CHAPTER 6. SUPPORT PRACTICE FACTOR (P)

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CHAPTER 6. CONTENTS

By definition, the support practice factor (P) in RUSLE is the ratio of soil loss with a specific support practice to the corresponding loss with upslope and downslope tillage. These practices principally affect erosion by modifying the flow pattern, grade, or direction of surface runoff and by reducing the amount and rate of runoff (Renard and Foster 1983). For cultivated land, the support practices considered include contouring (tillage and planting on or near the contour), stripcropping, terracing, and subsurface drainage. On dryland or rangeland areas, soil-disturbing practices oriented on or near the contour that result in storage of moisture and reduction of runoff are also used as support practices.

P does not consider improved tillage practices such as no-till and other conservation tillage systems, sod-based crop rotations, fertility treatments, and crop-residue management. Such erosion-control practices are considered in the C factor.

Values for P factors contained in this chapter were obtained from experimental data, supplemented by analytical experiments involving scientific observations of known cause-and-effect relationships in physically based models such as CREAMS (Knisel 1980). Recommended factor values are generally rounded to the nearest five-hundredth.

An overall P-factor value is computed as a product of P subfactors for individual support practices, which are typically used in combination. For example, contouring almost always accompanies stripcropping and terraces.

SUPPORT PRACTICE FACTOR (P) FOR CONTOURING

The effect of contour tillage on soil erosion by water is described by the contour P factor in the Revised Universal Soil Loss Equation (RUSLE). If erosion by flow occurs, a network of small eroded channels or rills develops in the areas of deepest flow. On relatively smooth soil surfaces, the flow pattern is determined by random natural microtopography. When tillage is oriented along the contour, the ridges or oriented roughness will partially or completely redirect the runoff, thereby modifying the flow pattern. When tillage leaves high ridges, runoff stays within the furrows between the ridges, and the flow pattern is completely determined by the tillage marks. High ridges from tillage on the contour cause runoff to flow around the slope, significantly reducing the grade along the flow path and reducing the flow's detachment and transport capacity compared to runoff directly downslope.

When grade is sufficiently flat along the tillage marks, much of the sediment eroded from the ridges separating the furrows is deposited in the furrows (Meyer and Harmon 1985). However, tillage is seldom exactly on the contour. Runoff collects in the low areas on the landscape and if accumulated water overtops the ridges, then rill and concentrated flow erosion usually occur, especially in recently tilled fields (Hill et al. 1944). Runoff from contoured fields is often less than that from fields tilled upslope-downslope (Van Doren et al. 1950). Contour tillage reduces erosion by reducing both the runoff and the grade along the flow path.

Values currently used in USLE (Wischmeier and Smith 1978) for the contour P factor are almost identical to those developed by Smith and Whitt (1947, 1948). At a 0% slope, Smith and Whitt reasoned that the value for the contouring subfactor should be 1.0 because no flow direction is defined. For steep slopes, they reasoned that the contouring subfactor value should be 1.0 for slopes steeper than 25% because a typical ridge 6 in high would store no water. At intermediate slopes, they chose a value of 0.6 for a 2% slope from the plot study of Van Doren et al. (1950) and a value of 0.5 for a 7% slope from the study of Smith et al. (1945).

This handbook recommends values for the RUSLE contour P factor based on erosion theory and analyses of experimental data. Data were from three sources: plots, small watersheds, and solutions of equations derived from erosion theory.

Data Analyses

Plot Data

Data from plot studies on the effect of contouring were found for the 18 locations identified in table 6-1. Plot dimensions varied from study to study with widths as narrow as 6 ft to as wide as 150 ft and lengths of 70 to 400 ft. Six studies were conducted with simulated rainfall, and 12 studies were on natural-runoff plots. The duration of the natural-runoff-plot studies ranged from a few days to 10 yr. Cropping and ridge height varied among the studies.

Contouring affected both runoff and erosion, but erosion was affected more than runoff. The ratio of (1) runoff and soil loss from a treatment tilled on the contour to (2) the runoff and soil loss from the same treatment tilled uphill-downhill was calculated for the period of record at a location. The results for runoff are shown in figure 6-1. The results for soil loss, the RUSLE contour P factor, are shown in figure 6-2.

Watershed Data

Soil-loss data collected from watersheds of 0.15-5 acres at four locations (table 6-2) were analyzed and plotted in figure 6-2. Straightforward comparisons of soil loss from uphill-downhill tillage with soil loss from contour tillage were impossible for many of the watershed studies. For example, the crop rotation at Clarinda, Iowa (Browning et al. 1948), differed among the watersheds. Data from a plot were compared against data from a watershed at LaCrosse, Wisconsin (Hays et al. 1949), to estimate a value for the contouring subfactor. At Bethany, Missouri (Smith et al. 1945), extensive gully erosion in the noncontoured watershed produced sediment that was measured at the watershed outlet but is not estimated with RUSLE. Also, the contoured watershed at Bethany had an extensive network of grassed waterways on 20% of the watershed, resulting in an unusually low sediment yield for this watershed. Therefore, the ratio of sediment yield to erosion from these two watersheds at Bethany gave a value for the contouring subfactor that was probably too low, in general. At Temple, Texas (Hill et al. 1944), areas of the watersheds were not equal. For example, the area of the watershed in the up-and-down tillage was 0.15 acre whereas the area of the contoured watershed was 1.5 acres. Such watershed differences result in appreciable differences in runoff, erosion, and sediment yield, so the data must be appropriately considered.

Analysis With CREAMS

The erosion component of the CREAMS model (Foster et al. 1981a) was used to compute erosion and sediment yield on several hypothetical watersheds under two levels of soil susceptibility to rill and concentrated flow erosion. The configuration of these watersheds was two planes that formed a V with a concentrated flow channel in the middle. Runoff on the planes was analyzed as flow in a series of furrows between ridges spaced 2.5 ft apart. An overland flow channel-channel hydrologic sequence was used in CREAMS to represent the watersheds. The overland-flow element represented the row side slopes, the first channel represented flow in furrows, and the second represented concentrated flow in the V between the planes. The maximum length of the concentrated flow channel in the V was 500 ft. Widths of the planes from their upper edge to the concentrated flow channel were 40 ft and 120 ft for two steep watersheds and 40 ft and 200 ft for two flat watersheds. The steepness of the planes on the steep watersheds was 12%, and the grade along the channel in the V was 6%. The steepness of the planes for the flat watersheds was 6%, and the grade along the channel was 4%. A critical shear stress value of 0.10 $lb \cdot ft^{-2}$ represented a field immediately after secondary tillage—a condition of high susceptibility to erosion by flow (Foster et al. 1980a). A critical shear stress value of 0.20 $lb \cdot ft^{-2}$ represented a field about a month or two after the last secondary tillage—a condition of moderate susceptibility to erosion by flow (Foster et al. 1980a).

Storm characteristics assumed in the analysis were 2.5 in for rainfall amount, 1.6 in for runoff amount, 2.0 $in \cdot h^{-1}$ for peak runoff rate, and 50 $ft \cdot tonf \cdot in(acre\text{-}h)^{-1}$ EI units for rainfall erosivity, which represent typical simulated rainstorms used in plot studies (Meyer 1960). These runoff values were not varied by watershed condition even though contouring affects runoff as shown in figure 6-1. Therefore, the computer analysis with CREAMS underestimated the effect of contouring.

Furrow grades in the analysis were 0.5%, 1%, 2%, and 4% for the flat watershed and 6% for the steep watersheds. As the grade of the furrows was increased, the upslope drainage area at the head of the concentrated flow channel was increased and the channel length of the concentrated flow in the V was shortened. The results from furrows on a 0.5% grade were assumed to represent excellent contouring and were plotted in figure 6-2.

Results

Figure 6-2 presents the basic data available in the literature. However, the application of RUSLE to contouring problems requires consideration of the storm erosivity and grade along the tillage marks when RUSLE is used in its standard way of taking slope length and steepness directly downslope.

Effect of Ridge Height

Five curves, drawn by inspection through the data shown in figure 6-2, represent the effectiveness of contouring where ridge heights are very low, low, moderate, high, and very high and where the ridges follow the contour so closely that runoff spills over the ridges uniformly along their length. Data showing the greatest effectiveness of contouring were generally from plots having high ridges (Borst et al. 1945, Moldenhauer and Wischmeier 1960). Conversely, data showing the least effectiveness of contouring were from plots having low ridge heights (Van Doren et al. 1950). The end points of the curves at the steep slopes were based on the steepness where typical ridge heights and row spacings would store no runoff.

These curves were described by the following equations:

$$P_b = a(s_m - s_c)^b + P_{mb} \qquad s_c < s_m \qquad [6\text{-}1]$$

$$P_b = c(s_c - s_m)^d + P_{mb} \qquad s_c \geq s_m \qquad [6\text{-}2]$$

$$P_b = 1.0 \qquad s_c \geq s_e \qquad [6\text{-}3]$$

where P_b = base values of the P factor for contouring, s_m = slope (expressed as sine of the slope angle) at which contouring has its greatest effectiveness, s_c = slope (expressed as sine of the slope angle) for which a value of P_b is desired, s_e = slope steepness (expressed as sine of the slope angle) above which contouring is ineffective, and P_{mb} = the minimum P value for a given ridge height with base conditions. The coefficients a, b, c, and d also vary with ridge height.

