PART II

PREDICTING

WATER

EROSION

LOSSES

PART II

A. ESTIMATING SOIL LOSS RESULTING FROM WATER EROSION (SHEET AND RILL)

The Revised Universal Soil Loss Equation, expressed as A = RKLSCP, is the only approved method of estimating sheet and rill erosion in Montana. The RUSLE is an update of Agriculture Handbook No. 537, containing an erosion model designed to predict the longtime average soil losses in runoff from a specific field area for specific cropping/forage and management systems. With appropriate selection of factors, the equation can be used to compute the average annual soil loss for a multicrop system, for a particular crop year within a rotation, or for a particular crop stage period within a crop year (Reference Agricultural Handbook No. 537 and RUSLE Handbook). It can also be used to design various supportive conservation practices including contours, terraces, and filter strips.

A = the computed spatial average soil loss expressed in tons per acre per year (T/A/Y).

R = the rainfall-runoff erosivity factor-is the average number of rainfall erosion-index units that occur in one year's rain. The erosion-index is a measure of the erosive forces of specific rainfall events that occur in one year. For areas west of the approximate continental divide, the R factor has been adjusted (Req) to reflect the effects of melting snow, rain on snow, and/or rain on thawing soil.

K = the soil erodibility factor-is the average long-term soil and soil-profile response to the erosive powers of rainstorms. It is a parameter that represents an integrated average annual value of the total soil and soil profile reaction to a large number of erosion and hydrologic processes. These processes consist of soil detachment and transport by raindrop impact and surface flow, localized deposition due to topography, and tillage induced roughness, and rainwater infiltration into the soil profile.

L = the slope length factor-is defined as the horizontal distance from the origin of overland flow to the point where either (1) the slope gradient decreases enough that deposition begins or (2) runoff becomes concentrated in a defined channel.

S = the slope steepness factor-reflects the influence of slope gradient on erosion.

C = the cover-management factor-reflects the effect of cropping and management practices on erosion. This factor measures the combined effect of all interrelated cover and management variables.

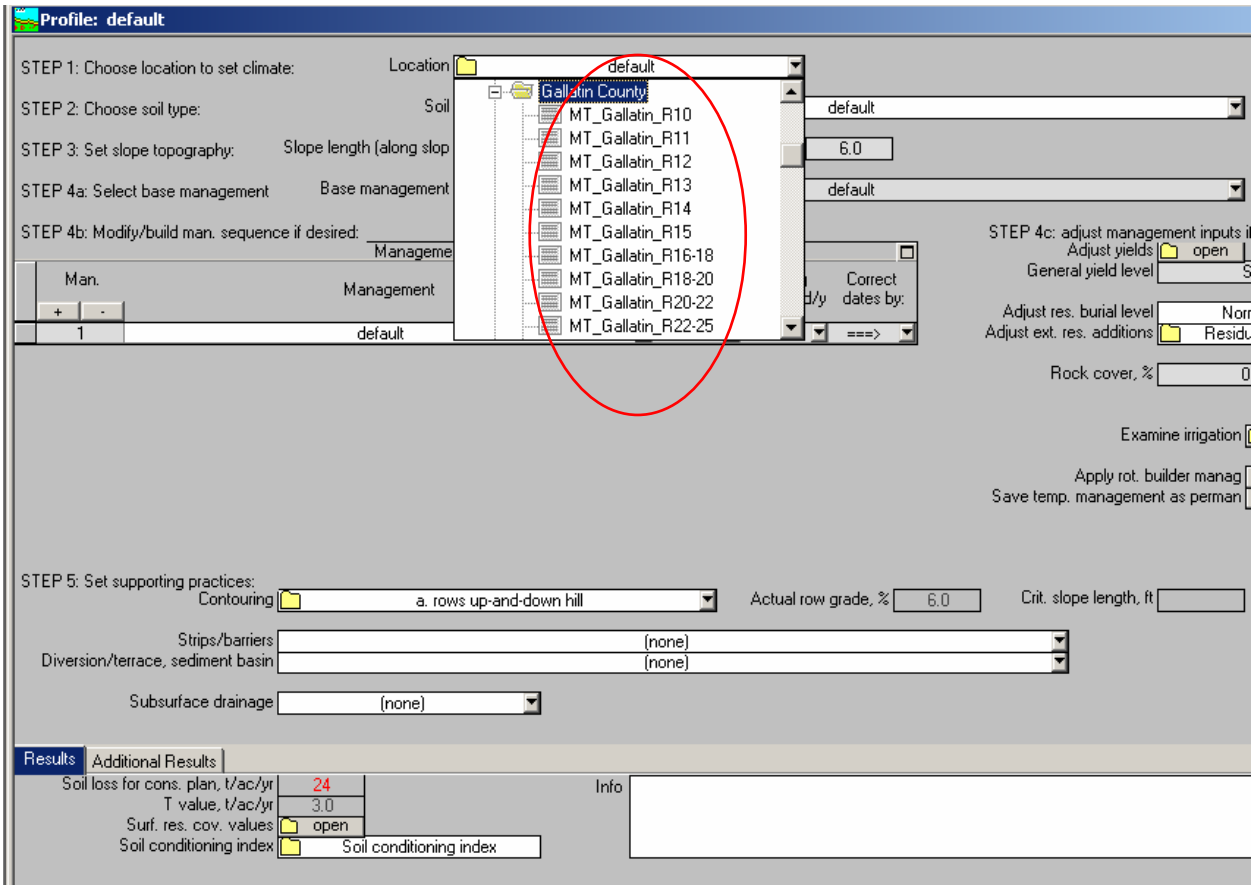
P = the support practice factor-is the ratio of soil loss of a specific support practice (contouring, stripcropping, or terracing) to the corresponding loss with straight row tillage up and down the slope.

T = the soil loss tolerance for any particular soil is expressed in tons per acre per year and denotes the maximum level of soil erosion that will permit a high level of crop productivity to be sustained indefinitely and economically.

