soil surface. The following steps are used to create a residue file.

1. **Open an existing residue file.** Open an existing residue object that is similar to the one being created and immediately save it under the new name.
2. **Select a residue type.** Select a list of five residue types a residue type based on how the residue responds to tillage. The fifth type of residue is a special case to represent rock and stone of gravel size. The other four residue types related to plant materials. The first residue type is for residue that is fragile and is typical available in small pieces that are easily buried. This residue is typical of soybeans. On the other extreme is residue that tends to occur in large, tough pieces. This residue type is chosen for woody debris like that common to disturbed forestland and shrub-dominated rangeland. In between is residue that primarily represents wheat and corn residue, where wheat tends to occur in smaller pieces than does corn.

A very important point to remember is that the residue types are defined only by the values ratios entered for flattening, burial, and resurfacing ratios. The definitions are for convenience only to maintain consistency.

3. **Enter values for decomposition coefficients.** RUSLE2 computes decomposition of residue at a location using daily average annual rainfall amount and temperature and a value for the decomposition coefficient that reflects how different materials decompose at different rates. **The intent of RUSLE2 is to reflect the main effects of material (represented by the decomposition coefficient) and location (represented by rainfall amount and temperature that varies with location).** RUSLE2 does not consider differences as a function of soil moisture as influenced either by evapotranspiration or soil texture. However, some of these effects can be captured in RUSLE2 by assigning different values for the decomposition coefficient based on these variables.

Enter values for the decomposition coefficients. These values can be entered as a coefficient value or as a half-life value. The half-life is the time required for half of the residue to decompose at the optimum temperature of ?? where moisture is not limiting. These conditions represent the fastest possible decomposition rate. The actual decomposition rate in the field as computed by RUSLE2 is less than this rate. Values for decomposition coefficients are given in AH703.

A different value can be entered in RUSLE2 for the decomposition of materials on the soil surface than buried residue. However, while the expectation is that decomposition occurs more rapidly in the soil than in the soil, the research data used to derive decomposition coefficient values for RUSLE2 were inconclusive regarding differences in values for these decomposition coefficients.

The value for the decomposition of buried residue is used for the decomposition of dead roots. No option is available in RUSLE2 for choosing separate values for the two types of residue.

4. **Enter values for mass-cover relationship.** Residue is tracked in RUSLE2 on the basis of mass. However, the effect of flat residue, which is residue laying flat on the soil surface, is better described by the portion of the soil surface that the residue covers rather than mass of residue. The mass-cover relationship used in RUSLE2 is $\text{percent} = [1.0 - \exp(-a \cdot \text{mass})]$. The values entered for the mass-cover pairs is used by RUSLE2 to determine a value for the coefficient a in this equation. Although space is provided to enter values for three pairs, actually data need be entered for only one pair. If data are entered for two or all three pairs, the data will be averaged to determine a value for the coefficient a .
5. **Enter notes.** Open the info folder and enter pertinent notes.
6. **Save.** Save the residue file under the new name.

OPERATIONS

Operations are discrete events that change properties of live vegetation, residue, and/or the soil that affect soil loss. Examples of operations include tillage, planting, harvesting, grazing, burning, frost, ripping, and blading.

The main element of operations is the processes that describe how operation affects vegetation, residue, and the soil. Both the processes themselves and their sequence determine the effect of an operation. Some processes have parameters that describe the degree of the effect of a particular process.

Having a good understanding of processes is fundamental to developing operation files and applying them in RUSLE2. The processes used to represent operations in RUSLE2 are:

No effect
 Begin growth
 Kill vegetation
 Flatten standing residue
 Disturb surface
 Live biomass removed
 Remove surface cover
 Add other cover

RUSLE2 maintains two types of vegetation, which are **live** and **dead**. It also tracks vegetation as that above ground and **below ground**. Below ground vegetation is referred to as **roots**, which are accounted for in the pools of live roots and **dead roots**. Above ground biomass is tracked in two pools of **live vegetation** and **residue**. The three pools of residue are maintained by RUSLE2. These pools are **standing, flat, and buried**. Two types of **surface cover** are used in RUSLE2, which are **canopy** and **ground cover**. Canopy cover is material that is above the soil surface that intercepts rainfall but does not affect surface runoff. Ground cover is material that is in direct contact with the soil surface and affects both raindrop impact and surface runoff. The processes mentioned above and described below are used in operations to move biomass among these various pools.

With three exceptions, the processes listed are used in RUSLE2 to transfer residue among these pools. The first exception is that senescence directly transfers biomass from the live biomass pool to the flat residue pool. The second exception is that natural processes can transfer standing residue pool to the flat residue pool as standing residue “falls” over. The third exception is that as flat residue decomposes, a portion of the decomposed biomass is arbitrarily added to the buried residue soil biomass. This procedure builds up organic matter in the upper layer of soil that is characteristic of no-till cropping and pasturelands having large amounts of litter.

Description of the Processes used in RUSLE2 Operations

No Effect: The “**no effect**” process has just that, no effect. It is used in a “**No Operation**” operation to cause RUSLE2 to display information on certain dates and for certain periods. Also, sometimes one user will place the “no operation” in a list of operations where another user will later substitute another operation.

Begin growth: The **begin growth** process is used by RUSLE2 to start a particular vegetation file and the use of data from the file. The zero date in the vegetation file is assigned to the calendar date in the management object (window) for the operation that includes the begin growth process. When an operation includes a begin growth process, the management object (window) requires an input for the vegetation name.

Kill vegetation: Begin growth begins use a vegetation file; **kill vegetation** ends use of a particular vegetation file, except for the residue information. The specific effect of the kill vegetation process is to convert live above ground biomass to standing residue and live roots to dead roots. It is used with many tillage and harvest operations that end vegetative growth. It would also be used in a killing frost operation.

Standing residue remains as standing residue unless it is transferred from the standing pool to the flat pool by the flattening process in an operation, or the standing residue “falls” (transfers) to the flat pool as a result of natural processes computed as a function of decomposition characteristics of the standing residue.

Flatten standing residue: The **flatten standing residue** process is used to transfer residue from standing residue to flat residue. One obvious use of the flatten standing residue process is to flatten standing residue where a machine has travel over the ground. This process is also used as a part of tillage operations that bury residue because RUSLE2 assumes that standing residue cannot be buried without first being flattened. Another use of the flatten standing residue process is to determine at how the residue is distributed between standing and flat residue. For example, about half of wheat residue is left standing, while only 15% and 5% of the residue are assumed to be left standing for corn and soybeans, respectively.

The fraction of standing residue that is flattened depends on the type of residue. A value for the flattening ratio is assigned for each operation that includes the flattening process for each of the five types of residue used by RUSLE2. The **flattening ratio** is defined as the ratio of mass of standing residue that is flattened to the mass of standing residue before the flattening process occurred.

The flattening ratio is greatest for those residue types that are most easily flattened by mechanical action. When the flattening ratio is used to describe the distribution of residue between standing and flat at harvest, the value chosen for the flattening ratio depends primarily on the nature of the nature of the vegetation and the height of the harvest operation.

Disturb Surface: The “**disturb surface**” process always loosens the soil and makes it more erodible, transfers residue between the flat residue pool and the buried residue pool, and redistributes buried residue and dead roots within the soil.

RUSLE2 follows several basic rules regarding transfer of residue among the standing, flat, and buried residue pools. The soil must be disturbed to **bury residue**, or conversely, residue cannot be buried without disturbing the soil. Residue must first be flattened before it can be buried, and thus a soil disturb process must be preceded by the flatten standing residue process. In addition to flattening and burying residue, a soil disturb process **resurfaces residue**.

The amount of residue that is flattened is described by the flattening ratio described above. The amount of residue that is buried is described by a burial ratio defined as the ratio of mass of residue buried to the mass of flat residue before the burial process. The amount of residue that is resurfaced is described by a resurfacing ratio defined as the ratio mass of residue brought to the surface to the mass of residue in the depth of the soil disturbance. The mass of flat residue left after a disturb surface process is the net between the amount buried and the amount resurfaced. The amount of flat residue can be either increased or decreased based on the amount of residue buried in the soil within the depth of disturbance.

RUSLE2 does not resurface dead roots, which are assumed to be bound to the soil mass.

Like the flattening ratio, values for these ratios are a function of the type of residue and the nature

of the soil disturbing process. Values for flattening, burial, and resurfacing ratios are placed in a table for each operation using flatten and soil disturb processes.