The curves described by equations [6-1] and [6-2] pass through P_m at the slope s_m, which varies with ridge height shown in table 6-3, and have a zero slope at s_m. In addition, values for the coefficients a and b must be chosen so that equation [6-1] passes through 1 at $s_c = 0$ and equation [6-2] passes through 1 at $s_c = s_e$. To meet these boundary conditions, a is given by the equation

$$a = \frac{1 - P_m}{s_m^b} \qquad [6\text{-}5]$$

and c is given by the equation

$$c = \frac{1 - P_m}{\left(s_e - s_m\right)^d} \qquad [6\text{-}5]$$

Values for b, d, s_m, and s_e, chosen by inspection to give good fits to the data shown in figure 6-2, are listed along with values for a and c given in table 6-3.

The data in figure 6-2 are assumed to be for the base condition of a 10-yr-frequency storm EI of 100 ft · tonf · in(acre · hr)$^{-1}$ and for a row crop with clean tillage on a soil classified as being in the hydrologic soil group C.

Effect of Storm Severity

Data from field studies indicate that contouring is less effective for large storms than for small storms (Moldenhauer and Wischmeier 1960, Jasa et al. 1986). The reduced effectiveness depends on both amount of runoff and peak rate of runoff. These runoff variables are directly related to rainfall amount and intensity, which are the principal variables that determine EI (storm energy times maximum 30-min intensity), the erosivity factor in RUSLE. Therefore, values for the contouring subfactor should be near 1 (little effectiveness) when EI is high and infiltration into the soil is low, and should be small (greater effectiveness) when EI is low and infiltration is high (Moldenhauer and Wischmeier 1960). Loss of contouring effectiveness is likely to occur from a few major storms (Hill et al. 1944, Jamison et al. 1968). Therefore, erosivity of a single storm, such as the storm having a 10-yr return frequency, should be a better indicator of loss of contouring effectiveness than is average annual erosivity.

In figure 6-2, the highest 10-yr storm EI for the locations represented in figure 6-2 was 165 ft · tonf · in(acre · hr)$^{-1}$ at Temple, Texas (Wischmeier and Smith

1978), where contouring had little effectiveness. Conversely, the lowest 10-yr storm EI was 50 ft · tonf · in(acre · hr)$^{-1}$ at Arnot, New York (Lamb et al. 1944), where contouring was most effective. The contouring P-factor values were also low at Clarinda, Iowa (Moldenhauer and Wischmeier 1960), where the 10-yr storm EI was 76 ft · tonf · in(acre · hr)$^{-1}$. Erosivity was high—140 ft · tonf · in(acre · hr)$^{-1}$ at Batesville, Arkansas (Hood and Bartholomew 1956), where ridge breakovers occurred and the contouring P-factor value was high.

A linear regression analysis using the complete data set showed an increase in the contouring P factor with an increase in the 10-yr single-storm EI $[(EI)_{10}]$. The analysis also showed that effectiveness of contouring increased with increasing ridge height (Moldenhauer and Wischmeier 1960).

The effectiveness of contouring in RUSLE is assumed to vary with runoff, which is a function of both rainfall and infiltration. Runoff, computed using the Natural Resource Conservation Service (NRCS) runoff curve number method and the rainfall amount estimated from the 10-yr single-storm EI, is used as a guide in RUSLE to adjust P-factor values for changes in effectiveness of contouring that result from runoff differences among locations, soils, and cover-management conditions.

Values for the 10-yr storm EI are obtained from the Citycode files in the computer program of RUSLE. These EI values are converted to storm rainfall amounts using the equation (Foster et al. 1980b)

$$V_r = 0.255\ [(EI)_{10}]^{0.662} \qquad [6\text{-}6]$$

where V_r = rainfall amount in inches. Values for rainfall amount, V_r, are used in the NRCS runoff curve method to compute a runoff amount. Cover-management conditions for cropland are grouped in the seven categories described in table 6-4. The runoff index values, equivalent to curve numbers, used to compute runoff for each of these conditions are given in table 6-5. (For Northwestern Wheat and Range conditions and runoff index values, see tables 6-25 and 6-26.)

Runoff was assumed to affect P-factor values for contouring in two ways: the minimum value of the P factor was assumed to vary directly with computed runoff, and the slope steepness above which contouring loses its effectiveness was also assumed to vary directly with runoff. The basis for these assumptions is that the effectiveness of contouring is assumed to be directly proportional to the shear stress applied to the soil by the runoff. This shear stress is directly proportional to runoff rate and slope steepness to the 1.167 power (Foster et al. 1982). Runoff rate was assumed to be directly proportional to runoff amount. Thus the slope steepness (s_e) at which contouring loses its effectiveness was computed as

$$s_e = s_{eb} \left(\frac{3.72}{Q_k} \right)^{0.857} \qquad [6\text{-}7]$$

where s_{eb} = slope steepness for a given ridge height on base conditions at which contouring loses its effectiveness, Q = computed runoff amount (in) for the given soil and cover-management condition indicated by subscript k, and 3.72 = runoff amount (in) computed for cover-management condition 6, hydrologic soil group C, and a 10-yr storm EI of 100 ft · tonf · in(acre · hr)$^{-1}$. This storm EI is typical of much of the central part of the eastern United States, and the hydrologic soil group C is assumed to be typical of many of the soils in the contouring experiments that produce the data shown in figure 6-2. Similarly, the minimum P-factor value (P_m) is computed from

$$P_m = P_{mb} \left(\frac{Q_k}{3.72} \right) \qquad [6\text{-}8]$$

where P_{mb} = minimum P-factor value for a ridge height on base conditions.

Equations [6-1], [6-2], and [6-3] give P-factor values for base conditions. These curves shift as field conditions vary from the assumed base conditions. The following approach was used to take into account these differences:

The first step is to compute a scaled slope steepness. For a slope steepness of less than s_m, the actual slope steepness is used directly in equation [6-1] to compute a P_b value. For slopes steeper than s_m, the slope used in equation [6-2] is computed from

$$s_c = \frac{(s - s_m)(s_{eb} - s_m)}{(s_e - s_m)} + s_m \qquad [6\text{-}9]$$

The computed P_b value is then scaled as

$$P = 1 - \frac{(1 - P_b)(1 - P_m)}{1 - P_{mb}} \qquad [6\text{-}10]$$

If the steepness exceeds s_e computed from equation [6-7], then P = 1.0. If the value computed by equation [6-10] is less than an absolute minimum value (P_z) given in table 6-3, the absolute minimum P_b value for that ridge height is assigned to P.

Effect of Off-Grade Contouring

Contouring alone is often inadequate for effective erosion control (Hill et al. 1944, Smith et al. 1945, Jamison et al. 1968). Runoff frequently flows along the furrows to low areas on the landscape, where breakovers occur. Grassed waterways are needed in conjunction with contouring to safely dispose of the runoff that collects in natural waterways at the breakovers (Smith et al. 1945).

Erosion in the concentrated flow areas occurs even if contouring is not used, although eroded concentrated flow channels extend farther upslope with contouring. Our analysis with CREAMS showed that if row grade is slight, 0.5% or less, deposition in the furrows more than offsets the erosion in the concentrated flow areas.

As grade along the furrows increases from tillage being off contour, the effectiveness of contouring decreases. Results from CREAMS and experimental data (McGregor et al. 1969, Meyer and Harmon 1985) showed a rapid loss of effectiveness of contouring as grade along the furrows increased. The furrows in these situations were for clean-tilled row crops.

Soil loss estimated with RUSLE using the slope length measured downslope and the contouring factor in figure 6-2 includes the erosion in concentrated flow (ephemeral gully) areas for about 500 ft of a concentrated flow channel. The reason for the inclusion of ephemeral gully erosion by concentrated flow in the P factor is that the watershed data used in the derivation of figure 6-2 were collected on small watersheds that contained eroding ephemeral gully areas.

The equation used in RUSLE to compute P-factor values for off-grade contouring is

$$P_g = P_o + (1 - P_o)\left(\frac{s_f}{s_l}\right)^{1/2} \qquad [6\text{-}11]$$

where P_g = P factor for off-grade contouring, P_o = P factor for on-grade contouring (as computed by equation [6-10]), s_f = grade (expressed as sine of the slope angle) along the furrows, and s_l = steepness (expressed as sine of the slope angle) of the land. This equation is similar to the relationship assumed by Dissmeyer and Foster (1980) for application of USLE to disturbed forest lands. The data collected by McGregor et al. (1969) seem to be the only field data available that can be used to directly evaluate equation [6-11]. Grade along furrows in that study varied between 0.2% and 0.4%. The P-factor value in the McGregor et al. (1969) study was 0.39 for 150-ft wide plots on a 5% slope with off-contour tillage whereas the P-factor value was 0.10 when the furrows were perfectly on the contour. Given a value of P_o = 0.10, the value of P_g computed by equation [6-11] for a 0.3% furrow grade is 0.32, slightly less than the 0.39 measured value.

ESTIMATING SOIL LOSS WITH CONTOURING WHEN SLOPE LENGTH EXCEEDS CRITICAL SLOPE LENGTH

Critical Slope Limits

At long slope lengths, contouring loses its effectiveness. Wischmeier and Smith (1978) gave a table of values for critical slope lengths for USLE that represented slope lengths beyond which contouring was assumed to lose much of its effectiveness. These critical slope-length limits were given only as a function of slope steepness, but Wischmeier and Smith suggested that critical slope length increased if residue cover exceeded 50%.