RAINFALL-RUNOFF EROSIVITY FACTOR (R)

The numerical values used for R quantifies the effect of raindrop impact and also reflects the amount and rate of runoff associated with the rain. The ***erosion index (R)*** was developed to address intensity of rainfall events. Additionally, a separate procedure for evaluating R for locations where there are significant forces causing runoff from snowmelt, rain on frozen soil, or irrigation was incorporated. For locations where this type of erosion is significant, a Req value is used for cropland and rangeland.

Local R values can be obtained directly from the R factor (or Req) maps found later in this section. However, the RUSLE electronic program (see below) requires the user to select the annual precipitation values within a particular county and then incorporates the R value automatically in the background.



Areas west of the Req line (see map enclosed in this section) must use Req values for cropland and rangeland situations. All other landuses must use R factors. The R factor and Req maps are detailed with isolines drawn in increments of 10. It may be necessary to interpolate between lines, in some instances. Interpolation may be estimated in increments of no lower than 5 (i.e. interpolation between 20 and 30 is 25). Interpolation is not allowed when using the electronic program.

SOIL ERODIBILITY (K) FACTOR

Soil erodibility is thought of as the ease with which soil is detached by splash during rainfall and/or by surface flow. RUSLE relates soil erodibility to the integrated effect of rainfall, runoff, and infiltration on soil loss.

The soil erodibility factor (K) is the long-term soil and soil profile response to the erosive powers of rainstorms. It is a parameter that represents an integrated average annual value of the total soil and soil profile reaction to a large number of erosion and hydrologic processes. These processes include soil detachment and transport by raindrop impact and surface flow, localized deposition due to topography and tillage induced roughness, and rainwater infiltration into the soil profile.

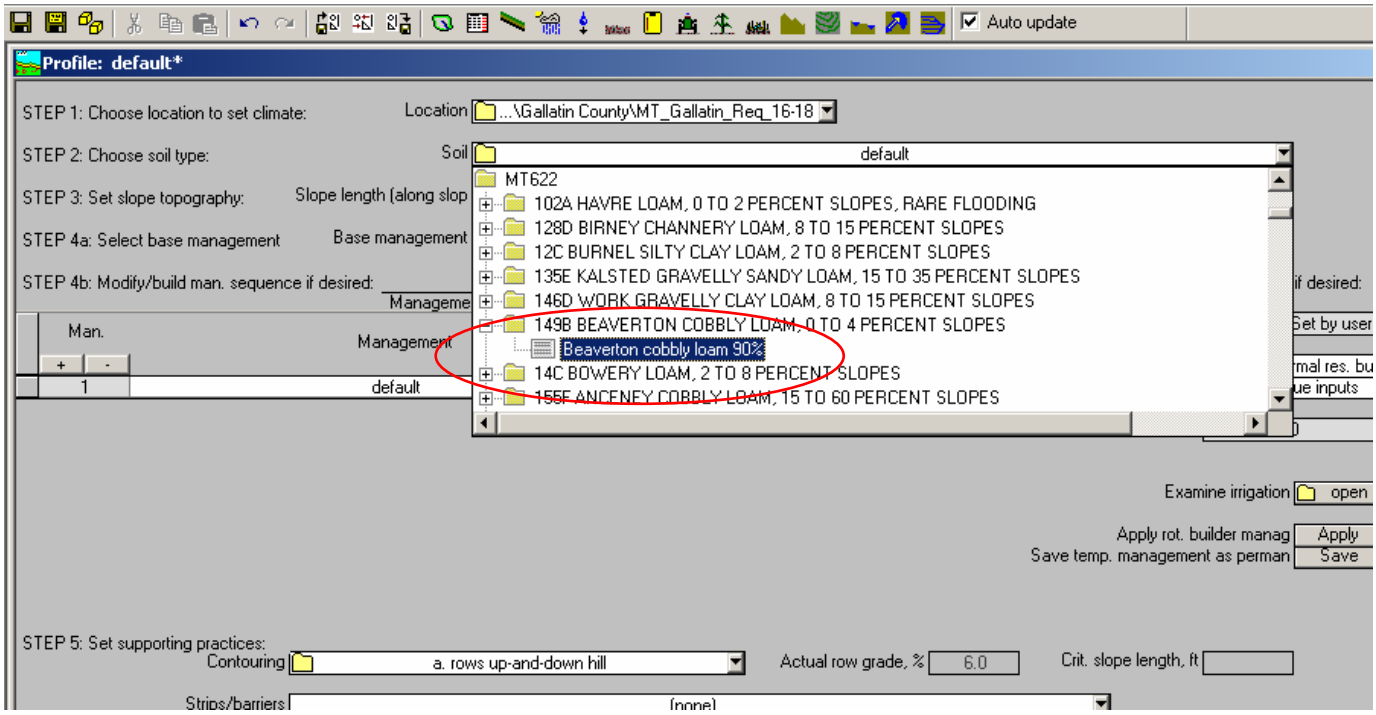
Approximately 16% of the land in the US consists of soils with rock fragments on the soil surface. These rock fragments, when present on the soil surface, may significantly reduce soil detachment by rainfall. When present in a course textured soil profile (having sand and loamy sand textures), the fragments can appreciably reduce infiltration. Surface rock fragments vary from site to site on otherwise identical soils. The fragments act as surface mulch by protecting the soil surface from raindrop impact in a manner similar to that of surface mulches of straw and chopped stalks. Rock fragments are usually not moved by water from interill areas, but remain on the soil surface and act as “armor.”

K values are also dependent on antecedent soil-water and soil-surface conditions. For this reason seasonal variations affect soil K factors. Seasonal factors that affect K values include soil freezing, soil texture, and soil water. The effects of all three are now included in the average annual K value. RUSLE calculates the seasonal or average soil-erodibility factor (K) using the EI distribution (erosive intensity).

Procedure

Soil survey databases include two kinds of K values for each soil component within a map unit. Kf represents soil erodibility of only the fine earth fraction (<2mm size). Kw represents a weighted value for the entire mapping component.

In RUSLE (the electronic version), the user simply selects the soil map unit component that will be used as the design soil for planning purposes. The spatial K factor is then determined automatically in the background based on the R value selected (see below).