In addition to values for these ratios that must be entered in a table for the operation object (window), values must be entered for other variables associated with the soil disturb process. These variables are:

Tillage type: **Tillage type** refers to the pattern that the disturbance leaves residue in the soil following burial and the pattern that buried residue and dead roots are redistributed in the soil. The tillage type **inversion+some mixing** is for implements like moldboard plows that invert the soil. These implements tend to bury residue deep in the tillage layer. The type **mixing only** is primarily for implements like rototillers that do almost no inversion and only mix the soil. These implements tend to bury residue near the soil surface. The type **mixing with some inversion** is for implements like tandem disks, chisel plows, and field cultivators that primarily bury residue by mixing but also cause some inversion of the soil. These implements bury more of the residue in the upper half of the tillage depth rather than in the lower half. The type **lifting, fracturing** is for implements like subsoilers and fertilizer injectors that do almost no mixing or inversion and bury residue very near the surface. The type **compression** is for operations like cattle trampling and a sheep foot's roller that bury residue by pressing it into the soil without loosening the soil.

Tillage intensity: **Tillage intensity** refers to the degree that the soil disturbance obliterates any roughness existing at the time of the disturbance. A tillage intensity of 1.0 means that the roughness following the operation is totally independent of the roughness that existed before the operation. A tillage intensity of 0.0 means that the soil disturbance has no effect on roughness. A moldboard plow and a rototiller are assigned tillage intensity values of 1.0 because they completely rework the soil. In contrast, a spike tooth harrow has a tillage intensity of 0.4 because roughness following a spike tooth harrow depends to a significant degree on the roughness that existed at the time of the operation. For example, the roughness will be greater when the harrow follows a moldboard plow than when it follows a tandem disk. Implements like field cultivators, tandem disks, and chisel plows have tillage intensity values that range from 0.5 to 0.9 depending on the "aggressiveness" of the implement.

Rec(ommended), minimum, and maximum tillage depths: The amount of residue that a soil disturbance (tillage) buries increases as the depth of the disturbance (tillage) increases. The value assigned for the burial ratio is the value that corresponds to the **recommended depth**. Reasonable **minimum and maximum operating depths** are specified for an implement, and RUSLE2 will vary the amount of residue buried based on the working depth that must be between the minimum and maximum depths. Unless another value is specified for tillage depth in the management object (window), RUSLE2 uses the recommended depth as the working depth.

Ridge height: Soil loss increases as **ridge height** increases. More important, ridge height gives contouring its effectiveness. Increased ridge height gives contouring increased effectiveness. **If RUSLE2 is not computing as much effect for contouring as desired, one possible change is to increase ridge height.** The value entered for ridge height is

the height immediately after the ridge is formed. Over time RUSLE2 reduces ridge height as a function of rainfall amount and interrill erosivity.

Initial roughness: The value entered for **initial roughness** value represents the roughness left by a implement for the particular standard condition of a silt loam soil and very high surface residue and root biomass. This value is an index value and consistency should be maintained among implement types. The effective roughness value that RUSLE2 uses to compute soil loss is increased for fine textured soils and decreased for coarse textured soils. In all cases, RUSLE2 decreases the effective roughness value as the amount of biomass involved in the tillage operation is decreased. This effect is one of the main ways that RUSLE represents the effect of increases in soil biomass on improved soil quality and reduced soil loss.

Final roughness: A **final roughness** value of 0.25 inches is typically used in RUSLE2 to be consistent with the unit plot conditions used to define the soil erodibility factor K. This roughness value represents the roughness at the end of a cropping season where a moldboard plow, tandem disk, field cultivator, and row cultivator have been used to till the soil. The 0.25-inch roughness is nearly but not completely smooth, which would be a value 0.0 inches. The 0.25-inch roughness represents the roughness of a few erosion resistance clods that still have some influence on soil loss.

However, some operations can leave a smoother surface than 0.25 inches. A rototiller used to prepare a very fine seedbed is one example. The rototiller creates a soil mixture of almost uniform-sized aggregates and leaves almost no coarse aggregates in comparison to a moldboard plow to produce roughness. Another example is where a bulldozer or a road grader cuts away soil leaving a very smooth surface. A value of 0.15 inches is used for these operations.

A value greater than 0.25 inches is entered for final roughness for some conditions. An example is a pasture or rangeland where roughness develops over time with vegetation patterns such as bunch grass rather than a sod forming grass. A final roughness of 0.6 inches is a typical value for this condition.

Surface area disturbed: Some operations like planters disturb only a portion of the soil surface. A value for the **fraction of the soil surface disturbed** is entered.

Live biomass removed: This process **removes live above ground biomass** without **killing** the current vegetation. Two variables are used to describe this process, which are fraction of the above ground biomass that is affected and the fraction of this biomass amount that is lost in the removal process.

Removal of live above ground biomass would in every case be expected to reduce canopy cover and perhaps live ground cover. Either a new vegetation file is called in conjunction with this process or the canopy and live ground cover values are adjusted to reflect the effects of this process. The best approach is use the “begin process” to start a new vegetation file.

The remove live biomass process is used in such operations as hay and silage harvests. The purpose of hay and silage harvest is to remove a high percentage of the above ground live

biomass. A typical value for the **fraction of the live above ground biomass that is affected** might be 95%. The portion not removed is left behind as live standing vegetation.

The removal process is generally not completely efficient and leaves behind some biomass on the soil surface as leaf shatter. This biomass is added to the flat residue pool. The variable **losses** is used to account for the material left behind. A typical value is 5%. To illustrate how these values are used, assume that the amount of above ground biomass might be 2000 lbs/acre. Using 95% for the fraction of the above ground biomass that is affected, 1900 lbs/acre (2000×0.95) are affected in the removal process. Using the 5% for the losses fraction, 95 lbs/acre (1900×0.05) are left behind on the ground as flat residue. Note that the loss fraction is applied to the amount affected rather than the total biomass.

Fractions are used as the variables to describe the removal process for a particular reason. A variable like height of removal could have been used, which would be a common measure used in a farming operation like hay harvest. Using cutting height would have required dealing with height of the vegetation and the distribution of biomass within the plant height. Using fractions, while not as immediately convenient as using a cutting height, gives RUSLE2 great power to allow users to control how RUSLE2 operates.

However, assignment of the fraction for the amount affected requires these considerations by the user. That is, the fraction assigned for an operation used to harvest a very tall crop would likely be higher than one used to harvest a short crop. Also, the fraction is a function of the height of cutting. The intent is for users to develop typical operations for harvesting several classes of crops as the crops are typically harvested.

Remove surface cover: The purpose of this process is to **remove above ground residue** that may be either standing or flat. This process is used in operations such as burning and baling of straw. It can also be used in operations to represent silage and hay harvests.

The first used to describe this process is whether the residue that is impacted is the current residue or all residues. Baling of straw typically involves only the current residue whereas a burn might involve all residue.

The second variable is the fraction of flat residue that is removed and the third variable is the fraction of standing residue that is removed. If only flat residue is removed without removing the standing residue, a value of 0.0 is entered for the fraction of standing residue that is removed. If only standing residue is removed, a value of 0.0 is entered for the fraction of flat residue removed. These fractions are based on mass. Of course both standing and flat residue can be removed in the fractions that are assigned.

Add other cover: The **add other cover** process is used to apply mulch on construction sites and on in strawberry fields, manure and organic papermill waste to cropland, or to add material to both the soil surface and within the soil. This process has a single variable associated with it, which is the fraction of the material that is added to the surface. The remainder of the added material is assumed to be placed in the soil.

If the add other cover process places some of the added material within the soil, a companion **disturb surface** process that determines where in the soil that the material is placed. The

assumption in RUSLE2 is that material cannot be placed within the soil without disturbing the soil. The amount and type of material that is added is set on the management object (window).

Combining Processes to Form Operations

Processes are combined in a particular sequence to represent operations.

The sequence of the processes is critically important. For example, the resulting flat residue cover, and thus computed soil loss, will be very different if it placed ahead of a disturb surface process than after it.

RUSLE2 is not a model in the strict sense in terms of representing events and processes. Rather, RUSLE2 computes soil loss based on values for variables that describe, not model, real world conditions. Thus, the user must understand how RUSLE2 works so that the proper steps can be followed according to RUSLE2 definition and rules to create the desired description rather than trying to mimic things as they occur in the real world.

Principal operations used in RUSLE2 are ones that represent tillage, planting, harvesting, shredding, adding biomass, and burning. RUSLE2 is almost limitless in the operations that can be created. Selecting and combining processes will be described for selected operations to illustrate how RUSLE2 operations are created from processes.

Tillage: In general, three processes are used to describe a tillage operation. These are **kill vegetation, flatten standing residue, and disturb surface**. The order of the sequence is critical. The kill vegetation process must come first for the operation to flatten and bury residue for vegetation that is currently growing at the time of the operation. The **kill vegetation** process converts the live biomass to standing residue. The **flatten standing residue** process converts a portion, using the value assigned to the flattening ratio, of the standing residue to flat residue. The **disturb surface** process buries a portion of the flat residue based on the burial ratio and resurfaces a portion of the buried residue within the tillage depth based on the resurfacing ratio. The combination of the residue that is buried and the residue that is brought back to surface determines the net residue left on the surface following the operation.