Foster et al. (1982) investigated the hydraulic conditions under which surface residue failed and allowed serious erosion to occur. Their analysis considered the shear stress exerted by the runoff on the soil and the residue. When the shear stress exerted on the residue exceeded a critical value, the residue was assumed to move. Similarly, when the shear stress exerted on soil exceeded a critical shear stress, flow was assumed to erode the soil.

The equation derived by Foster et al. (1982) for movement of mulch used discharge as the principal hydraulic input variable. Critical slope-length limits in RUSLE are computed with a simplification of the Foster et al. (1982) equation for mulch stability. The equation is

$$\lambda_c = \frac{20182 n_t^{1.5}}{s^{1.1667} Q} \qquad [6\text{-}12]$$

where λ_c = critical slope length, n_t = Manning's n, s = slope (expressed as sine of the slope angle), and Q = runoff amount from the 10-yr storm EI. The value 20,182 was obtained by calibrating equation [6-12] to compute a critical slope length of 200 ft for a 7% slope, moderately high ridges, clean-tilled row crops, a soil classified in the hydrologic soil group C, and a 10-yr storm EI of 100 $ft \cdot tonf \cdot in(acre \cdot hr)^{-1}$. This critical slope-length value agrees with Wischmeier and Smith (1978). Values for Manning's n_t are given in table 6-6 and were chosen from those suggested for the CREAMS model (Foster et al. 1980a) and from field research on the movement of mulch (Foster et al. 1982).

Existing recommended values for critical slope length (Wischmeier and Smith 1978) were based on judgment and field observations. The condition chosen for calibration seems to best represent the typical condition that would have been observed in the field. Values for a range of slopes were computed with equation [6-12] and are shown in table 6-7 along with values from Wischmeier and Smith (1978). The values computed by equation [6-12] are very close to those from Wischmeier and Smith (1978) except for slopes less than 4%. A value of 1,000 ft is set in RUSLE as a maximum critical slope length. Values for critical slope length for a range of conditions are given in tables 6-8, 6-9, and 6-10.

Derivation of RUSLE Equation for Effective P

The procedure for applying RUSLE to irregular slopes (Foster and Wischmeier 1974) was used to develop the equations to calculate effective P-factor values. The beginning point in the derivation is RUSLE applied to a point, as follows:

$$D = (m + 1)\ RKSCP \left(x_* \frac{\lambda}{72.6} \right)^m \qquad [6\text{-}13]$$

where D = erosion rate at a point, m = slope-length exponent, R = rainfall-runoff erosivity factor, K = soil erodibility factor, S = slope steepness factor, C = cover-management factor, and P = support-practice factor for contouring.

The normalized distance x_* is x/λ, where x is distance along the slope length λ *and 72.6 is* length (ft) of the RUSLE unit plot. All factor values apply to conditions at the point x. The derivation is for a uniform slope. If a more complex situation is being analyzed, the full irregular slope procedure should be used.

Equation [6-13] can be rearranged to give

$$D = (m + 1)\ RKSCP \left(\frac{\lambda}{72.6} \right)^m (x_*)^m \qquad [6\text{-}14]$$

where the term $(\lambda/72.6)^m$ is the slope length factor of RUSLE.

Soil loss, G, for the slope length is obtained by integrating equation [6-14] for the two parts of the slope: the upper part where contouring is assumed to be fully effective and the lower part where no effectiveness of contouring is assumed. The equations for this soil loss are

$$G = \int_0^{x_c} D dx + \int_{x_c}^{1} D dx \qquad [6\text{-}15]$$

Substitution of equation [6-14] into equation [6-15] gives:

$$G = (m+1)\,\lambda \left(\frac{\lambda}{72.6}\right)^m \left(P \int_0^{x_c} x_*^{\,m}\, dx_* + \int_{x_c}^{1} x_*^{\,m}\, dx_* \right) \qquad [6\text{-}16]$$

Soil loss expressed in units of mass per unit area is obtained by dividing sediment yield G from the slope by slope length λ. Completion of the integration and division by λ gives the equation for soil loss A of

$$A = RKLSC\,[P_{eff}] \qquad [6\text{-}17]$$

where

$$P_{eff} = \left[1 - x_c^{\,m+1}(1 - P)\right] \qquad [6\text{-}18]$$

is the effective P factor to compute average soil loss for the slope length λ. Values for P_{eff} were computed using equation [6-18]. Slope-length exponent values for a range of slopes and rill-to-interrill erosion classes are in table 4-5.

Discussion

Use of the effective P-factor values from table 6-10 gives an estimate of the average soil loss for the slope length λ. Soil loss on the lower part of the slope where contouring has been assumed to fail can be considerably greater than the average soil loss for the entire slope. When using this method in conservation planning, the conservationist must consider whether it is permissible to allow soil losses on the lower part of the slope in excess of the soil loss tolerance. Chapter 4 describes how to use RUSLE to compute soil loss on segments and how to adjust segment values to compare with soil-loss tolerances to provide for consistency in RUSLE applications.

SUPPORT PRACTICE FACTOR (P) FOR CROSS-SLOPE STRIPCROPPING, BUFFER STRIPS, AND FILTER STRIPS

Stripcropping is a support practice where strips of clean-tilled or nearly clean-tilled crops are alternated with strips of closely growing vegetation such as grasses and legumes. Another form of stripcropping used on cropland in the Northwestern Wheat and Range Region is very rough, tilled strips instead of strips of closely growing vegetation. The crops are generally rotated sequentially so that at some time in the rotation cycle, every crop will have been grown on every strip. To be compatible with the crop rotation, the width of all strips in the system is usually the same. Stripcropping performs best when the upper edge of each strip is perfectly on the contour.

Stripcropping for the control of water erosion is variously described as contour stripcropping, cross-slope stripcropping, and field stripcropping. Each of these practices has the common characteristic of crops in rotation forming strips of nearly equal width. The difference between the practices is the degree of deviation from the contour. All of them, including contour stripcropping, involve some degree of off-grade contouring. The effectiveness of all of them can be determined with the same equations in the RUSLE computer model. All are versions of the same technology with no sharp distinction despite the wide variation in effectiveness, depending on grade of the row. Therefore, the term "cross-slope stripcropping" is used to refer to the various conditions described above.

Buffer strips, located at intervals up the slope, are resident strips of perennial vegetation laid out across the slope. Like the strips in cross-slope stripcropping, they may or may not be on the contour. These strips, predominantly composed of grass species, are not in the crop rotation, are usually much narrower than the adjacent strips of clean-tilled crops, and may be left in place for several years or permanently. The effectiveness of buffer strips in trapping sediment and reducing erosion can also be evaluated by the RUSLE model.

Vegetated filter strips are bands of vegetation at the base of a slope. Riparian filter strips are located along stream channels or bodies of water. These conservation practices are designed to reduce the amount of sediment reaching offsite water bodies. Neither practice traps eroded sediment on the hillslope and therefore has minimal benefit as a P factor.

Densely vegetated strips or very rough strips that induce deposition of eroded sediment are assigned a P-factor value. Deposition must occur on the hillslope in areas where crops are routinely grown to deserve a low P factor indicative of greatest value to soil conservation. Therefore, P-factor values for maintenance of soil productivity are lowest for cross-slope stripcropping, moderate for buffer strips, and highest for filter strips. A P value of 1.0 is often assigned to filter strips because they provide little protection to the majority of the field where crops are grown.

A major advantage of stripcropping is the rotation of crops among the strips. By rotating crops among strips, each clean-tilled crop receives benefit from the sediment deposited in a previous year by the closely growing crop or the rough strip. Stripcropping significantly reduces the rate of sediment moving down the slope. Because filter strips are located at the base of slopes, the strips do not greatly affect this rate. In general, the benefit of deposition depends on the amount of deposition and its location. Sediment deposited far down the slope provides less benefit than does sediment deposited on the upper parts of the slope. With buffer strips, the sediment is trapped and remains on small areas of the slope, such as terraces; thus the entire slope does not benefit as much as it does in stripcropping.

A strip is effective in reducing soil loss when it significantly reduces the transport capacity of the runoff as it leaves one strip and enters the next strip. For deposition to occur, the transport capacity must be reduced to less than the sediment load being transported by the runoff. If no deposition occurs, the P value is 1.0. The following examples illustrate the basis for assigning P-factor values.

Examples

The first example is the situation of strips of a clean-tilled row crop separated by strips of grass hay. It is assumed that the uppermost strip is in corn and that erosion occurs at a high rate on this strip. Sediment load will be large in the runoff at the lower edge of the corn strip. The hay strip has a much greater hydraulic resistance to flow than does the clean-tilled area, and this resistance greatly reduces the transport capacity of the runoff as it enters the hay strip. If transport capacity is reduced at the upper edge of the hay strip to a level much less than the sediment load of the runoff entering the hay strip, much deposition occurs and gives a P-factor value of less than 1. As the runoff moves through a sufficiently wide hay strip, deposition reduces the sediment load to less than the transport capacity of the flow in the hay strip. The flow can be erosive as it exits the lower edge of the hay strip.

The relationship of erodibility of a clean-tilled strip to the transport capacity in the densely vegetated strip is illustrated by the extreme example of strips of concrete separated by dense grass strips. It is assumed that the uppermost strip is concrete. Flow over the concrete has great transport capacity, but its sediment load is very low (and approaches zero) because the concrete is not erodible. Even though the grass strip at the lower edge of the concrete greatly reduces the transport capacity of the flow, no deposition occurs because the transport capacity was not reduced to a level less than the sediment load in the flow. Therefore, the value of the P factor for this case is 1.0.