SLOPE LENGTH AND STEEPNESS FACTORS (LS)

The effects of slope length and slope gradient on water erosion are accounted for in RUSLE by the combined topographic factor L and S (LS). **The LS values recorded in Table 2 through 5 are for slopes having nearly the same uniform gradient throughout their length.** Slope length (L) is defined as the horizontal distance from the origin of overland flow to the point where either (1) the slope gradient decreases enough that deposition begins or (2) runoff becomes concentrated in a defined channel. The slope steepness factor (S) reflects the influence of slope gradient on erosion. The values are ratios of average soil loss over the entire length of a uniform slope compared to the soil loss from a uniform 9 percent slope 72.6 feet long plot under otherwise identical conditions.

There are four separate LS tables in RUSLE. Table 2 is used for rangeland and pasture where the ratio of rill to interill erosion is low. Table 3 is used for cropland where the ratio of rill to interill erosion is moderate, such as on cropped land with little to moderate cover. Table 4 is used for construction sites where the ratio of rill to interill erosion is high and the soil has a strong tendency to rill. Table 5 is used for thawing soil where most of the erosion is caused by surface flow (Req area). Note that only Tables 2 and 5 may be used in the Req area of the state.

Soil loss is also affected by the "shape" of the slope. Many field slopes will either steepen toward the lower end of flatten toward the lower end. Use of the values for average gradient in Tables 2 through 5 would incorrectly estimate soil movement on these irregular slopes. For this reason Tables 2 through 5 should not be used for anything other than uniform slopes. In addition, successive slope segment cannot be evaluated as independent slopes because runoff flows from each segment cannot be evaluated as independent slopes because runoff flows from each segment to the next. For irregular slopes, therefore, LS values must be adjusted to account for effects of slope shape.

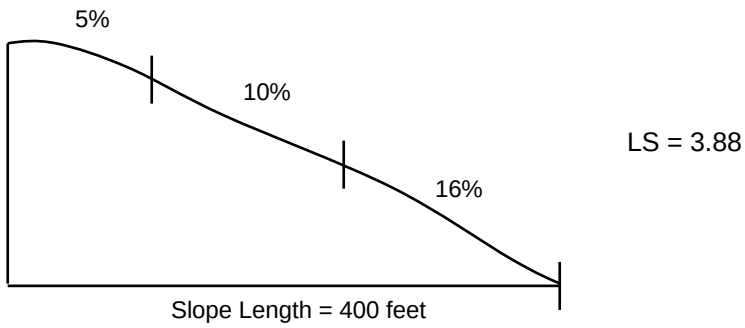
DETERMINING IRREGULAR SLOPE LS VALUES[1]

1. Divide the complex slope into two or more equal length segments in such a manner that the gradient within a particular segment for practical purposes can be considered uniform (see figure 1).

2. Determine the percent slope for each segment.

3.	List the segment gradients in the order in which they occur on the slope, beginning at the upper end.
4.	Record the (LS) factor, using Table 2 through 5, that represents each segment gradient and corresponds to the total slope length.
5.	Multiply these segment LS values by the corresponding factors from Table 6. Add the products and divide by the number of segments. This average represents the effective LS value of the irregular slope.

Figure 1



[1] Example of dividing complex slope into equal length segments of uniform slope

In the electronic form of RUSLE, the user simply inputs the slope and slope length in the equation and the LS factor is automatically selected (see below).