Most tillage implements like moldboard plows, chisel plows, and tandem disks are full width where the entry for the fraction of the surface disturbed is 100%. However, the entry for fraction of the surface disturbed for tillage operations used to cultivate row crops is less than 100%, typically about 85%, which indicates that less than full width of the surface is tilled.

Values assigned for burial ratios for less than full width tillage are based on full width whereas the value entered for roughness is for the portion of the surface that is disturbed.

Planting: If vegetation is planted with a planter or drill that disturbs the soil surface, the two processes of **disturb surface** and **begin growth** are used. These implements typically disturb only a relatively small portion of about 15% of the total surface. If the vegetation is planted by aerial seeding or another method that does not disturb the surface, the only process that would be used is **begin growth**.

If the vegetation is volunteer like weeds and begins growth on its own, an operation is still needed in RUSLE2 to begin growth where the only process in the operation is **begin growth**. When RUSLE2 is applied to a permanent pasture, the vegetation is already established. However, RUSLE2 also needs an instruction to read the data file that has the data for the permanent vegetation. An operation with the **begin growth** process is used to start the vegetation.

A **begin growth** process in an operation requires the entry in the management object (window) of the name an appropriate vegetation file. The date of this operation must correspond with the zero date in the vegetation file.

Harvest of grain crops: The harvest of grain crops involves the removal of the grain without any removal of residue. In most cases like corn, soybeans, and wheat, harvest kills the crop. In a few cases like Raton rice in Texas, the crop is not killed, but regrows after the harvest.

The two process of **kill vegetation** and **flatten standing residue** is used for the harvest of crops like corn, soybeans, and wheat. The critical entry for this harvest operation is the flattening ratio. Values for this ratio are typically 0.50, 0.85, and 0.95 for wheat, corn, and soybeans, respectively. The ratio of 0.50 for wheat means that 50% of the above ground biomass is left as standing stubble whereas 15% and 5% are left as standing residue for corn and soybeans. This percentage is related to the height that the vegetation is cut. Corn stalks are cut off fairly close to the ground with modern combines whereas the flattening ratio might only be about 40% for corn harvested with an old style picker where most of the flattening occurs by the machine knocking over the stalks rather than the machine cutting off the vegetation.

Raton rice production involves two harvest operations. After the first rice harvest, the rice regrows and produces a second crop that is harvested. The operation for the first rice harvest uses the processes of **kill vegetation, flatten standing residue, and begin growth**. The **kill vegetation** process creates residue and converts all of the live roots to dead roots. The **flatten standing residue** process determines how much of the biomass at harvest is left as standing residue. The **begin growth** starts the Raton rice crop.

Two vegetation files for the rice are used, where the first file is started uses a **begin growth** process in the operation that seeds the rice. The second vegetation file is started with the **begin growth** process in the first rice harvest operation. RUSLE2 cannot be configured in exactly the correct way for Raton rice production. The preferred way to handle the first rice harvest would be to convert the above ground biomass to residue without killing the roots, but that capability is not possible in RUSLE2. To offset this limitation, the root biomass in the Raton crop should start from zero and increase at the same rate that the dead roots are lost by decomposition.

The second harvest of the Raton crop uses a standard grain harvest operation. The harvest operation for a non-Raton rice crop would be the same as the operation for a standard grain harvest.

Harvest of silage: When a crop grown for silage is harvested, live biomass is removed and the vegetation is killed. Thus the two processes in a silage operation are **remove live biomass** and **kill vegetation**. The entry for the amount of the live biomass affected is about 95%, which leaves

5% of the live biomass standing as live biomass. A value of about 5% is entered for the losses, which means that 5% of the biomass affected becomes flat residue, which represents leaf shatter left behind in the field. The **kill process** converts the remaining live biomass to standing residue and the live roots to dead roots.

Note that no flatten standing residue process was included because no residue was flattened. The **remove live biomass** process left the proper amount of standing residue.

If a crop regrows after the silage harvest, see the operation for hay harvest.

Harvest of hay: When hay is harvested, live biomass is removed and the vegetation regrows. Thus, the two processes used to describe hay harvest are **remove live biomass** and **begin growth**. The values for the live biomass removal are basically the same as for silage harvest.

The **begin growth** process starts the vegetation that grows back after the hay harvest. The canopy values on day zero should reflect the canopy left after harvest. This value might 10% and 0.1 ft for canopy cover and fall height, respectively. The values for root biomass on day zero should be the same as that on the harvest date. Any decrease of root biomass from one day to the next is taken by RUSLE2 as a transfer of biomass from the live root biomass pool to the dead root biomass pool.

Shredding: Shredding take place under several different conditions. One case is the shredding of a crop, like a small grain, that kills the crop. The processes in such a shredding operation would be **kill vegetation** and **flatten standing residue**. The **kill vegetation** process converts all of the above ground biomass to standing residue. The **flattening standing residue** process converts a portion of the standing residue to flat residue. The value entered for flattening ratio in the operation describes the portion of the above ground biomass that ends up as flat residue. That value depends on the height of the shedding, the height of the vegetation, and the distribution of the plant biomass with height. A flattening ratio of 95% means that 95% of the above ground biomass at shredding would be added to mass of flat residue on the soil surface.

Another case where a previously killed vegetation is shredded. In that case, the process used in the operation is **flatten standing residue**. The value assigned for the flattening ratio would be based on the height of shredding and the characteristics of the vegetation.

The third case of shredding is where regrowth of vegetation follows the shredding. The processes for this shredding operation is **remove live biomass and begin growth**. These processes are not exactly a model of the real world, but they create values that represent the real world. The value entered for the fraction of the above ground biomass that is affected is the fraction of the above ground biomass that is shredded. The value entered for losses would be 100%, which leaves all of the shredded biomass on the ground as flat residue. The **begin growth** process starts the vegetation that comes back after the shredding. Values for root biomass, canopy cover, fall height, and live ground cover should represent conditions immediately after the shredding.

Application of manure, mulch, and other biomass: The operation for adding biomass to the soil surface is the single process of **add other cover**. The value for the fraction of the residue added to the surface is 100%. A **flatten standing residue** process might be used if the machines applying the biomass flatten standing residue left by previous vegetation.

If biomass, such as manure, is injected into the soil, the two processes of **disturb surface** and **add other cover** in this sequence. The fraction of the added biomass that is left on the surface is entered. The remainder of the biomass is placed in the soil at the depth between one half of the tillage depth and the tillage depth.

Burning: The usual assumption is that burning kills vegetation and removes a portion of the residue. The processes used in a burn operation are **kill vegetation** and **remove surface residue**. The kill vegetation converts live vegetation so that the above ground biomass becomes residue and live roots become dead roots. The entries are for whether the current residue or all residues are affected, the fraction of the standing residue that is removed, and the fraction of the flat residue that is removed.

Killing vegetation with herbicide application: The processes for this operation are **kill vegetation** and possibly **flattening standing residue** if the herbicide is applied with a machine that pushes down vegetation to the ground.

Baling straw: When small grain is harvest, about half of the above ground biomass is left standing as stubble (standing residue) and the remainder is left as flat residue. The process used for baling straw is **remove residue**. The entries would be to remove the last residue rather than all residue. The entry for the fraction of standing residue removed would be zero and the entry for the fraction of the flat residue removed is 100% to remove all of the straw. A lower value could be used to reflect that the baling does not completely remove all of the straw.

Building Operation Files

Building an operation object (file) involves three steps of entering values related to speed of the operation; flattening, burial, and resurfacing ratios; and the sequence of processes and entering values associated with those processes that require values to describe their behavior.

Steps

1. **Open the file for an existing operation:** Choose an operation that is similar to the operation being built. The information already in the file can serve as a guide in creating the file for the new operation. Also, only a small amount of information may need to be changed or added.
2. **Save the file under a new name:** Immediately save the file using the name for the new operation. Doing this step at this point prevents losing the original when the new operation is saved using the **save** command rather than the **save as** command.
 2. **Enter values related to speed:** Three values related to speed are entered. Residue burial is a function of speed of the operation. Generally, the amount of residue that is buried increases as speed increases. The first speed is the rec(commended) speed, which is considered the typical manufacturer recommended speed. The burial ratio entered is assumed to correspond to this speed.

Enter values for minimum and maximum speeds. RUSLE2 will adjust the amount of residue buried for speeds between these two speeds. The speed used by RUSLE2 is the speed in the management object (window). The default speed is the value entered for the recommended speed. That speed can be changed by entering another speed, but the value entered must not be outside of the range specified by the minimum and maximum speed entered in the operation object (window).