Another example more realistic than the above concrete-grass example illustrates the same principle. This example involves strips of no-till corn interspersed among strips of grass. It is assumed that the uppermost strip is no-till corn with a very heavy cover of residue. Very little erosion occurs on the strip of no-till corn. When the runoff reaches the grass strip, little reduction in the transport capacity of the runoff occurs because that of the grass is only slightly greater than the hydraulic resistance of the no-till corn. Therefore, since the sediment load in the runoff leaving the strip of no-till corn is very low because of little erosion on the no-till corn, no deposition will occur because the grass strip did not reduce the transport capacity of the runoff to a level less than the sediment load in the flow from the no-till strip. In this case, the P-factor value is 1.0.

In summary, the effectiveness of stripcropping, buffer strips, and filter strips as support practices depends on the sediment load generated from the erodible strips relative to the transport capacity of the strips that have greater hydraulic resistance.

Development of P-Factor Values for Strips

The first step in developing RUSLE P-factor values for strips was to review the literature. Unfortunately, most of the experimental research on stripcropping was conducted from 1930 to 1960 and did not include modern conservation tillage systems (Hill et al. 1944, Borst et al. 1945, Smith et al. 1945, Hays et al. 1949, Hood and Bartholomew 1956, Hays and Attoe 1957). Also, crop yields during that period were much less than modern yields, and canopy cover and residue amounts were less than those with modern practices.

Therefore, published experimental data alone are inadequate for developing the necessary P-factor values for the wide range of current practices. The approach taken was to develop a simple erosion-deposition model based on fundamental erosion concepts (Renard and Foster 1983, Flanagan et al. 1989) that could be used in RUSLE to estimate P-factor values for strips. Steps in addition to developing the model included developing parameter values based on theory and experimental data from fundamental erosion studies and adjusting parameter values to obtain an adequate fit of the model to the limited field data. The model is included in RUSLE to compute values for the P factor for stripcropping, buffer strips, and filter strips for a wide variety of situations.

A value for the P factor for strips is computed from

$$P_s = \frac{(g_p - B)}{g_p} \qquad [6\text{-}19]$$

where P_s = value for P factor for strips, g_p = sediment load at end of slope that would occur if the strips caused no deposition, and B = credit for deposition.

Table 6-11 shows values for sediment yield from experimental data for stripcropping found in the literature, along with values computed by the model.

The model computes erosion, sediment transport, and deposition on a strip-by-strip basis, routing the sediment from the top to the bottom of the slope. One of the four following conditions exists on each strip:

(1) Net erosion occurs everywhere along the strip.

(2) Net deposition occurs everywhere along the strip.

(3) Net deposition occurs on an upper area of the strip and net erosion occurs on a lower area of the strip.

(4) Runoff ends within a strip, and no runoff or sediment leaves the strip.

The objective in each case is to compute the amount of deposition (M_i) on each strip and the sediment load (g_i) leaving each strip.

Case 1. Net Erosion Occurs Everywhere Along the Slope

For this case to apply, one condition is that the rate of increase in transport capacity along the strip must be greater than the detachment rate along the strip. For this condition, net erosion is computed by

$$D_{ni} = \xi_i\left(x_i^n - x_{i-1}^n\right) \qquad [6\text{-}20]$$

where ξ = an erosion factor, x = relative distance from the top of the slope to the lower edge of a strip (absolute distance/slope length), n = an exponent set to 1, and I = subscript indicating a particular strip. Values of ξ are given in table 6-12. Sediment load at the lower edge of the strip is given by

$$g_i = g_{i-1} + D_{ni} \qquad [6\text{-}21]$$

where g = sediment load.

The exponent n is set to 1 for all conditions. The reasoning for this value is that contouring is an integral part of stripcropping. When contouring is completely effective, it eliminates rill erosion. Much of the effectiveness of contouring is because of deposition in the furrows left by tillage. Erosion on strips where cover is dense is minimal and is mostly interrill erosion rather than rill erosion. In both situations, the appropriate value of the exponent is 1 (Renard and Foster 1983). The value of the exponent should be about 1.5 where rill erosion is significant. A single value of 1 is used in RUSLE because the principal intent of equation [6-21] is to provide an index of net erosion.

Local deposition, such as in depressions left by tillage, can occur within a strip because the detachment rate exceeds the rate of increase in transport capacity along the strip. For this condition, the deposition equation developed by Renard and Foster (1983) is used to compute net erosion as

$$D_{ni} = \left[\frac{\left(\dfrac{\phi dT_i}{dx} + \xi_i\right)}{(1 + \phi)}\right]\left(x_i - x_{i-1}\right) \qquad [6\text{-}22]$$

where $\phi = V_f/\sigma$, V_f = fall velocity of the sediment, and σ = excess runoff rate (rainfall intensity - infiltration rate). A value of 15 was selected by calibration for ϕ. Although the value for ϕ varies with sediment size and density, the single value of 15 is used in RUSLE. Equation [6-23] is based on the following equation for deposition (Renard and Foster 1983):

$$D = \left(\frac{V_f}{q}\right)(T - g) \qquad [6\text{-}23]$$

where D = deposition rate, q = discharge rate, and T = transport capacity of the runoff.

Case 2. Deposition Occurs Everywhere Along Strip

Deposition occurs at the upper edge of a strip if the transport capacity at the upper edge of a strip is less than the sediment load reaching the upper edge. Deposition will occur over the entire strip if the strip is narrow or if runoff rate decreases with distance within the strip. This latter condition occurs where the infiltration rate in a particular strip is much greater than the infiltration rates on upslope areas.

The basic equation used for strips where deposition occurs is equation [6-23]. Discharge rate q is given by the equation

$$q = q_{i-1} + \sigma_i \left(x - x_{i-1}\right) \qquad [6\text{-}24]$$

In RUSLE, the excess runoff rate is computed as the ratio of runoff amount, expressed as a depth, for the given strip condition to the runoff amount from a clean-tilled row-crop strip, which is condition 6 in table 6-4. Runoff amounts are computed by use of the NRCS runoff curve number method and runoff index values given in table 6-5.

When the infiltration rate on a strip is greater than the rainfall intensity, discharge rate decreases within the strip; if the strip is wide, runoff ends within the strip. Because the NRCS runoff curve number method would ordinarily compute no runoff for this condition, the method was modified to compute the rainfall amount that would just produce runoff. This equation is

$$r = V_r - 0.2\left[\left(\frac{1000}{N}\right) - 10\right] \qquad [6\text{-}25]$$

where r = excess runoff depth (in), V_r = rainfall amount, and N = runoff index. The equation for transport capacity (T) is

$$T = \zeta q \qquad [6\text{-}26]$$

where ζ = a sediment transport capacity factor. Values of ζ are relative and were chosen based on the Manning's n_t recommended for the CREAMS model (Foster et al. 1980a), the relation of runoff velocity to Manning's n_t, and the assumed relationship that transport capacity varies with the cube of runoff velocity (Foster and Meyer 1975). Values for ζ are given in table 6-12.

The equation derived from equations [6-24], [6-25], and [6-27] to compute sediment load where deposition occurs along the entire strip is

$$g_i = \left(\frac{\phi dT_i}{dx} + \xi_i\right) q_i \left[\sigma_i(1 + \phi)\right]^{-1} + \left(\frac{q_{i-1}}{q_i}\right)^{\phi} \left\{ g_{i-1} - \left(\frac{\phi dT_i}{dx} + \xi_i\right) q_{i-1} \left[\sigma_i (1 + \phi)\right]^{-1} \right\} \qquad [6\text{-}27]$$

The change of transport capacity with distance dT_i/dx is given by

$$\frac{dT_i}{dx} = \zeta_i \sigma_i \qquad [6\text{-}28]$$

The amount (M) of deposition on the strip is computed from

$$M_i = g_i - g_{i-1} + D_{ni} \qquad [6\text{-}29]$$

Case 3. Both Deposition and Erosion Within a Strip

If the sediment load at the upper edge of a strip is greater than the transport capacity at that location, deposition occurs over an upper area of the strip.