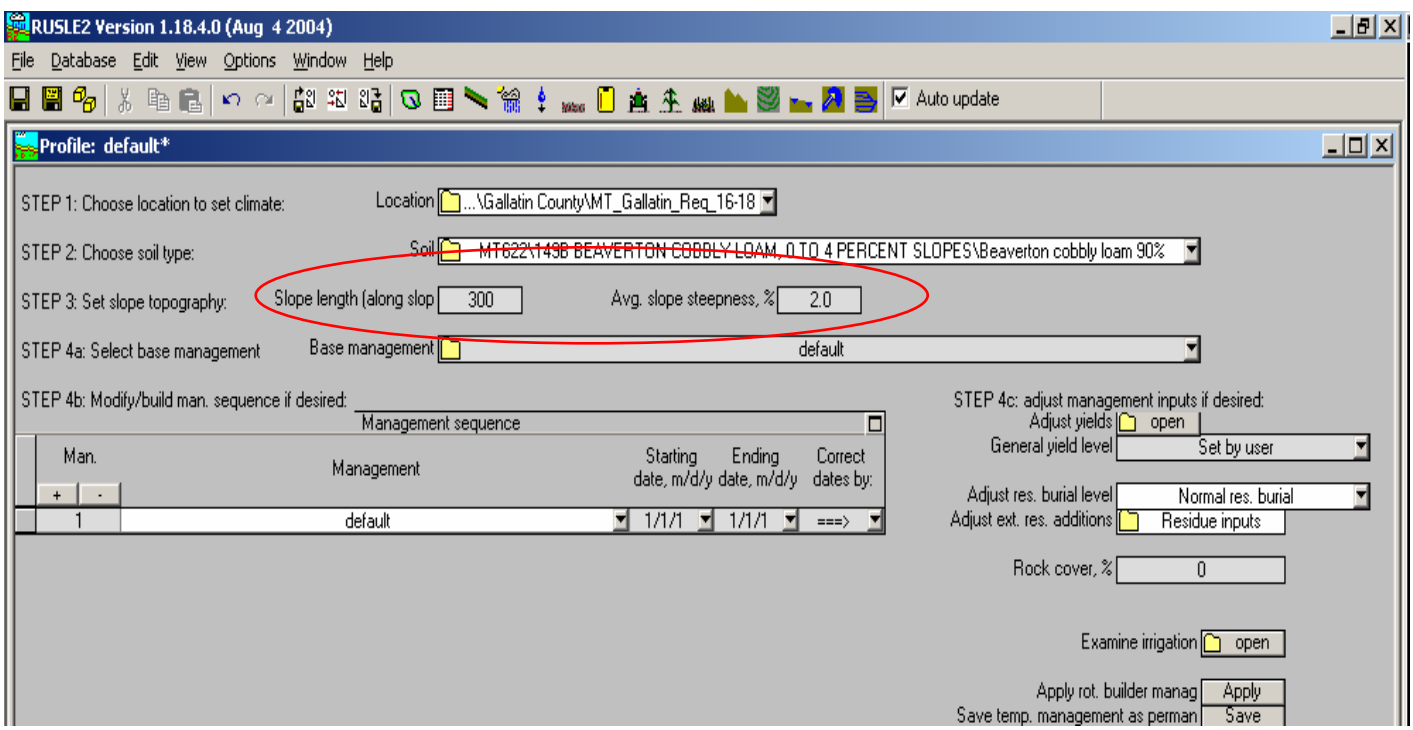


TABLE 6

FACTORS TO ADJUST LS VALUES FOR SUCCESSIVE SEGMENTS OF A SLOPE

Segment no. (Top to Bottom)	Number of equal-length Divisions of a slope			
	2	3	4	5
1	.71	.58	.50	.45
2	1.29	1.06	.91	.82
3		1.36	1.19	1.06
4			1.40	1.25
5				1.41

See Figure 1 for graphic. Assume a convex slope 400 feet long. The upper third averages 5 percent slope; the middle third averages 10%; the lower third averages 16%. From LS Table 3, record the values that correspond to 400-feet slope length and the gradient – 5%, 10%, 16% (from top to bottom of slope). Multiply each of these LS values by the adjustment factor shown in Table 6. In this example, you would use the column for three slope segments. Add the three values together and divide by the number of segments (three). In tabular form, the computations are as follows:

Segment No.	Slope	LS	Table 6 Adj.	Segment LS
1	5	1.13	.58	0.66
2	10	2.84	2.84	3.01
3	16	5.86	5.86	7.97
				11.64

Effective LS = 11.64 ÷ 3 = 3.88

For a concave slope 400 feet long, where the slope segments are in the reverse order, 16%, 19%, 5%, the Table 3 values and segment factors are combined slightly differently. The LS values would be the same, but the adjusted segment LS's would be 3.39, 3.01 and 1.54 respectively, with an effective LS value of 2.65.

COVER – MANAGEMENT FACTOR (C)

The Cover-Management Factor (C) in RUSLE is used to reflect the effect of cropping and management practices on erosion rates. The C-factor indicates how manageable operations will affect the average annual soil loss and how that soil-loss potential will be distributed in time during construction activities, crop rotations, tillage operations, and other management schemes.

In RUSLE, the C-factor is compared to a reference condition. The standard C-factor is one that is obtained on an area under clean-tilled, continuous fallow conditions. This standard is called the Soil Loss Ratio (SLR) and is an estimate of the ratio of soil loss under actual conditions to losses under the reference condition. The SLR is divided into a series of subfactors that impact cropping and management on soil losses. Subfactors included in the SLR ratio are prior land use (PLU), canopy cover (CC), surface cover (SC), surface roughness (SR), and soil moisture (SM). The subfactors are expressed as functions of one or more variables including residue cover, canopy cover, canopy height, surface roughness, below ground biomass (root mass plus incorporated residue), prior cropping, soil moisture, and time. Each of the SLR values is then weighted by the fraction of rainfall and runoff erosivity

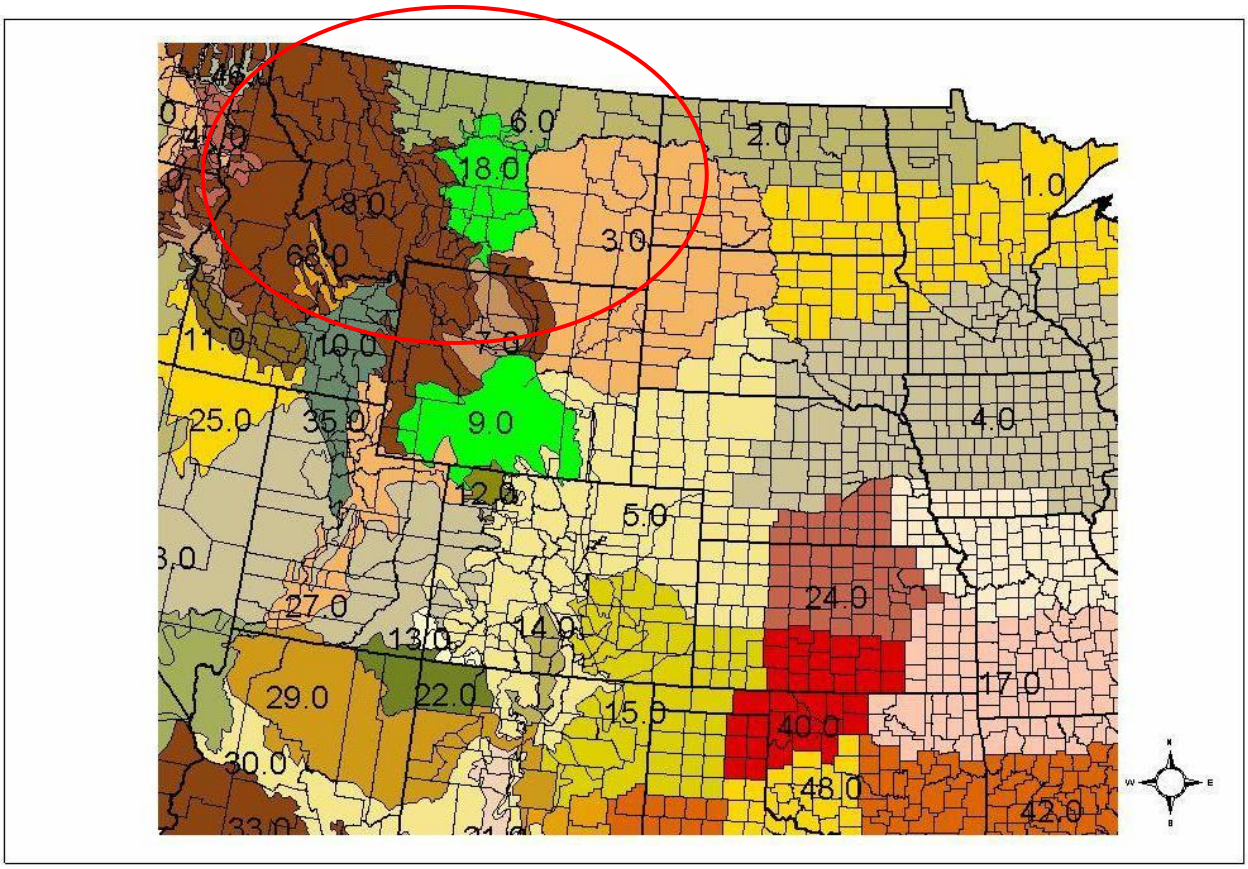
(EI) associated with the corresponding time period, and these weighted values are combined into an overall C-factor.