3. **Enter values for flattening, burial, and resurfacing ratios:** Values are entered for these ratios only if the operation uses either a **flatten standing residue process** or a **disturb surface process**. Refer to information on core values for guidelines on choosing values.
4. **Select the processes, their sequence, and their parameter values:** Select the processes and their sequence that will be used to describe the operation. Use the “+” button to add lines that can be used to select a process. The “-“ can be used to remove unnecessary lines. The list of processes can be displayed by clicking on the upside down arrow.

Some processes, like **disturb surface**, require that values be entered to describe the process. Click on the “yellow folder” to the name of the process to open the window so that values can be entered to describe the process.

5. **Save the new operation:** Save the new operation with the new name selected for the new operation.

Support Practices

The effect of cultural practices like crop rotations and conservation tillage on erosion is described by cover-management effects in RUSLE2. The effects of supporting practices like contouring, stripcropping, buffer and filter strips, and terraces are described with specific equations for the effects of these practices. Most support practices affect erosion by redirecting runoff or reducing its transport capacity. Redirection of the runoff frequently results in deposition and reduced erosion.

Given the uniqueness of types of supporting practices, each will be discussed individually.

Contouring

Contouring is the practice of using ridges and furrows left by tillage to redirect runoff from a path directly downslope to a path around the hillslope. If contouring is perfectly on the contour, the grade along the furrows is zero and water spills uniformly over the ridges along their length. If furrows are not level, runoff flows along the furrows until it reaches low areas on the landscape. Breakovers and ephemeral gully erosion can occur in these areas.

The effectiveness of contouring as measured on experimental plots and watersheds varied greatly. For example, contouring reduced measured soil loss as much as 90 percent on a 6 percent slope in one study, while in another similar study, contouring gave no reduction. In **RUSLE2**, this

range has been partially interpreted as being the influence of ridge height and storm erosivity. This range also partially represents the great variation in effectiveness of contouring in field situations. Consideration of this variability emphasizes that **RUSLE2** describes main effects of conservation systems rather than describing exactly how a particular system performs in every site-specific, field situation.

The effectiveness of contouring increases as ridge height increases. A moderate ridge height in **RUSLE2** represents the ridge height characteristic of conventionally tilled row crops that are cultivated once or twice. Maximum ridge height is characteristic of the high ridges left by a lister or beds used in vegetable production. The lowest ridge height is characteristic of that from drilling small grain.

Ridge height, along with row grade, is the single most important variable that determines the effectiveness of contouring in **RUSLE2**. If **RUSLE2** is computing less contouring effect than expected, a possible reason is that ridge heights are too low.

RUSLE2 has been calibrated as closely as possible to use ridge heights that are measured in the field. However, these measures may not always properly reflect how **RUSLE2** should compute the effectiveness of contouring. The best approach is to follow the values provided in the core data files supplied with **RUSLE2**. Consistency must be maintained among operations.

If contouring is to be considered by **RUSLE2**, an operation must be used to create a ridge height. Ridge heights decay with amount of rainfall and adjusted rainfall erosivity. Also, ridge height that exists after an operation is that created by the operation. Ridge height after an operation is totally determined by the operation, and the ridge height that existed before the operation has no effect on ridge height left by an operation.

Keep in mind that ridge height can rapidly decay so that the ridge height being used by **RUSLE2 is much less than the ridge height that is entered for that left by an operation.**

Dense or closely growing stems of stiff vegetation like mature small grains grown across slope slow runoff and acts like ridges. **RUSLE2** uses an effective vegetative ridge height based on the type of vegetation and the stage of growth. **RUSLE2** adds the effective vegetative ridge height to the soil ridge height for an overall ridge height. The base value for the effective ridge height is set by the choice of the retardance class chosen for the particular vegetation in the vegetation object. This class is adjusted based on yield and stage of growth.

The effectiveness of contouring decreases as runoff increases. Experimental field data showed that as much soil loss can occur with contouring as with up and down hill tillage during very severe storms. Therefore, **RUSLE2** uses the rainfall amount estimated from the erosivity of the $(EI_{30})_{10}$ storm and the NRCS runoff curve number method to compute a runoff value that in turn is used to compute the effect of contouring. As runoff decreases, **RUSLE2** computes a greater effectiveness for contouring.

As grade along furrows increases, as tillage deviates increasingly from being on the true contour, the effectiveness of contouring decreases. **RUSLE2** uses the ratio of furrow grade to the slope of the direct, downhill flow path to estimate the lost effectiveness of contouring.

Row grade can be specified in one of two ways in RUSLE2. The up and down hill selection for row grade means that no contouring is being employed. The first way that row grade can be entered as an absolute row grade. The alternative way of entering row grade is to enter it as a fraction (or percent) of the average land slope for the hillslope profile being analyzed. The advantage of entering row grade as a fraction of the land slope is that the relative quality of contouring is the same for all land steepness. Entering row grade as a fraction of land slope is the recommended way for entering row grade.

Unless the topography is quite uniform, having the furrows perfectly on the contour is practically impossible. NRCS specifications for effective contouring allow a certain amount of deviation from a perfect contour. When contouring is practiced according to NRCS specifications, a furrow grade that is one tenth of the downhill slope should be used. For example, if the land slope is 5 percent, RUSLE2 uses a row grade of 0.5 percent slope would be used. If the land slope is 20 percent, RUSLE2 uses a row grade of 2 percent. If the contouring significantly exceeds NRCS specifications, a relative row grade of 5% should be used.

Also, use a 5% relative row grade for rotational strip cropping, buffer strips, and filter strips laid out and maintained according to NRCS specifications. If these practices are installed and maintained almost perfectly on the contour, use a 0% relative row grade for contouring.

Row grade is also used to give credit for row grade between 10% of the land slope and up and down hill. Suggested relative row grades would be 15%, 25%, and 50% to represent general classes of off contour farming. Using classes to any finer detail is not warranted.

RUSLE2 allows the selection of contouring objects where the only variable is row grade. Keep in mind that the other important component of contouring are the ridge heights specified for the individual operations.

Beyond a critical slope length, contouring is assumed to completely lose its effectiveness. On a slope where slope length exceeds the critical slope length, no contouring effect is computed beyond the critical length. Critical slope length is computed as a function of the 10 yr EI storm, which captures the main effect of location for causing failure of contouring. The 10 yr EI storm is used rather than the annual erosivity because a few single erosivity storms caused the greatest damage to contouring.

Critical slope length is also of a function of runoff computed using the NRCS curve number method, where curve number values are computed as a function of ground cover, roughness, soil biomass, and degree of soil consolidation. The degree that the presence of roughness and ground cover reduces runoff shear stress that acts on the soil is another major factor. The last major factor affecting critical slope length is slope steepness because of how it affects runoff shear stress acting on the soil.

RUSLE2 tracks how the cover-management variables change through the year as well as how the storm erosivity changes during the year. When contouring is computed to have failed, the effectiveness of contouring is not restore until the next operation with a disturb surface operation that creates a ridge. Failure of contouring is assumed to occur in RUSLE2 by runoff breaking through ridges, and thus ridges have to be recreated to restore contouring effectiveness.

Well-accepted values for critical slope length are given in Agriculture Handbook No. 537. Parameter values in **RUSLE2** were selected to fit these values a conventional, continuous, cultivated corn grown for the Columbia, Missouri location because that location represents typical erosion conditions. The equations in **RUSLE2** adjust these base values for other locations. The variation of critical slope length with runoff, cover, and slope is based on shear stress concepts well established by research on principles of basic erosion mechanics.

Strips

Three types of strip systems as supporting practices can be considered by **RUSLE2**. These strip systems are rotational strip cropping, buffer strips, and filter strips. **RUSLE2** Objects have set up for each type based on certain assumptions. Also, **RUSLE2** can also be used to analyze non-standard strip system.

A rotational strip cropping system is generally referred as simply strip cropping. However, “rotational” refers to these systems involving a rotation of crops rather than involving permanent strips of vegetation like grass used in buffer and filter strips.

Strip cropping is assumed to involve a crop rotation grown in equal width strips on the hillslope profile. The crop rotation generally involves some crops of very close growing vegetation such as a hay crop. The other crops are often row crops like corn and soybeans that are either clean tilled or residue cover is somewhat less than that for no-till. The starting point of the rotation in each strip is varied so that the “clean tilled” strips are alternated with the dense growing crops.

Buffer strips are narrow strips of permanent dense growing vegetation, often sod forming grasses, that separate wide strips of cultivated crops. A filter strip system is actually a special case of a buffer strip where only one strip of permanent vegetation is used at the end of the slope length.