Deposition ends within a strip if the rate of increase in the transport capacity, dT/dx, exceeds the detachment rate ξ, and if the strip is wide. The location where deposition ends is the location where the sediment load equals the transport capacity. The discharge rate (q_{de}) for this condition is given by

$$q_{de} = \left(\frac{a_2 \phi \sigma_i}{a_1 \sigma_i + \xi_i} \right)^{\frac{1}{1+\phi}} \left[q_i \right]^{\frac{\phi}{1+\phi}} \qquad [6\text{-}30]$$

where coefficients a_1 and a_2 are given by

$$a_1 = \frac{\left(\frac{\phi dT_i}{dx} + \xi_i \right)}{\left[\sigma_i \, (1 + \phi) \right]} \qquad [6\text{-}31]$$

$$a_2 = g_{i-1} - a_1 q_{i-1} \qquad [6\text{-}32]$$

The location x_{de} where deposition ends is computed from

$$x_{de} = \frac{\left(q_{de} - q_{i-1} + \sigma_i \, x_{i-1} \right)}{\sigma_i} \qquad [6\text{-}33]$$

The sediment load at the location where deposition ends is given by

$$g_{de} = \zeta_i \, q_{de} \qquad [6\text{-}34]$$

If $dT_i/dx > \xi_i$, sediment load at the lower edge of the strip is given by

$$g_i = g_{de} + \xi_i \left(x_i^n - x_{de}^n \right) \qquad [6\text{-}35]$$

If $dT/dx < \xi_i$, sediment load at the lower edge of the strip is given by

$$g_i = g_{de} + \left[\frac{\left(\frac{\phi dT_i}{dx} + \xi_i \right)}{(1 + \phi)} \right] (x_i - x_{de}) \qquad [6\text{-}36]$$

The amount of deposition (M) is given by

$$M_i = g_i - g_{de} + \left[\frac{\left(\frac{\phi dT_i}{dx} + \xi_i \right)}{(1 + \phi)} \right] (x_{de} - x_{i-1}) \qquad [6\text{-}37]$$

Another possibility is for net erosion to occur on the upper area of a strip and local deposition to begin within the strip. This condition occurs when the sediment load is less than the transport capacity at the upper edge of a strip and the rate of increase in the transport capacity is less than the detachment rate, $dT_i/dx < \xi_i$. The location where local deposition begins is where sediment load (g_i) equals transport capacity (T). The sediment load at the lower edge of the strip is given by

$$g_i = g_{db} + \left[\frac{\left(\frac{\phi dT_i}{dx} + \xi_i \right)}{(1 + \phi)} \right] (x_i - x_{db}) \qquad [6\text{-}38]$$

where g_{db} = sediment load where local deposition begins and x_{db} = location where deposition begins. The amount of deposition (M) is zero for this condition if $g_i > g_{db}$. If $g_d < g_{db}$, then $M = g_{db} - g_i$.

Case 4. Runoff Ends Within a Strip

Sometimes the difference in infiltration can be so great between strips that all runoff from upslope is infiltrated within a strip having high infiltration rates. No runoff or sediment leaves these strips.

The location where runoff ends is calculated by use of equations [6-24] and [6-25]. The amount of deposition is the amount of sediment in the runoff entering the strip plus the amount of sediment detached within the strip between the upper edge of the strip and the location where runoff ends.

Application

Computation of P-Factor Value

The P-factor value for stripcropping is computed from

$$P_s = \frac{g_p - B}{g_p} \qquad [6\text{-}39]$$

where P_s = a P-factor value for conservation planning; g_p = potential sediment load if no deposition, other than local deposition, would have been caused by the strips; and B = amount of deposition considered to benefit the long-term maintenance of the soil resource. This benefit is computed by

$$B = \sum_{i=1}^{n} M_i \left(1 - x_{i-1}^{1.5}\right) \qquad [6\text{-}40]$$

where n = number of strips. The potential sediment load (g_p) is computed from

$$g_p = \sum_{i=1}^{n} D_{ni} \qquad [6\text{-}41]$$

where D_{ni} is computed for each strip according to equation [6-20] or [6-22].

The model also computes a sediment delivery ratio (P_y) for the slope by use of the equation

$$P_y = \frac{g_\lambda}{g_p} \qquad [6\text{-}42]$$

where g_λ = sediment load at the end of the slope.

Values for P computed for several stripcrop systems are shown in table 6-13.

The above equations and parameter values given in table 6-12 are used in RUSLE to compute a P-factor value and a sediment-delivery-factor value for any combination of strips, including buffer and filter strips. The parameter values in table 6-12 were developed to produce average annual P-factor values. The data used to determine the parameter values were heavily weighted by erosion in late spring and early summer, conditions when most erosion occurs with row crops in the eastern United States. Thus, the parameter values in table 6-12 most represent these conditions, but other conditions can be represented by choosing parameter values from table 6-12 based on surface conditions at a given time. The model can be applied several times during the year to compute an average P-factor value for the year, or the model can be applied over several years to compute a rotational P-factor value.

The equations used to compute deposition by strips do not take into account deposition in the ponded runoff on the upper side of the grass strip. The effect of the ponded runoff can be partially taken into account by adding the width of the ponded area to the width of the grass strip.

The effectiveness of strips as a soil conservation practice primarily results from the deposition induced at the upper edge of heavily vegetated or rough strips. In traditional applications of stripcropping, uniform-width strips are moved up the slope according to a crop rotation such as corn-wheat-1st yr hay-2d yr hay. In buffer strip applications, permanent vegetated strips that are much narrower than the cropped strips are installed. In rotational stripcropping, clean-tilled crops are grown on the strips where deposition occurred in prior years. In contrast, the benefit of narrow, permanent strips is that sediment is trapped and kept on the slope, but the immediate benefit is localized. The benefit to the entire slope is very little if a permanent strip is narrow and located at the end of the slope. If a single, narrow strip is placed high on the slope, none of the slope segment above the strip benefits from the deposition. This portion of the slope continues to erode at the same rate as if the strip were not present. The strip does, however, decrease the rate at which sediment moves off the slope over the long term; thus the slope segment below the strip benefits from the deposition induced at the upper edge of the strip.

The P-factor values and the resulting soil-loss values computed by RUSLE are intended to be used in conservation planning for maintenance of the soil resource base. Full credit is not taken for the total amount of deposition for conservation planning. The benefit assigned by equation [6-40] to the deposition depends on the location of deposition. The degree of benefit increases as the location of deposition moves up the slope; conversely, little benefit is assigned when the strip is near the end of the slope. This approach is conceptually consistent with the way that P-factor values are assigned to terraces (Foster and Highfill 1983).

RUSLE also computes a sediment delivery factor. Multiplication of this factor by the product RKLSC gives an estimate of sediment yield leaving the slope. Sediment-yield values are typically less than the soil loss computed with RUSLE because RUSLE does not give full credit to deposition as a benefit for maintenance of the soil resource over the entire slope.

The effectiveness of stripcropping is assumed to be independent of strip width up to the point that rilling begins. Results were varied in experimental studies on the effect of strip width. Once strips become so wide or slope lengths become so long that rilling occurs, stripcropping begins to lose its effectiveness. Because of the complexity of the problem, no approach is suggested to estimate a P-factor value representing the lost effectiveness of stripcropping due to excessively long slope lengths. Critical slope lengths for conservation planning for stripcropping are assumed to be 1.5 times the critical slope length for contouring. Critical slope lengths for stripcropping are related to the maximum slope lengths for contouring because contouring is an integral part of stripcropping. Computation of soil loss when slope lengths exceed critical slope lengths is the same as computation of soil loss for contouring.

For maximum effectiveness, stripcropping is installed with the upper edge of the strips on the contour. However, strips are sometimes installed off contour, resulting in a grade along the upper edge of the strips. The effectiveness of these strips is difficult to evaluate. Deposition occurring at the upper edge of the densely vegetated strips builds up a ridge of soil that can cause runoff to flow along the upper edge of the strip and not pass through the strips. On tilled strips, runoff can flow along the tillage marks and never reach the strip if tillage is on a grade. The net result is that the system behaves no differently than off-grade contouring with a weighted C factor based on the area occupied by the various strips. This approach produces a P-factor value that represents the minimum effectiveness of strips. The maximum effectiveness can be estimated by use of the stripcrop model by choosing a designation for the cropped strips having an erodibility greater than that for the contour tilled condition, to represent the reduced effectiveness of off-grade contouring. The overall P factor is a combination of two P factors: one for off-grade contouring, and one for stripcropping with an adjusted surface designation because of increased sediment (resulting from off-grade contouring) reaching the densely vegetated strips.

The stripcrop model in RUSLE estimates the amount of deposition induced by a strip by representing the main factors that affect sediment transport and deposition. However, even though the parameter $\phi = V_f / \sigma$ represents the effect of sediment characteristics, a single value is used for all conditions. Therefore, actual deposition will be greater and sediment delivery will be less than that computed with RUSLE for soils high in either clay or sand content compared to typical silt loam soils. The converse is true for soils whose silt content is higher than that in silt loam soils. Furthermore, upslope localized deposition in depressions left by tillage or deposition by upslope strips reduces the particle size and thus the amount of sediment deposited by downslope strips. In estimating sediment passing through strips that induce deposition, the CREAMS model (Foster et al. 1980a) or the SEDIMOT II model (Wilson et al. 1986) considers more factors over a wider range of conditions than does RUSLE.

SUPPORT PRACTICE FACTOR (P) FOR TERRACING

Terraces reduce sheet and rill erosion on the terrace interval by breaking the slope into shorter slope lengths. Also, deposition along the terraces may trap much of the sediment eroded from the interterrace interval, particularly if the terraces are level and include closed outlets, have underground outlets, or have a very low grade. Deposited sediment remains on the field and is redistributed over a significant portion of the field, thus reducing soil deterioration caused by erosion. In this way, terraces help to maintain the soil resource much as contour stripcropping does. Furthermore, properly designed terraces and outlet channels collect surface runoff and convey it off the field at nonerosive velocities. Without the terraces and outlet channels, runoff in natural waterways on unterraced fields can cause significant erosion.

Deposition Behind Terraces

The amount and location of sediment deposited on terraced fields are important in assigning P-factor values to calculate soil loss for conservation planning. If no soil is trapped, none is saved by deposition. Even if deposition traps all sediment eroded from the interterrace interval, the area benefiting directly is that near the terraces. Some of the interterrace interval is still degraded as if no deposition occurs. The P factor for computing soil loss for conservation planning to maintain the soil resource is computed as a function of spacing between terraces. The maximum benefit assigned to deposition is that half of the deposition directly benefits maintenance of the soil resource at spacings of less than 110 ft. At spacings of greater than 110 ft, the benefit is assumed to decrease to the point that no benefit is assigned for spacings of 300 ft and greater.