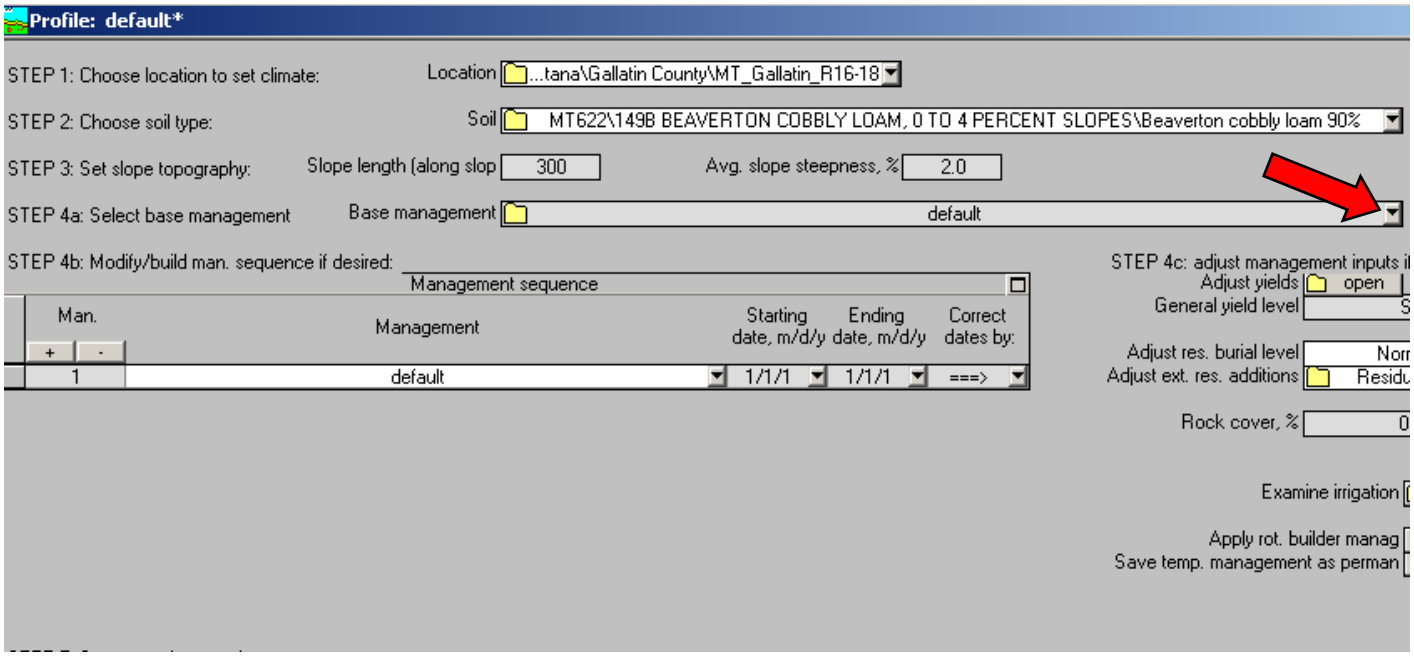
The C-factor is dependent on rainfall intensity patterns as well. Therefore, a C factor for a particular cropping system will not be the same for all parts of Montana, but is location specific. For areas such as pasture or rangeland that have reached a relative equilibrium, the parameters used in computing SLR values may change very slowly with time, so calculated SLR values will also change little. In these cases it may prove adequate to calculate a C factor based on a single average SLR representing the entire year

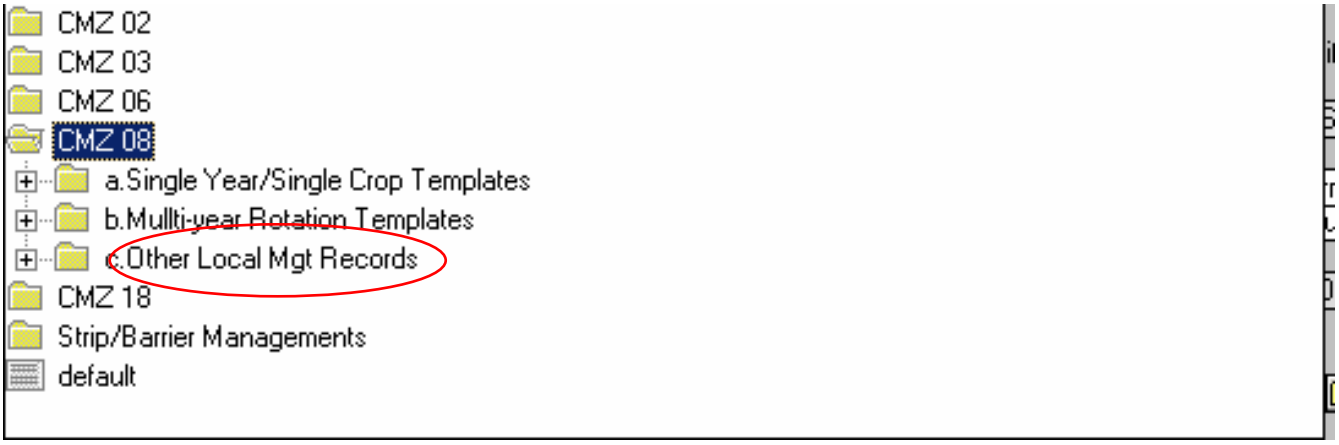
Cropland

A C-factor is determined by using RUSLE2 software after selecting the appropriate R factor, soil map unit, and entering slope and slope length. To calculate a C-factor (see screen shoot below) access the appropriate crop management zone by clicking on the drop-down menu. Crop management zones are associated with areas with similar planting dates, climatic conditions, harvest dates, and geography.