An important assumption in all strip systems is that runoff begins at the top of the hillslope profile can continues to the end of the profile. No feature of strip systems is assumed to end slope length. Under some conditions, **RUSLE2** will compute an infiltration rate so large that no runoff is computed to leave particular strips. **RUSLE2** takes this end of runoff within the slope length in its computations.

The main effect of strips is that the dense strips of vegetation slow runoff and reduce its transport capacity. Deposition is computed where the transport capacity is less than the incoming sediment load. Thus, the relative effectiveness of strip systems depends on the amount of sediment produced on the more erodible strips relative to the transported capacity on the strips with dense vegetation. Thus, relative effectiveness of strips may be less where no-till is used on the cropped strips rather than clean tillage, but the overall soil loss will much lower with the no-till cropping than with the clean till cropping.

Deposition reduces sediment yield from strip systems, especially if the last strip on the slope is dense vegetation. The conservation planning soil loss value soil loss for filter strips and buffer strips gives partial credit for the deposition. The credit depends on both the location and amount of deposition.

Stripcropping

RUSLE2 considers two effects of stripcropping. One effect is the deposition caused by the strips of dense and close growing vegetation, the other is the reduced sediment production on these same strips, and the reduced soil loss on the clean-tilled strips because of the residual effect from the soil biomass produced on the strips with the dense vegetation.

Well-placed strips on the contour can spread runoff. When runoff reaches a strip of close growing vegetation, it can be concentrated in rills. The strip spreads the runoff so that runoff leaves the strip as a broadsheet flow. This flow has less erosivity than flow concentrated in rills, but having no sediment in the flow as it exits the strip increases its erosivity. These effects are assumed to balance and cancel each other.

If strips are not close to being on contour, deposition or a ridge left by tillage at the upper edge of the strips can redirect the runoff along the upper edge of the strips. Thus the strips act as partial terraces. Thus, high quality contouring must accomplish strip cropping. Assume a relative row grade of 5% for strip cropping that meets and NRCS specifications and a relative row grade of 0% for strip cropping that exceeds NRCS specifications with respect to being on the contour. **Do not use strip cropping with a relative row grade greater than 10%.**

Deposition is given full credit on rotational strip cropping such that the sediment yield from the hillslope profile should be used for the soil loss values to use in conservation planning for strip cropping.

The amount of deposition that is computed by **RUSLE2** depends on the sediment load reaching a location of reduced transport capacity. Transport capacity in **RUSLE2** is computed as a function of the 10 yr EI storm, the amount of runoff computed using the NRCS curve number method, surface roughness, ground cover, and retardance of live vegetation. The curve number value used in the runoff computation is computed as a function of roughness, ground cover, degree of soil consolidation, and soil biomass.

Also, the amount of deposition computed by **RUSLE2** is a function of the sediment characteristics. Sediment properties are determined by soil texture at the point of detachment. Upslope deposition enriches sediment in fines so that reduced deposition occurs downslope. **RUSLE2** computes the particle distribution of the sediment leaving a hillslope profile.

In order for deposition to occur with a strip cropping system, the tilled strips must be alternated with strips of close growing vegetation. That arrangement is created in **RUSLE2** in the management folder on the profile object (window) or in the stripcropping object by offsetting the rotation on the various strips by one or more years.

The following examples illustrate how to offset a rotation to achieve a strip cropping system in **RUSLE2**. Assume a simple rotation of two years of corn and two years of hay represented by C1C2H1H2. The two years of each crop are grown together for convenience. Assume four strips on the slope although the strips on the slope need not match the length of rotation. In fact, in

most cases the number of strips will be less than the number of years in the rotation. If no offset is used, the strips would be:

Strip Number	Years of Offset	Crop Year 1	Crop Year 2	Crop Year 3	Crop Year 4
1	0	C1	C2	H1	H2
2	0	C1	C2	H1	H2
3	0	C1	C2	H1	H2
4	0	C1	C2	H1	H2

This system is not stripcropping, but a crop rotation with the same cropping on all parts of the slope at a given time. To achieve stripcropping, some of the strips need to be offset as demonstrated in the table below.

Strip Number	Years of Offset	Crop Year 1	Crop Year 2	Crop Year 3	Crop Year 4
1	0	C1	C2	H1	H2
2	2	H1	H2	C1	C2
3	0	C1	C2	H1	H2
4	2	H1	H2	C1	C2

Notice that the 2-year offset on strips 2 and 4 shifted the rotation by two years so that runoff from at least one corn strip runs through at least one hay strip.

The table below illustrates another possible arrangement achieved with a different set of years of offset.

Strip Number	Years of Offset	Crop Year 1	Crop Year 2	Crop Year 3	Crop Year 4
1	0	C1	C2	H1	H2
2	1	H2	C1	C2	H1
3	2	H1	H2	C1	C2
4	3	C2	H1	H2	C1

This set of offset years produces a stripcropping system that is not as effective as the other strip cropping system. The problem with this system is year 4 where runoff from none of the corn strips passes through the hay strips.

The NRCS specifications require certain widths related to convenience of the farming operation. Do not be concerned if the dimensions chosen by RUSLE2 don't exactly match the dimensions required by the NRCS specifications. Remember that RUSLE2 is a guide to conservation planning, not an exact model of real world conditions. If the strips widths are reasonably close, RUSLE2 will do well in capturing the main effects of strip cropping.

Buffer Strip Systems

A buffer strip system is one with multiple strips of close growing vegetation like grass (the buffer strips) that separates strips of cultivate crops. The inputs for the buffer strip object is to select a width for the buffer strips, which are assumed to be of equal width, the number on the hillslope profile, and whether or not the lowest strip is at the bottom of the hillslope.

The other inputs required for RUSLE2 is to select the management practice for the tilled strips and to select the management practice for the permanent strips, which is usually a continue grass or forage type vegetation. A rotation of any length can be used on the tilled strips, but the same rotation must be used on all strips with the buffer strip object. However, the management folder in the profile object (window) in RUSLE2 can be used to enter different managements for each strip.

A buffer strip object cannot be combined with a stripcropping object.

The same RUSLE2 considerations and requirements for contouring and strip width apply to a buffer strip system as applies to a stripcropping system regarding contouring and strip widths.

Filter Strip Systems

A filter strip system is a cultivated strip with a narrow permanent strip of close growing vegetation like a grass or other forage crop at the lower end of the hillslope profile. The input for the filter strip object is the width of the strip and the management on the two strips.

A filter strip object can be combined with a stripcropping object but not with the buffer strip object, but a filter strip system can be constructed from the buffer strip object by placing the last buffer strip at the bottom of the slope.

The same RUSLE2 considerations and requirements for contouring and strip width apply to a filter strip system as applies to a stripcropping system regarding contouring and strip widths.

Terraces

Terraces are support practices where high and large ridges of soil are constructed across the slope at intervals of typically 100 ft and greater. These ridges and their accompanying channels intercept runoff and divert it around the slope to a disposal point. Disposal can be into an outlet channel that is usually lined with dense vegetation to protect against erosion or into a small impoundment with an underground outlet. Grade along gradient terraces is often fairly uniform. Gradient terraces usually discharge into an outlet channel, although these terraces can be level with closed outlets for moisture conservation. Grade along parallel terraces and tile outlet terraces can be highly variable, but grade is usually controlled to avoid erosion in the terrace channel.

Terraces affect rill and interrill erosion in two ways. One way is to reduce slope length, and the other effect of terraces is to cause deposition in the terrace channel if grade is sufficiently flat, or in the impoundment associated with a tile outlet terrace.

For conservation planning, only a part of the deposition is credited as protecting the soil resource. When terraces are closer than about 90 ft, one half of the deposition is credited for conservation planning. As terrace spacing increases, the amount of credit taken for deposition is decreased to where almost no credit is taken if spacing exceeds 300 ft.

Gradient terraces

The amount of deposition in a terrace channel is a function of the sediment load reaching the terrace channel, the transport capacity of the flow in the terrace channel, and the characteristics of the sediment reaching the terrace channel. If the sediment load is low reaching the terrace channel because of erosion control on the inter-terrace interval or transport capacity is high in the terrace channel because of a steep channel or high runoff, no deposition will occur in the channel. The transport capacity in the channel must be less than the sediment load reaching the channel for deposition to occur.

When deposition is computed, the amount of deposition computed by RUSLE2 is a function of properties of the sediment reaching the terrace channel. For example, the sediment from a high silt soil is finer than the sediment eroded from a coarse textured soil and thus less deposition will be computed for the hillslope with the high silt soil than one with the coarse textured soil. Similarly, if a filter strip or a concave slope is just ahead of the terrace channel, deposition in the terrace channel will be reduced because of upslope deposition reducing the sediment load reaching the terrace channel and deposition enriching the sediment in fines, which reduces deposition.