Erosion of the upslope and deposition on the downslope portion, within the terrace interval, cause a flatter slope that can be permanently maintained above storage-type terraces. On deep soils, a permanent bench can be formed, resulting in less erosive topography and easier farming (Jacobson 1981).

Measured elevations on gradient terraces (Borst et al. 1945, Copley et al. 1944, Daniel et al. 1943, Pope et al. 1946, Smith et al. 1945) showed that after 8 yr, deposited soil accumulated on terrace ridges, channel bottoms, and front and back slopes. The sediment accumulation on ridges and backslopes was produced by displacement during tillage and terrace maintenance. With closed outlet and underground outlet terraces, sediment accumulates where runoff enters standing water.

Effect of Grade

An analysis of terrace data from the 1930's and 1940's showed that deposition varies greatly with terrace grade (Foster and Ferreira 1981). Sediment yield from single-terrace watersheds with a range of grades was measured for about 8 yr at several locations. Results of this analysis show that the sediment yield from uniform-grade terraces increases according to the following exponential relationship:

$$P_y = 0.1e^{2.4s} \qquad s<0.9\% \qquad [6\text{-}43]$$

$$P_y = 1.0 \qquad s\geq 0.9\% \qquad [6\text{-}44]$$

where P_y = sediment delivery factor and s = terrace-slope grade (%). The P factor for conservation planning is computed as

$$P = 1 - B(1-P_y) \qquad [6\text{-}45]$$

where B = the benefit assigned to deposition, and the quantity $1-P_y$ = that amount of deposition, comparable to M in the stripcropping computations. Values for B are given in table 6-14.

Terrace P Factor for Conservation Planning

The P factor for terraces for use in conservation planning considers both the benefit of deposition and the amount of sediment deposited. This net soil loss is the soil loss on the interterrace interval minus the amount of deposited soil that is credited for helping to maintain the soil resource. Table 6-15 gives terrace P-factor values for use in conservation planning (Foster and Highfill 1983). Table 6-16 gives values for use in estimating sediment yield from terraces.

To compute soil loss with RUSLE for conservation planning, values for the terrace P factor are multiplied by other factor values for contouring and stripcropping on the interterrace interval.

SUPPORT PRACTICE FACTOR (P) FOR SUBSURFACE DRAINED AREAS

Limited field data indicate that subsurface drainage is effective in reducing overland flow and erosion (Formanek et al. 1987, Bengtson and Sabbage 1988). Both the Formanek and the Bengtson and Sabbage studies reported P values with an average of about 0.6, although individual annual values and storm values varied appreciably.

Because of limited information and differences in procedures among studies, further research is needed to develop a range of P-factor values for subsurface drained areas that are applicable across many conditions of climate, soil, crop, and slope. The technique needing development may well include a procedure similar to that reported by Skaggs et al. (1982). This technique may involve estimating runoff volume, peak runoff rate, and storm EI by use of a physically based model like CREAMS (Knisel 1980) to estimate P-factor values for simulations with and without subsurface drainage situations over a wide range of field conditions.

SUPPORT PRACTICE FACTOR (P) FOR RANGELANDS

The support practice factor (P) in RUSLE reflects the effect on rangeland erosion of mechanical practices such as ripping, root plowing, contour furrowing, and chaining. Some common mechanical practices applied on rangelands are listed in tables 6-17, 6-18, and 6-19. These practices affect erosion in several ways, including the removal of surface cover, which is perhaps the most important single factor affecting erosion. However, that effect is considered by the cover-management factor C in RUSLE. Mechanical practices described by the P factor can affect runoff amount, runoff rate, flow direction of runoff, and hydraulic forces exerted by runoff on the soil.

Almost every mechanical practice that disturbs rangeland soils increases infiltration, which in turn reduces runoff and erosion. An exception is the compaction and smoothing used for water harvesting. The degree to which infiltration is increased depends on the soil. The increase in infiltration and the reduction in runoff can be very large on the coarse-textured soils of the southwestern United States, whereas the increase in infiltration and the reduction in runoff can be slight on fine-textured soils like those in South Dakota. In fact, the crusting of fine-textured soils after mechanical practices that expose the soil can cause decreased infiltration. The ratings for runoff reduction given in tables 6-16, 6-17, and 6-18 are general. More precise ratings are possible from knowledge of the hydrologic properties of local soils.

A practice like contour furrowing that produces ridges and furrows will redirect surface runoff from flowing directly downhill to a flow path around the hill on a reduced grade. The reduced grade can greatly decrease the erosivity of the runoff. A practice like ripping at right angles to the slope, which leaves a very rough surface, also slows the runoff and reduces its erosivity. Depressions formed by the roughness provide areas where sediment is deposited, thus reducing soil loss.

The effectiveness of mechanical practices decreases over time as the soil surface seals and the depressions and furrows are filled with sediment. The rate at which a practice loses its effectiveness depends on the climate, soil, slope, and cover. The estimated times of effectiveness for practices listed in table 6-19 are general and should be adjusted for local conditions. Values for P should be increased over time from the minimum value immediately after treatment, because the practices are estimated to lose their effectiveness.

Runoff Reduction and Surface Roughness

The effect of increased infiltration and surface roughness are considered together when selecting a value for P because the influence of runoff and surface roughness are interrelated with slope steepness. The effect of surface roughness on the reduction of soil loss will decrease as the slope steepness increases.

Values for the P factor for rangelands for the effect of roughness, infiltration, and slope are computed in RUSLE with the equation

$$P = \frac{D_y}{D_e} \qquad [6\text{-}46]$$

where D_y = sediment transported from the slope, and D_e = sediment produced on the slope by detachment.

The P factor considers that the roughness is assumed to cause some of the sediment produced by detachment to be deposited in the depressions left by the roughness. The amount of sediment leaving the slope (D_y) is computed by the deposition equation used to compute values for P with stripcropping (Renard and Foster 1983), as follows:

$$D_y = \left(\phi \ dT/dx + D_e\right) / \left(1 + \phi\right) \qquad [6\text{-}47]$$

where ϕ = a parameter that indicates how readily sediment is deposited, and dT/dx = change in transport capacity with distance.

A value of 15 was assigned to ϕ, the same as in the stripcropping computations. The equation for dT/dx is based on the transport capacity equation used in WEPP (Foster et al. 1989), as follows:

$$dT/dx = k_t \ s \ \sigma \ r_f \qquad [6\text{-}48]$$

where k_t = a transport coefficient, s = sine of the slope angle, σ = excess rainfall rate (rainfall rate minus infiltration rate), and r_f = a roughness factor.

The parameter k_t was assigned a value of 33.28, which was chosen so that the model would fit experimental data for deposition as a function of slope (Meyer and Harmon 1985). Excess runoff rate is computed from

$$\sigma = 1 - f_r \qquad [6\text{-}49]$$

where f_r is a runoff reduction factor that varies between an initial value at the time of disturbance and zero after decaying over time as the soil consolidates after the disturbance according to

$$f_r = f_{ri}\ c_d \qquad [6\text{-}50]$$

where f_{ri} = the initial runoff reduction, and c_d = the consolidation factor that is given by

$$c_d = \exp\left(-d_t\ t_d\right) \qquad [6\text{-}51]$$

where d_t = a decay parameter, and t_d = time (yr) since the soil was disturbed.

Consolidation is assumed to begin immediately. The decay parameter is computed from

$$d_t = -\ln(0.05)\ /\ t_c \qquad [6\text{-}52]$$

where t_c = time (yr) for 95% of effect of disturbance to have disappeared by consolidation.

Runoff reduction at the time of disturbance is computed by use of the 10-yr frequency single-storm erosivity, and the NRCS runoff index method. Values for runoff index as a function of cover roughness are described in table 6-20; cover roughness conditions are shown in table 6-21. The runoff index values are a function of the rainfall intensity pattern in a storm. Runoff index values are greater for thunderstorm-type rains than for long-duration, gentle, frontal-activity rains. The ratio of 10-yr storm erosivity, $(EI)_{10}$, to average annual precipitation (P) is used as an index to determine curve number values. For $(EI)_{10}/P > 3$, values for thunderstorm-dominated areas are used; for $(EI)_{10}/P < 1$, values for areas dominated by frontal activity are used. Linear interpolation is used for values of $(EI)_{10}/P$ between 1 and 3.

The roughness factor (r_f) is computed from

$$r_f = 0.23\ r_i^{-1.18} \qquad [6\text{-}53]$$

where r_i is a roughness index (in). The coefficient 0.23 and exponent -1.18 were selected to give values for the roughness factor (r_f), which are similar to the values used for ζ in the stripcropping computations.

The value used for r_i is the value that represents the current surface condition. That value is determined by interpolating between the roughness immediately after disturbance and the roughness after consolidation. Equations [6-50] and [6-51] are used in this interpolation. Roughness values for the RUSLE range condition classes are given in tables 6-21 through 6-24.

Detachment (D_e) is assumed to be the same for all conditions except for the effect of disturbance. Detachment is computed with the equation

$$D_e = D_b + \left(1 + D_b\right) c_d \qquad [6\text{-}54]$$

where D_b is the minimum value of detachment after it decreases over time after consolidation relative to the detachment immediately after disturbance. A value of 0.45 is assumed for D_b, the same as used in the C-factor computations.

Redirection of Runoff

When applied on rangelands, practices like contour furrowing are effective because they redirect surface runoff from a downslope path to a less erosive path around the hill. Any rangeland practice that leaves ridges sufficiently high to redirect runoff in this manner has an effect that is considered in the P factor.