Select the appropriate crop management zone (see the crop management zone map below). Each zone has various crop management templates already prepared where the user has only to edit dates, change operations, adjust yields, etc., to complete a custom cropping system.

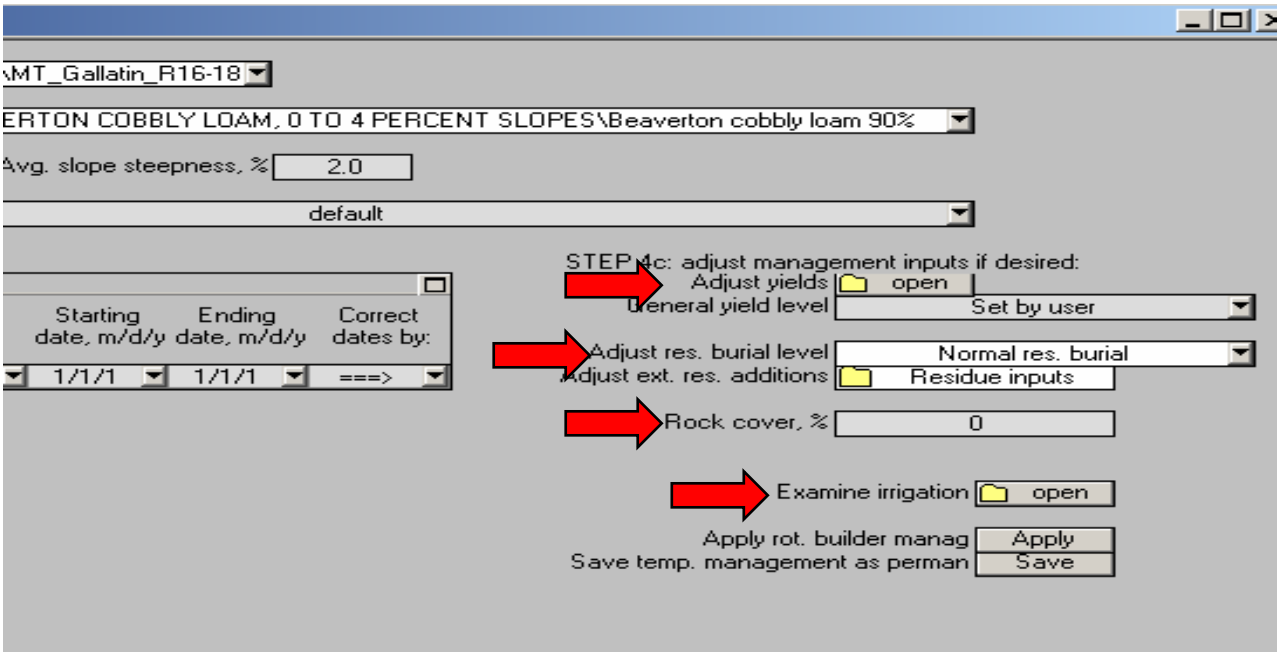






Once a single year template or a multi-year template is selected and the user makes changes that best depict their situation. The management system may be saved as “other local mgt records” for use at a later time so that reentry of data is not required.

The cropping system may be customized by editing dates of operations, yields, tillage operations, water applied through irrigation, rock cover, crop species, etc. The actual C-factor is calculated in the background and automatically changes the calculated soil loss every time there is a change to the input data.



In almost all cropland scenarios and in many cases where rangeland and pasture are being managed, the crop and soil parameters change with time due to either specific management practices or natural cyclic effects such as winter knockdown and spring growth. For this reason, RUSLE calculates SLR every 15 days throughout the year, and that the important parameters are assumed to remain constant during those 15 days.

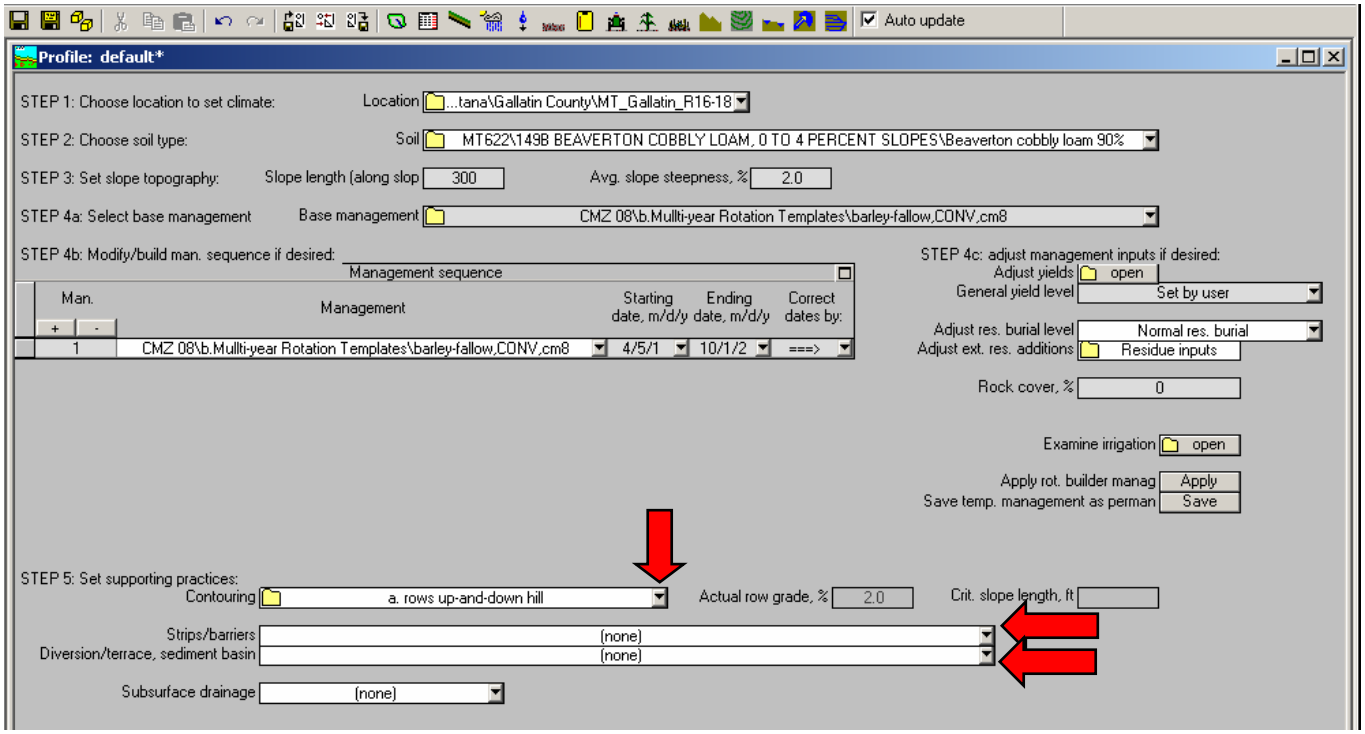
SUPPORT PRACTICE FACTOR (P)