The input for the terrace object is the number of terraces on the hillslope, the grade of the terrace channel, and whether or not the last terrace is at the bottom of the hillslope.

[Note: the following material will be revised later

Wind rowed debris can act as a terrace on disturbed forestland treated with a root rake or similar implements.

RUSLE applies to bench terraces, but with special considerations. If the bench of the terrace is inward sloping as illustrated in Figure 37, RUSLE is separately applied to the bench and to the backslope. RUSLE has no limitation on how short a slope length can be.

The area where the bench and backslope intersect forms a channel that conveys runoff around the hillslope. Deposition in this area and its effect on soil loss for conservation planning can be estimated using the standard RUSLE P factor relationships for terraces. These computations must be done in parts rather than as a system.

The alternative bench terrace system is one where the benches slope outward. The stripcropping portion of RUSLE is used to analyze this type of bench terrace system. Slope lengths and steepness of each terrace segment are entered. Also, the irregular slope procedure should be used to compute an LS value. If the

benches are sufficiently flat, RUSLE will compute deposition, and treat that deposition in the same way that it treats deposition with multiple strips.

Diversions.....]

Small impoundments

Deposition computed by RUSLE2 for small impoundments like those used with tile outlet terraces and small sediment basins on construction sites is based on a simple retention time concept. The equations are calibrating to empirical data for basins that are performing well.

The fraction of the sediment load requiring the impoundment is a function of the characteristics of the sediment reaching the impoundment. Impoundments can be placed in series in RUSLE2. The downstream impoundment will trap much less sediment than the upstream impoundment because deposition in the upstream impoundment will have greatly enriched the sediment in fines.

The amount of deposition is not a function of the geometry of the basin. Thus RUSLE2 computes a very approximate estimate of sediment trapping. Other models should be used to design sediment basins.

Soil Loss Ratios

A soil loss ratio is the ratio of soil loss in a given period, like a crop stage, between harvest and planting, or between tillage operations, from a given cover-management system to the soil loss from the “unit plot” where all other conditions are the same. RUSLE2 computes values for soil loss ratios that can be compared with values published in Agriculture Handbook 537 (AH-537).

The soil loss ratios for “conventional tillage” given in AH-537 were used to calibrate **RUSLE2**. Internal parameter values were adjusted until the soil loss ratio values computed by **RUSLE2** matched, as closely as possible, those in the AH-537. The values in AH-537 for conservation tillage were not used in the development of **RUSLE** because the values in AH-537 were based on data collected in the late 1960's and early 1970's that do not represent modern conservation tillage systems. An extensive set of data from a literature survey was assembled and used to validate **RUSLE2** for conservation tillage, especially no-till.

Also, the soil loss ratios in AH-537 for crop stage four, the period following harvest, were also not used. Most of the data represented by AH-537, except for conservation tillage, were collected from about 1935 to 1955. In those times, corn harvesting left stalks that stood much more erect than do modern combines that shred and spread the stalks. Also, some of the soil loss ratios in AH-537 are based on a surface cover effect curve with a b value of 0.026, much lower than the now accepted value of 0.035 used in **RUSLE2**. The data analyzed for **RUSLE2** to determine b included the same data originally used to estimate a b value for the surface cover effect curve given in AH-537 as well as more recent data.

Soil loss values given by **RUSLE** for conventional tillage are sometimes lower than those shown in AH-537. Data collected from 1960 and 1970 that were not considered in the development of

AH-537 were analyzed for **RUSLE**. Another factor to consider is that the yields in AH-537 were low relative to modern yields. For example, the yield for high production corn is 112 bu/ac in AH-537, whereas a modern yield of corn in the Midwest is easily 150 bu/ac or more.

Soil loss ratios given in AH-537 are independent of location, whereas values computed by **RUSLE2** vary with location. For example, soil loss ratios **RUSLE2** for corn will be significantly lower in the upper Midwest than in the lower part of the Mid-South because of the low soil biomass in the Mid-South caused by high decomposition rates in the humid, warm climate of the region in comparison to the climatic conditions of the upper Midwest. This difference in results from **RUSLE2** using precipitation and temperature values to compute loss of biomass on and in the soil. Climatic conditions at Columbia, Missouri were used to calibrate **RUSLE** and to represent typical conditions that would produce soil loss ratios to compare with those given in AH-537.

A core set of data for crops and operations has been developed for **RUSLE2**. **RUSLE2** adjusts these core values for root biomass linearly as above ground biomass changes, canopy percentage by the 0.5 power, and fall height by the 0.2 power.

RUSLE2 internally adjusts amount of residue at harvest based on yield. This calculation uses an equation where residue is a linear function of yield.

In addition to displaying soil loss ratio values, **RUSLE2** also displays the values for the subfactors used to compute the effects of cover-management. The template NRCS Field Office (Expanded) is used to display those values.

USLE/RUSLE1 Factor Values

RUSLE2 computes net values for the K, LS, C, contouring, ponding, and ridge factors by weighting daily values with the erosivity distribution, exactly in the same way that it is done in the USLE and **RUSLE1**.

These values can be compared with those used in the USLE and **RUSLE1**. These comparisons give insight into differences between **RUSLE2** and the USLE and **RUSLE1**.

However, the product of these values, even when computed by **RUSLE2**, does not give the **RUSLE2** soil loss value in the same way that they give the USLE and **RUSLE1** soil loss because of the numerical integration procedures used in **RUSLE2**.

The effective mathematical structure in **RUSLE2** is:

$$A = R \sum (f_i K_i L_i S_i C_i P_i)$$

Where f = the distribution of erosivity and the subscript refers to a period, which is daily in **RUSLE2**. The equation structure in **RUSLE1** is:

$$A = R \sum (f_k K_k) LS \sum (f_k C_k) P$$

Where the subscript k refers to a 15-day period. The equation structure in the USLE is:

$$A = R K LS \sum (fmCm) P$$

Where the m subscript refers to a crop stage period.

Even if RUSLE2 computed exactly same values for the variables on a daily basis as the other equations, the soil loss value would not be the same between the equations. Without question, the mathematical structure in RUSLE2 is far superior to the structure in the other two equations. The difference can be up to 15% depending on cropping-management system and the location.

Another special consideration has to be given to the contouring factor computed by RUSLE2. The effect computed by RUSLE2 for contouring is determined by taking the ratio between soil loss with contouring to soil loss with up and down hill row grade. This value, which is the proper effect of contouring as reflected by RUSLE2 often differs with the value shown for the contouring factor value.

The reason is because of the mathematical integration procedure used by RUSLE2 where the effect of contouring is combined with the other variables on a daily basis rather than considering the contouring factor as a single variable.

APPLICATION OF RUSLE2 TO OTHER LAND USES

Irrigated Lands

When **RUSLE2** is applied to irrigated land where the water is applied by sprinkler irrigation, the erosivity of the applied water should be added to the erosivity from rainfall. Erosivity of the applied water can be computed from the application rate and size and impact velocity of the water drops. To compute this erosivity, an equation for unit energy is developed using information on drop size and impact velocity available from the manufacturer of the irrigation equipment. In contrast to the unit energy equation for natural rainfall, the unit energy equation for sprinkler-applied water is independent of application rate. Do not use the unit energy equation for natural rainfall to compute erosivity of sprinkler-applied water.

Once unit energy, e , is computed, erosivity for a single application is:

$$R_a = e V_a I/100$$

where R_a = erosivity for a single application, e = unit energy (ft tons) (ac in)⁻¹, V_a = application amount (in), and I = application rate (in hr⁻¹).

The R_a values computed for each application are added to the annual **R**-value for natural rainfall to obtain a total erosivity value that represents both rainfall and the water applied by sprinkler irrigation. In addition, the distribution of erosivity during the year may require a slight adjustment to account for the additional erosivity during the irrigated period.

RUSLE2 cannot be used to compute soil loss from surface irrigation, but it can be applied to surface irrigated land to compute soil loss from natural rainfall. Since irrigation leaves the soils

wetter and thus produces more runoff from natural rainfall than without irrigation, the permeability code in the soil erodibility nomograph can be adjusted one step to a less permeable soil. However, in climates where little rainfall occurs during the irrigation season, this adjustment is unnecessary.

The other consideration given to surface irrigated land is that these lands are frequently graded to produce long gentle slopes. Slope lengths for these fields can be much longer than slope lengths on similar fields that have not been graded.

Disturbed Forest Lands

RUSLE2 can be used to compute soil loss on disturbed forestlands where significant overland flow occurs along the slope length. **RUSLE2** cannot be applied to lands where no overland flow occurs, such as undisturbed forestlands.