Slope Length and Steepness Taken Downhill

Ideally, the grade along the furrows between the ridges should be flat or near flat so that runoff may spill uniformly over the length of the ridges. Ridges perfectly on the contour ensure maximum runoff storage and infiltration and also minimize runoff and erosion. P values for this condition are computed using equations [6-1] through [6-10] by use of the parameter values given in tables 6-21 through 6-24. Slope length is then taken directly down the hill perpendicular to the contour.

The effectiveness of contouring depends on the storm erosivity and the reduction in runoff caused by mechanical practices. Because a few major storms determine the overall effectiveness of contouring, the erosivity (EI_{10}) of the storm with a 10-yr return interval is recommended as the basis for adjusting contour factor values to account for the influence of storm erosivity.

The effectiveness of contouring depends on the ridge height, as indicated by the contour factor values in figure 6-2. A low-height ridge (2-3 in) is like that left by a typical rangeland drill or light disk. Moderately high ridges are those that are left by an agricultural chisel plow with twisted shanks. Very high ridges (>6 in) are like those left by typical contour furrowing on rangelands.

To get the ridges exactly on the contour is practically impossible. When the ridges are off-contour, runoff flows along the furrows to low places in the landscape. As water accumulates, breakovers in these depressed areas often occur and cause concentrated flow erosion. The effectiveness of contouring is rapidly lost as grade along the furrows increases.

The same relationships used in the cropland section and the parameter values given in tables 6-21 through 6-24 are used to compute the effect of storm erosivity, increased infiltration, ridge height, and grade along the ridges for contouring on rangeland.

Terraces, Diversions, and Windrows

Terrace and diversion channels on a slight grade across a slope will intercept surface runoff and direct it around the slope on a slight grade. As a part of chaining, brush and other debris are sometimes pushed into windrows that are on the approximate contour. If these windrows intercept surface runoff and direct it around the hill, they too should be treated as terraces.

Terraces and similar practices usually reduce the slope length. Therefore, when RUSLE is applied to terraced land, the slope length is taken from the origin of surface runoff on the upslope terrace ridge or other watershed divide to the edge of the flow in the terrace channel. Slope steepness used in the S factor is the slope of the interterrace area. This procedure for selecting slope length is used when the terraces are on a uniform grade. Sometimes the terraces may be on a nonuniform grade and may be so far apart that concentrated flow areas develop on the interterrace interval. When this situation exists, terraces may have little effect on slope length, and the slope is taken in the same way as if the terraces were not present.

Terrace, diversion, or windrow channels on a sufficiently flat grade cause considerable deposition, with the amount deposited being a function of erosion between terraces and channel grade. Sediment yield from the terrace outlets may be obtained by multiplying the RUSLE soil-loss estimate for the interterrace area by the sediment delivery ratio values in table 6-16.

Conservationists debate the value of deposition in terraces for maintaining soil productivity. It is usually given some credit on cropland because tillage is assumed to partially redistribute the deposited sediment. Because tillage is infrequent, if ever, on rangelands, no credit should be given for a benefit of deposition. However, if this credit is taken for conservation planning purposes, the suggested values in table 6-15 may be used.

Undisturbed Strips

Undisturbed strips of land adjacent to channels are sometimes left to minimize the sediment yield into a channel and the accelerated channel erosion. If the undisturbed strips have heavy ground cover, the deposition of sediment can occur when water flows through the strips from the disturbed areas. The effectiveness of these practices on rangeland are judged to be highly variable, and a procedure for applying RUSLE to these strips is not provided.

P-FACTOR VALUES FOR STRIPCROPPING ON CROPLAND IN THE NORTHWESTERN WHEAT AND RANGE REGION

Runoff and erosion processes occur very differently on cropland in the Northwestern Wheat and Range Region than on cropland in other parts of the United States. Much of the erosion occurs during the winter from rain or snowmelt on thawing soils. These soils remain wet and highly erodible over several weeks from repeated freezing and thawing. A transient frost layer near the surface allows little infiltration, producing high amounts and rates of runoff for given amounts and intensities of rainfall.

The definition of cover-management conditions and the values for the runoff indices used in RUSLE for cropland in the Northwestern Wheat and Range Region for these winter conditions differ from values used for other locations. These definitions and the adjusted values for winter are shown in table 6-25 and 6-26, respectively.

Strips with residue and stubble that are rough tilled with implements similar to chisel plows and moldboard plows that turn the soil uphill can have high infiltration rates—often so large that runoff from upslope completely infiltrates within the strip if the strip exceeds about 50 ft. No runoff or sediment leaves the rough-tilled strip. The soil must be left in a rough-tilled condition with residue from the previous crop for these high infiltration rates to occur. Infiltration on these rough strips seems to be greater than that for permanent grass strips.

The cover and roughness of this rough-tilled condition is represented by condition VR in table 6-25. The rough-tilled strip is assumed to behave the same during the winter as at other times during the year. Values for the runoff index for the remaining strips where frost affects infiltration are selected from table 6-26. Values for runoff indices for periods not influenced by frost are selected from table 6-5.

The choice of slope length must be considered where all upslope runoff infiltrates on a strip. Two approaches may be used. The preferred approach is to use the entire slope length as if infiltration did not differ among the strips. The effect of all sediment reaching a strip being deposited within the strip is considered by RUSLE in the computation of P.

The alternative approach is to assume that the effect of the stripcropping system is like that of terraces. A slope length equal to the width of the strip is selected and a P-factor value is computed for terraces assuming a closed-outlet terrace.

Table 6-1.
Summary of data from plot studies on the effect of contouring on runoff and soil loss

Study number	Location	Reference	Plot dimensions			Type of study[1]
			Length (ft)	Width (ft)	Slope (%)	
1	Auburn, Alabama	Diseker and Yoder (1936)	50	15.1	0, 5, 10, 15, 20	Both
2	Urbana, Illinois	Van Doren et al. (1950)	180	53	2	Nat
3	Temple, Texas	Hill et al. (1944)	[2]—	[2]—	3.5	Nat
4	McCredie, Missouri	Jamison et al. (1968)	420	104	3.5	Nat
5	Morris, Minnesota	Young et al. (1964)	75	13.5	4, 7.5, 10.5	Sim
6	Batesville, Arkansas	Hood and Bartholomew (1956)	90	30	4	Nat
7	Central, Illinois	McIsaac et al. (1987)	35	10	5	Sim
8	Lincoln, Nebraska	Jasa et al. (1986)	35	10	5	Sim
9	Bethany, Missouri	Smith et al. (1945)	270	45	7	Nat
10	Guthrie, Oklahoma	Daniel et al. (1943)	[3]—	[3]—	7	Nat
11	Clarinda, Iowa	Browning et al. (1948)	158	84	9	Nat
12	Auburn, Alabama	Nichols and Sexton (1932)	50	15	10, 15	Sim
13	Concord, Nebraska	Jasa et al. (1986)	35	10	10	Sim
14	Arnot, New York	Lamb et al. (1944)	310	21	11	Nat
15	Sioux City, Iowa	Moldenhauer and Wischmeier (1960)	726	10	12	Nat
16	Zanesville, Ohio	Borst et al. (1945)	726	6	13	Nat
17	Sussex, New Jersey	Knoblauch and Haynes (1940)	70	13.5	16	Nat
18	Holly Springs, Mississippi	McGregor et al. (1969)	70	150	4.2	Nat

[1]Nat = study with natural rainfall, Sim = study with simulated rainfall, Both = study involving both natural and simulated rainfall.
[2]These are 0.01-, 0.03-, and 0.084-acre plots; other plot dimensions not available.
[3]A 0.25-acre plot; other dimensions not available.

Table 6-2.
Summary of data from watershed studies on effect of contouring on runoff and soil loss

Study number	Location	Reference	Watershed dimensions: Area (acre)	Watershed dimensions: Average slope (%)
1	Temple, Texas	Hill et al. (1944)	0.15, 1.5, 2.2	3, 5
2	Bethany, Missouri	Smith et al. (1945)	4.5, 7.4	7
3	Clarinda, Iowa	Browning et al. (1948)	2, 3.2	8
4	LaCrosse, Wisconsin	Hays et al. (1949)	2.2	15

Table 6-3.
Values for coefficients in equations [6-1] and [6-2] used to fit the base data for the P factor for contouring

Ridge height	Coefficient							
	a	*b*	*c*	*d*	s_m (%)	s_{eb} (%)	P_{mb}	P_z
Very low[1]	24,120	4	10.36	1.5	5	11	0.85	0.50
Low	27,201	4	13.31	1.5	6	15	0.65	0.3
Moderate	23,132	4	12.26	1.5	7	20	0.45	0.15
High	18,051	4	10.24	1.5	8	26	0.27	0.08
Very high	22,255	4	6.83	1.5	8	36	0.1	0.05

[1]See fig. 6-2 for ridge height definitions.