The P Factor in RUSLE is called the **support practice** factor because, in general, whenever sloping soil is to be cultivated and exposed to erosive rains, the protection offered by sod or close-growing crops in the system needs to be supported by practices that will affect erosion by modifying the flow pattern, grade, or direction of surface runoff and by reducing the amount and rate of runoff. For cultivated land, the support practices considered include contouring (tillage and planting on or near the contour), strips or barriers, diversion/terracing/sediment basins, and subsurface drainage. It should be noted that a stabilized waterway or other medium for disposal of excess rainfall may be necessary with the supporting practices to effectively reduce erosion causing water energy.

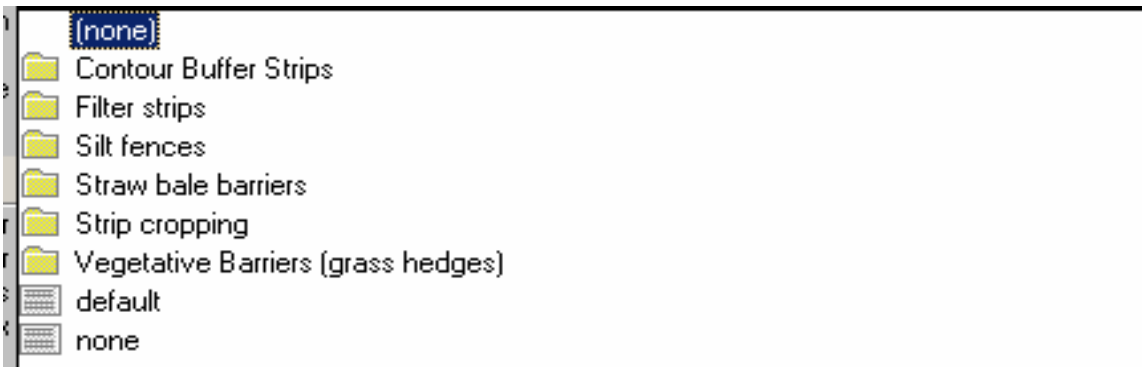
An overall P-factor value is computed as a product of P subfactors (contouring, barriers, terracing, and subsurface drainage) for individual support practices. Many of the subfactors are typically used in combination with the other sub-factors. For example, contouring usually accompanies stripcropping and/or terraces. RUSLE P factor data was derived from erosion theory and analyses of experimental data. Data were obtained from three sources: plots, small watersheds, and solutions of equations derived from erosion theory.

Procedures

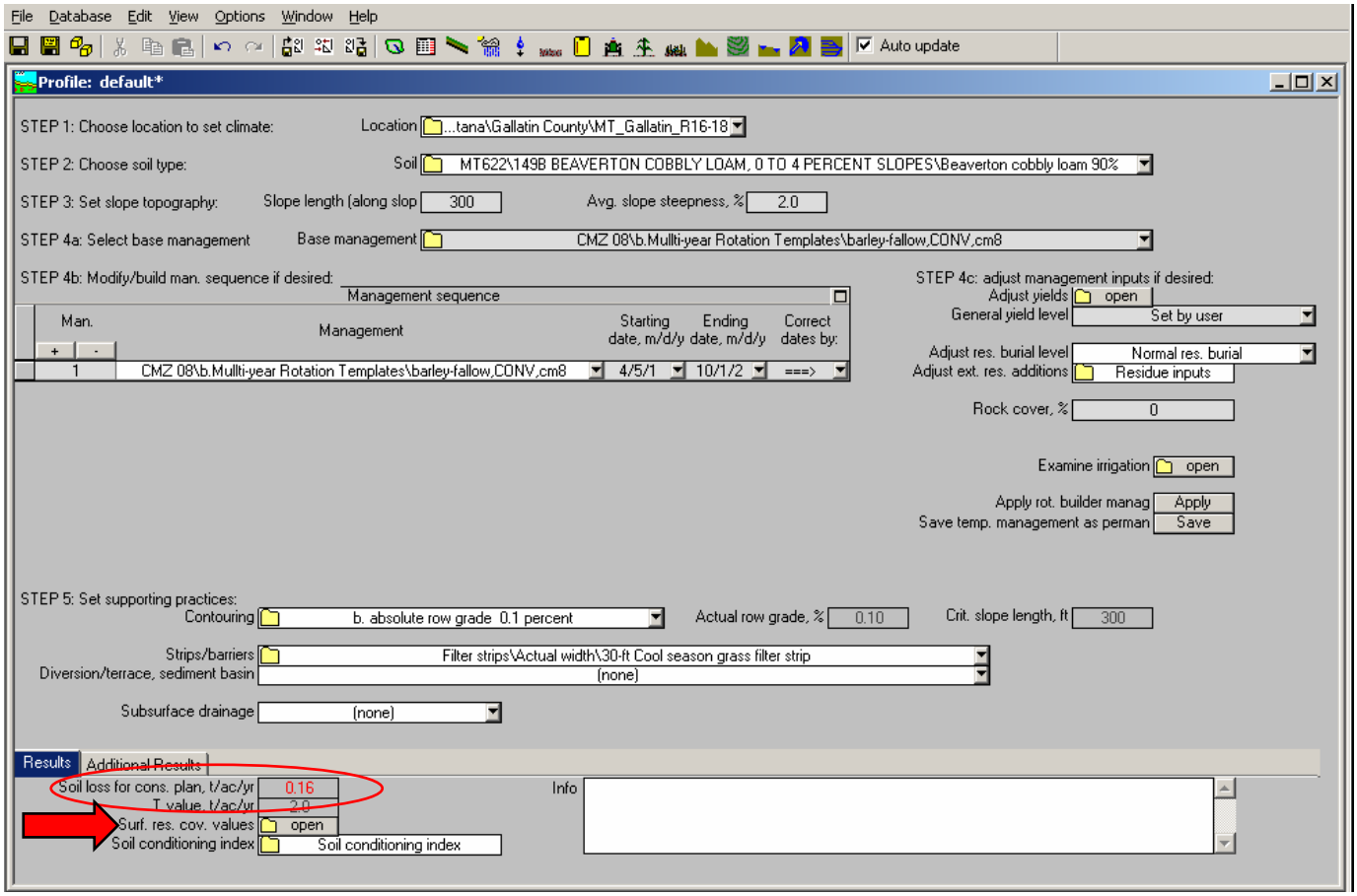
Once Steps 1 through Step 4c are completed, access the supportive practices by clicking on the pull down window adjacent to “contouring” first. Select an absolute (designed and constructed contour grade of a relative row grade.