The publication “A guide for predicting sheet and rill erosion on forest land”,⁷ should be used as the major guide in applying **RUSLE2** to disturbed forestlands with the following considerations.

Operation, vegetation, and residue data files will need to be constructed specifically for disturbed forestlands. The required vegetation files include one to initialize the root mass at the time of first disturbance and “crops” for each succeeding year following this disturbance. The key values for the initial vegetation are the amount of biomass of roots in the upper 4 inches of the soil and a parameter value for the decomposition of these roots. The most important roots are the roots that decompose within four years. As a guide, roots smaller than 1/4 inch in diameter are included in the estimate of root biomass. A value of 0.006 is suggested as a value to use for the decomposition coefficient of both surface and buried woody debris and tree roots.

The vegetation in the years after disturbance should characterize the cover that is either established or that develops as a volunteer stand.

Operations should be developed that characterize the mechanical aspects of the disturbances regardless of whether the disturbance is by burning, chopping, root-raking, traffic, disking, or other means.

Values for the runoff index (NRCS curve number) for disturbed forest conditions may need adjustment from those recommended for cropland. Refer to NRCS hydrology technical guides for assistance in choosing runoff index values.

Construction Sites

A major consideration in applying **RUSLE2** to construction sites is the degree that the soil surface has been disturbed and/or removed.

⁷ G. E. Dissmeyer and G. R. Foster. 1980. “A guide for predicting sheet and rill erosion on forest land,” Technical Publication SA-TP-11, USDA-Forest Service and Private Forestry-Southeastern Area.

{Note this information will be revised later.

If the surface soil has been completely removed, a K value that reflects subsoil conditions should be chosen based on values in the NRCS soils database or an equation in Agriculture Handbook No. 703 used to estimate K values for subsoils.

If the soil has been highly disturbed, such as for a fill, where little biomass is present, the high ratio of rill to interrill erosion should be used to compute LS values. When the soil is a cut, the moderate rill to interrill ratio should be used.

If the construction site is a fill, the soil should be in an “unconsolidated state”, which can be established by having an operation that disturbs 100 percent of the surface as the first operation in the schedule of operations. If the site is a cut slope, no soil disturbing operation should be used in the schedule of operations unless a soil disturbing activity occurs in the period being analyzed.

To compute a C factor value in the complete RUSLE, “crops” must be defined to establish an initial condition. A cut soil would have little biomass, but the prior land use (PLU) value would be about 0.45 because the soil is consolidated. A “no crop” for about 2 years can be used to establish this condition. Conversely, a fill can be represented with a “no crop” and an implement that tills the upper 4 inches to represent a highly erodible fill condition. Along with the “initial” crop, additional crops are used to represent changing conditions over time after the disturbance.

Some construction activities only partially remove and disturb soil. “Crops” and “implements” comparable to those used in cropland are developed to represent these conditions. An example of a partial disturbance is a soil disturbed by track driven equipment used to knife-in an underground cable.

A “no-rotation” is used rather than a rotation for most construction situations. Repeated disturbances can also be represented. A one-year rotation should be used on a military training site that is regularly disturbed.

The cropland P factor components can be used to compute the effect of rough surface conditions on runoff and erosion. Values for the runoff index (NRCS curve number) should typically be increased from cropland values to represent increased runoff from construction sites in comparison to cropland. Refer to NRCS hydrology technical guides for assistance with choosing runoff index values for construction sites.}

INTERPRETATION OF RESULTS

After **RUSLE2** has been used to compute a soil loss, the result must be interpreted and at least a mental assessment made of the result. The primary use of **RUSLE2** is in conservation planning where the computed soil loss is compared against a soil loss tolerance value **T**. If the computed

soil loss is less than **T**, erosion with the given practice at the particular site is assumed not to be a problem.

RUSLE2 is intended to be used as a guide in conservation planning and other applications. Large values of soil loss are computed more accurately than are small values. For example, you can have confidence that if **RUSLE2** computes a soil loss of 20 tons $\text{ac}^{-1} \text{yr}^{-1}$ with one practice and 10 tons $\text{ac}^{-1} \text{yr}^{-1}$ with a second practice, the second practice will substantially reduce erosion. However, if **RUSLE2** computes 1 and 2 ton $\text{ac}^{-1} \text{yr}^{-1}$, especially on pasture land, the difference between the two practices may not be great, and the most that can be said is that soil loss will likely be less with one practice than with the other, and that soil loss will be low with both practices.

RUSLE2 is intended to describe main effects represented in erosion data. Erosion data are characterized by much variability. Fine-tuning in the **OPERATION**, vegetation, and residue databases is not warranted except to describe main effects. A single value of depth of tillage should be used for major classes of tillage operations, but since erosion is very sensitive to surface cover, multiple “chisel plows”, for example, can be set up because surface cover can vary significantly among chisel plows as a class.

Because of the variability in erosion data, much care must be exercised in comparing **RUSLE2** values against research data reported in the literature. For example, the reported reduction in erosion for a 50 percent cover on no-till cropping is from 55 to 98 percent. The range in soil loss ratio for the seedbed period for conventional tillage is from 0.2 to 0.8. Thus the results from any single study can greatly differ from the representative value when all data are considered. **RUSLE2** is designed to represent the overall trends.

RUSLE2 probably describes the effect of slope length more accurately than any other factor, although slope length seems to be the variable that gives users the most difficulty in selecting a value. Fortunately the effect of slope length is not great, especially on very flat slopes. For example, an error of 10 percent in slope length will result in about a 5 percent error in soil loss. **RUSLE2** is much more sensitive to slope steepness than to slope length. Slope steepness should be more carefully chosen than slope length, and the irregular slope procedure used if the landscape profile is not uniform.

Surface cover has more effect on soil loss than any other single factor. When you compute soil loss, compare estimated surface residue cover to what you observe in the field. However, make sure that you carefully estimate cover in the field, considering that it can vary with location in the field, during the year, and from year to year. Experience shows that when cover is accurately measured, cover is often less than assumed.

An important variable in soil conservation is percent surface cover at planting. Like soil loss, this value can vary greatly from year to year and from location to location. The important consideration in evaluating **RUSLE2** against experimental data is to ensure that the data being used are representative of the effect being evaluated. Comparing the results of **RUSLE2** against data from a single study is often misleading and is always inappropriate even if the two compare favorably. An earlier section discusses important considerations when comparing **RUSLE2** with

the USLE and RUSLE1. No science-based justification exists for preferring the USLE or RUSLE1 to **RUSLE2**.

Although cover is the single most important variable in **RUSLE2**, other factors such as canopy, roughness, and below ground biomass are important and should not be overlooked when evaluating a **RUSLE2** result.

Of all **RUSLE2** factors, the effects computed for supporting practices are the one most subject to error. Ridges and other micro-topographic features vary greatly within a field and from field to field. The effects computed by **RUSLE2** for supporting practices represent how these practices generally affect erosion, but the measured result for any particular field could be significantly different from that computed by **RUSLE2**.

ACCURACY OF RUSLE

A few limited studies have been conducted to evaluate the accuracy of **RUSLE2**. (Footnote with reference to Renard's students and Nearing study.) The general result is that **RUSLE2** computes average annual soil loss within "25 percent for soil loss values greater than about 4 tons $\text{ac}^{-1} \text{yr}^{-1}$ and within "50 percent for average soil loss values between about 0.5 and 4 tons $\text{ac}^{-1} \text{yr}^{-1}$. The uncertainty goes up very rapidly for soil loss values less than 1 ton $\text{ac}^{-1} \text{yr}^{-1}$, and can easily be as large as 500 percent when estimated soil loss is 0.1 tons $\text{ac}^{-1} \text{yr}^{-1}$. The uncertainty also increases but not greatly for soil loss values greater than 30 tons $\text{ac}^{-1} \text{yr}^{-1}$.

Being able to conduct a reliable estimate of the accuracy of **RUSLE2** is extremely difficult because too few replications were typically used and statistical designs at single locations or between locations do not allow common statistical tools to be used in the analysis of the data.

A major issue is variability in the data. A difference of 30 percent in soil loss measurements between adjacent plots in a rainfall simulator study is not uncommon. Such differences are often unexplainable by differences in soil, plot preparation, or plot condition. Finding a hillslope where an adequate number of replications can be studied without excessive variation in soil properties that might affect erosion is very difficult. Also, conducting field studies is time consuming, labor intensive, and expensive. Reduced replications are typical for practical reasons to allow the research to be conducted within resource constraints.

Plots are typically used rather than small watersheds to study rill and interrill erosion. Even small watersheds have non-uniform soils and variable topography that complicate deriving the types of relationships needed by **RUSLE2**. Deposition and erosion in ephemeral gully areas must be estimated and accounted for. While ephemeral gully erosion can be determined by measuring the size of eroded channels, deposition can be difficult to determine if it occurred when erosion rates are low.