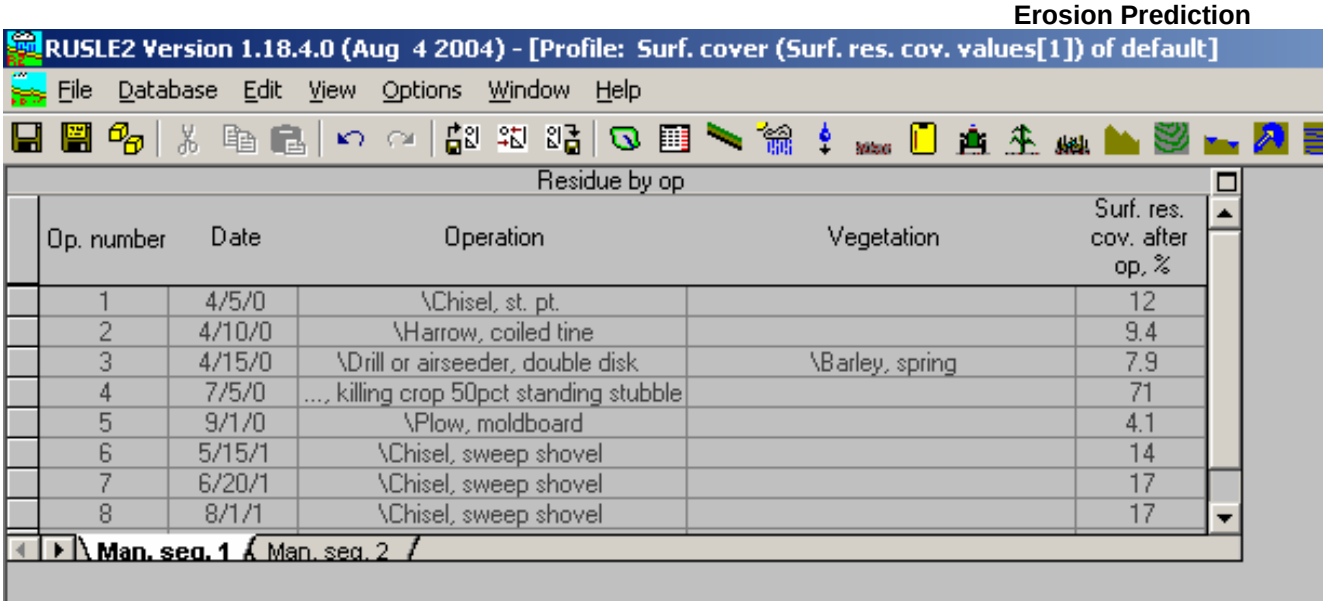
Then, access the strip/barrier pull down window. Select the type of strip or barrier that will be implemented into the conservation system (see pull down window below). Select the appropriate practice and width of the barrier. Finally, access the diversion, terrace subsection by accessing the pull down window and selecting the appropriate practice and percent row grade being designed for the system. Once the subfactors are all selected, the P-factor is calculated automatically and the resultant soil loss calculated simultaneously.



Once all the factors are selected, erosion calculations are completed automatically (see below). The soil map unit soil loss tolerance (T) is also listed automatically. Surface residue cover factors may be viewed by clicking on the manila file folder adjacent to the “Surf. res. Cov. Values” (see below).



The surface residue cover values are a useful tool when deciding what period of time within the cropping system results in less than adequate crop residue. Users can also access additional results of the erosion prediction model to view sediment delivery T/A/Y off of filter strips or barriers. This data may also be used to design conservation practices and to validate that a particular system is providing water quality benefits.



Op. number	Date	Operation	Vegetation	Surf. res. cov. after op, %
1	4/5/0	\Chisel, st. pt.		12
2	4/10/0	\Harrow, coiled tine		9.4
3	4/15/0	\Drill or airseeder, double disk	\Barley, spring	7.9
4	7/5/0	..., killing crop 50pct standing stubble		71
5	9/1/0	\Plow, moldboard		4.1
6	5/15/1	\Chisel, sweep shovel		14
7	6/20/1	\Chisel, sweep shovel		17
8	8/1/1	\Chisel, sweep shovel		17

The soil conditioning index is also populated automatically and only requires wind erosion prediction to finish the calculation. The soil conditioning index provides a numerical value pertaining to the trend of soil health (utilizing organic matter, erosion, and tillage operations) for the particular unit and system installed.