Measurement of erosion rates less than 1 ton $\text{ac}^{-1} \text{yr}^{-1}$ is difficult, and the results are usually highly variable. Slight difference between plots either in plot preparation or in local difference in cover within a plot can result in large differences on a percentage basis between plots. Also, leaving a small amount of bare soil near a plot end can produce a grossly inaccurate soil loss where soil loss values are very low.

The accuracy of **RUSLE2** is limited by the equation structure that it employs to estimate soil loss. It has no explicit runoff component, which limits its accuracy when long-term soil loss is produced by a few major storms, or cases where low runoff limits soil loss.

Prediction technology like **RUSLE2** should be interpreted in the context of its intended purpose. **RUSLE** is an empirical, index-based method that estimates average annual soil loss to be used as a guide in conservation planning. It is designed to capture the main effects of the factors that affect soil loss by raindrop impact and its associated overland flow. It should be used as a tool, and if a better method is available for the intended purpose, by all means use it.

Because it is mostly an empirically derived procedure, the best that **RUSLE2** can do is to represent the data from which it was derived. Therefore, the adequacy of **RUSLE2** for a particular application is largely determined by how well the plots used to derive **RUSLE2** represent the expected field condition.

The following paragraphs describe where **RUSLE2** works best.

Temporal Variability

RUSLE2 is designed to estimate average annual soil loss. It should not be used to estimate soil loss from individual storms nor estimate probability of erosion by storm, season, or year. Although probability values are available for the erosivity factor, the variability of soil loss is greater than the variability of erosivity. **RUSLE2** has no way to consider variability in cover-management condition by a particular season or particular year, but does compute how soil loss is expected to vary on an annual basis from season to season.

Soils

RUSLE2 is most applicable to medium textured soils. It works moderately well for fine textured soils and acceptably well for coarse textured soils. Errors can be large when applied to coarse textured soils that are typical of the Southwestern U.S. It should not be applied to organic soils.

Topography

RUSLE2 works best for slope lengths that are between 50 and 300 ft long. It works moderately well for slopes less than 20 ft long and for slope lengths between 300 and 600 ft. It works acceptably for slope lengths between 600 and 1000 ft long, and it should not be used for slopes longer than 1000 ft.

RUSLE2 works best for slope steepnesses between 3 and 20 percent. It works moderately well for slope steepness less than 3 percent and between 20 and 35 percent. It works acceptably well for steepness between 35 and 100 percent, and it should not be used for slopes steeper than 100 percent.

Geographic Region

RUSLE2 works best where rainfall occurs regularly, rainfall is the dominant precipitation, and average annual rainfall exceeds 20 inches. **RUSLE2** is acceptable for use in areas of low rainfall like the western U.S., but its results must be interpreted as being more representative of what might occur if average conditions could exist rather than representative of actual conditions. That is, **RUSLE2** is more accurate on providing relative information than on providing absolute estimates of soil loss. Also, **RUSLE2** can be used to estimate soil loss in the special winter condition represented by the Northwest Wheat and Range Region. It does not specifically estimate soil loss from snowmelt.

Irrigation

RUSLE2 can be used to estimate soil loss by rainfall where irrigation is used and to estimate the erosion caused by sprinkler irrigation. It cannot estimate soil loss from furrow, flood, or similar types of irrigation.

Land Use

RUSLE2 works best for cropland and construction sites. It works moderately well on pastureland, rangeland, minespoil and disturbed forestland. It works acceptably on minimally disturbed forestland, abandoned crop and pastureland, and similar wildlife lands with few trees. It should not be used for undisturbed forestland.

Processes

RUSLE2 is designed to estimate rill and interrill erosion from rainfall and its associated runoff as overland flow. It is acceptable for estimating sediment yield from hillslope profiles where overland flow occurs. It cannot estimate erosion or deposition in concentrated flow areas like within-field ephemeral gullies, incised gullies, and stream channels. It does not estimate erosion by mass wasting or by water flowing through pipes in the soil.

These guidelines are general. Although a specific site might fit the general guidelines, local conditions can be such that **RUSLE2** should not be applied. Used properly, **RUSLE2** is a very powerful tool to assist in conservation planning.

SENSITIVITY ANALYSIS

RUSLE2 describes the effect of many interacting factors whose effects are not always immediately obvious. A sensitivity analysis can be helpful to understanding how a particular practice or factor affects soil loss. For example, the effect of slope length can be seen by computing soil loss for several slope lengths while holding all other variables constant. However, results from sensitivity analyses should be generalized only after careful consideration. **RUSLE2** may be sensitive to a variable in a particular situation but not at all in other situations. For example, on very flat slopes, computed soil loss hardly varies with slope length, while on steep slopes, computed soil loss is moderately sensitive to slope length.

Since cover is critically important in erosion control, a sensitivity analysis might be conducted to study the effect of cover. However, conducting this analysis must be approached carefully because of interactions in **RUSLE2**. One way to control the amount of surface cover in **RUSLE2** is to vary the yield of the crop. However, varying the yield affects the amount of biomass that is incorporated into the soil. Also, root biomass varies with yield. The computed variation of soil loss as a function of yield is a combination of the effect of surface cover, roughness, buried residue, and root biomass. If a sensitivity analysis is desired where only the pure effect of cover is evaluated, a special crop has to be entered into **RUSLE2** where the relation of biomass to yield is so slight that buried biomass does not affect erosion, and the only major effect is that of surface cover.

Care must also be taken in sensitivity analyses to ensure that the effect of a variable being studied is not being “swamped” by another variable. An example is depth of secondary tillage. If the cropping-management system has a primary tillage operation that precedes the secondary tillage operation, very little effect of depth of tillage by the secondary tillage implement will be seen if the primary tillage tool buries most of the residue at a depth significantly deeper than that of the secondary tillage.

SUMMARY

Version2 of the Revised Universal Soil-Loss Equation (**RUSLE2**) computes rill and interrill erosion from rainfall and the associated overland flow. **RUSLE2** is a powerful tool useful in conservation planning, inventory, assessment, and estimation of sediment yield. Soil loss values computed by **RUSLE2** should be used as a guide rather than being considered absolute.

RUSLE2 computes average annual rill and interrill erosion for a landscape profile. The soil loss value computed for that profile is representative of an area to the degree that the profile represents the area. It does not compute average sheet and rill erosion for a field unless soil loss is computed for several profiles and the results weighted according to the fraction of the field that each profile represents. **RUSLE2** does not compute sediment yield except for hillslope profiles and at the outlet of terrace channels.

RUSLE2 is a revision of **RUSLE1** and the Universal Soil Loss Equation (**USLE**), which has been widely used by the USDA-Natural Resources Conservation Service and numerous other agencies in the U.S. and in other countries. **RUSLE2** is based on an extensive database and modern erosion science. Thus users of **RUSLE2** can be confident that they are using a well-proven conservation tool.

HOW **RUSLE CAME TO BE**

The Universal Soil Loss Equation (**USLE**) was developed in the late 1950s and became widely used in conservation planning on cropland in the 1960s. Beginning in the 1970s, the **USLE** was applied to many other land uses in addition to cropland and to other applications besides conservation planning.

The USLE was updated in 1978, but by 1985 with passage of the Farm Bill and much new research information, the USLE needed another update. A project led by G. R. Foster, USDA-Agricultural Research Service, was initiated at a workshop in Lafayette, Indiana in 1985 to update the USLE. This workshop attended by leading U.S. erosion research scientists and USLE users from the USDA-Natural Resources Conservation Service (formerly, Soil Conservation Service) and Forest Service, USDI-Bureau of Land Management, and U.S. Army Corps of Engineers set objectives and approaches for the update.

By 1987 when K.G. Renard, USDA-Agricultural Research Service, assumed leadership of the project, much of the background work on updating the USLE was well underway and some had been completed. However, the project evolved into much more than an updating of the USLE. The USLE was undergoing a major revision, and hence the USLE became **RUSLE1**, the **Revised USLE**. Also, another major addition to the project was the development of a computer program to implement **RUSLE1**. **RUSLE2** is a major revision of **RUSLE1** with a totally new graphical user interface. **RUSLE2** is a far different model than is the USLE and is different in many ways from **RUSLE1**. Almost all of the relationships in **RUSLE2** have been revised from corresponding relationships in **RUSLE1**. **RUSLE2** is a far more powerful model than is either the USLE or **RUSLE1**. The interface and underlying modeling engine of **RUSLE2**, along with its computational routines, makes **RUSLE2** the most modern, powerful, and easy to use erosion prediction available for use in conservation planning at the local field office.

The USDA-Agriculture Handbook 703 describes in detail many of the relationships used in **RUSLE1**.