Table 6-4.
Description of cropland cover-management conditions used in RUSLE for estimating P-factor values

Categories of conditions	Description of condition
C1. Established meadow (very dense cover)	Grass is dense and runoff is very slow, about the slowest under any vegetative condition. Becomes condition 2 when mowed and baled.
C2. 1st yr meadow, hay (moderately dense cover)	Hay is a mixture of grass and legume just before cutting. Meadow is a good stand of grass that is nearing the end of 1st yr. Becomes condition 4 when mowed and baled.
C3. Heavy (dense) cover or very rough or both	Ground cover for this condition is about 75-95%. Roughness is like that left by a high-clearance moldboard plow on a heavy-textured soil. Roughness depressions appear 7 in or more deep. Vegetative hydraulic roughness like that from a good legume crop (such as lespedeza) that has not been mowed.
C4. Moderate cover or rough or both	Ground cover for this condition is about 40-65%. Roughness is like that left by a moldboard plow in a medium-textured soil. Depressions appear 4-6 in deep. Vegetative hydraulic roughness is similar to that produced by winter small grain at full maturity.
C5. Light cover or moderate roughness or both	Ground surface cover is 10-30%. Surface roughness is like that left by first pass of tandem disk over a medium-textured soil that has been moldboard plowed. This roughness could also be similar to that left after a chisel plow through a medium-textured soil at optimum moisture conditions for tillage. Roughness depressions appear 2-3 in deep. In terms of hydraulic roughness produced by vegetation, this condition is similar to that produced by spring small grain at about 3/4 maturity.
C6. No cover or minimal roughness or both	This condition closely resembles the condition typically found in row cropped fields after the field has been planted and exposed to a moderately intense rainfall. Ground cover is less than about 5%. Roughness is like that of a good seedbed for corn or soybeans. Surface is rougher than that of a finely pulverized seedbed for seeding vegetables.
C7. Clean-tilled, smooth, fallow	Surface is essentially bare, 5% or less of cover. Soil has not had a crop grown on it in the last 6 mo or more, so much of the residual effects of previous cropping has disappeared. Surface is smooth, similar to the surface that develops on a very finely pulverized seedbed exposed to several intense rainfalls. This condition is most likely found in fallow and vegetable fields.

Table 6-5.
Values of runoff index used to compute runoff to estimate P-factor values for cropland

Cropland cover-management condition	Hydrologic soil group A	B	C	D
C1	30	58	71	78
C2	46	66	78	83
C3	54	69	79	84
C4	55	72	81	85
C5	61	75	83	87
C6	64	78	85	88
C7	77	86	91	94

Table 6-6.
Values of Manning's n_t used in RUSLE cropland conditions

Cover-management condition[1]	Manning's n_t
C1	0.200
C2	0.110
C3	0.070
C4	0.040
C5	0.023
C6	0.014
C7	0.011

[1]Refer to table 6-4 for a description of cover-management conditions.

Table 6-7.
Critical slope length values computed by equation [6-12] and critical slope length values from AH 537

Slope (%)	From Equation [6-1][1] (ft)	From AH 537 (ft)
1.5	1000	400
4.0	384	300
7.0	200	200
10.5	125	120
14.5	80	86
18.5	60	64
23.0	50	50

[1]Moderate ridge height, hydrologic soil group C, C6 cover-management condition (defined in table 6-4), 100 ft·tonf·in (acre h)$^{-1}$ $(EI)_{10}$ storm

Source: Wischmeier and Smith (1978).

Table 6-8.
Computed critical slope length as a function of $(EI)_{10}$ storm erosivity and cover-management conditions[1]

	For cover-management condition[2]						
$(EI)_{10}$ Storm erosivity	C1 (ft)	C2 (ft)	C3 (ft)	C4 (ft)	C5 (ft)	C6 (ft)	C7 (ft)
10	1,000	1,000	1,000	1,000	1,000	1,000	933
25	1,000	1,000	1,000	1,000	1,000	824	348
50	1,000	1,000	1,000	1,000	885	387	184
100	1,000	1,000	1,000	1,000	446	201	104
200	1,000	1,000	1,000	579	243	111	61

[1] 7% slope, hydrologic soil group C
[2] Cover-management conditions are defined in table 6-4.

Table 6-9.
Critical slope length computed as a function of hydrologic soil group and $(EI)_{10}$ storm erosivity[1]

$(EI)_{10}$ storm	For hydrologic soil group A (ft)	B (ft)	C (ft)	D (ft)
10	1,000	1,000	1,000	1,000
25	1,000	1,000	1,000	1,000
50	1,000	1,000	1,000	1,000
100	1,000	1,000	1,000	969
200	1,000	700	579	537

[1]7% slope, cover-management condition C4

Table 6-10.
Critical slope length computed as a function of hydrologic soil group and $(EI)_{10}$ storm erosivity[1]

	For hydrologic soil group			
$(EI)_{10}$ storm	A (ft)	B (ft)	C (ft)	D (ft)
10	1,000	1,000	1,000	1,000
25	1,000	1,000	824	687
50	1,000	525	387	343
100	407	246	201	185
200	178	127	111	106

[1]7% slope, cover-management condition C6

Table 6-11.
Values for sediment delivery for stripcropping as determined from experimental data

Location	Rotation	Sediment delivery	
		Observed	Model
Bethany, Missouri (Smith et al. 1945)	C-W-M	0.44	0.53
Zanesville, Ohio (Borst et al. 1945)	C-W-M	0.36	0.53
Owen, Wisconsin (Hays and Attoe 1957)	C-W-M-M	0.42	0.48
LaCrosse, Wisconsin (Hays et al. 1949)	C-W-M-M	0.55	0.48
Batesville, Arkansas (Hood and Bartholomew 1956)	C-Ct-O/L	0.80	0.68
Temple, Texas (Watershed 1) (Hill et al. 1944)	C-Ct-O	0.52	0.51
Temple, Texas (Watershed 2) (Hill et al. 1944)	C-Ct-O	0.30	0.51

C = corn, Ct = cotton, W = wheat, O = oats, O/L = oats/lespedeza mixture, M = meadow.

Table 6-12.
Erosion and sediment transport factor values for P factor model for strips

	Cover-management condition[1]	Factor values: Erosion (ξ)	Factor values: Transport (ζ)	Length exponent (n)
C1	Very dense cover	0.005	0.02	1.0
C2	Dense cover or extreme roughness or both	0.02	0.05	1.0
C3	Moderately dense cover	0.03	0.10	1.0
C4	Moderate cover or roughness or both	0.12	0.14	1.0
C5	Light cover or moderate roughness or both	0.25	0.25	1.0
C6	Clean row crop tillage, no cover or minimal roughness or both	0.50	0.50	1.0
C7	Clean-tilled, smooth, fallow	1.00	1.50	1.5

[1]Cover-management conditions defined in table 6-4.

Table 6-13.
Values for P factor for sediment delivery and conservation planning computed with model for selected stripcropping, buffer, and filter strip systems[1]

System[2]	Sediment delivery (P_y)	Conservation planning (P_s)
RC-WSG-M1-M2[3]	0.53	0.78
RC-RC-WSG-M1[4]	0.54	0.80
RC-RC-WSG-M1-M2	0.47	0.77
RC-SSG-RC-SSG	0.75	0.91
RC-SSG[5]	0.83	0.93
RC-WSG[6]	0.71	0.86
RC-M1	0.58	0.78
RC-M1-RC-M1 (year 1)[7]	0.39	0.69
SSG-M2-SSG-M2 (year 2)		
M1-RC-M1-RC (year 3)		
M2-SSG-M2-SSG (year 4)		
RC-RCrt-RCrt-M1	0.65	0.84
Cnt-SBrt-SBnt	1.00	1.00
Crt-SBrt-Crt-WSGrt	0.89	0.96
0.5 filter[8]	0.06	0.51
0.1 filter[9]	0.24	0.91
Buffer strips[10]	0.15	0.67
Buffer strips[11]		0.71
Buffer strips[12]		0.75

[1]Values for filter strip systems are primarily for illustration as filter strips are usually not used to protect upslope areas from productivity loss.
[2]RC = row crop, WSG = winter small grain, SSG = spring small grain, M1 = 1st yr meadow, M2 = 2d yr meadow, C = corn, SB = soybeans, rt = reduced tillage, nt = no till.
[3]Wischmeier and Smith (1978) P = 0.50.
[4]Wischmeier and Smith (1978) P = 0.75.
[5]Wischmeier and Smith (1978) P = 1.00.
[6]Wischmeier and Smith (1978) P = 1.00, but they note that winter small grain can be effective in some cases.
[7]Location of strips by year in rotation; that is, Y1 is year of rotation.
[8]Permanent meadow filter strip that covers 0.5 of slope below row crop.
[9]Permanent meadow filter strip that covers 0.1 of slope below row crop.
[10]Permanent meadow buffer strips located at 0.4-0.5 and 0.9-1.0, separated by row crop strips.
[11]Permanent meadow buffer strips located at 0.35-0.40 and 0.65-0.70, separated by row crop strips.
[12]Permanent meadow buffer strip at 0.4-0.5, separating two row crop strips.

Table 6-14. Benefit assigned to deposition behind terraces

Terrace spacing (ft)	Benefit (B)
≤110	0.5
125	.6
160	.7
200	.8
260	.9
≥300	1.0

Table 6-15.
Terrace P-factor values for conservation planning[1]

Horizontal terrace interval (ft)	Terrace P-factor values			
	Closed outlets[2]	Open outlets, with percent grade of[3]		
		0.1-0.3	0.4-0.7	>0.8
Less than 110	0.5	0.6	0.7	1.0
110-140	.6	.7	.8	1
140-180	.7	.8	.9	1
180-225	.8	.8	.9	1
225-300	.9	.9	1	1
More than 300	1	1	1	1

[1]Multiply these values by other P-subfactor values for contouring, stripcropping, or other support practices on interterrace interval to obtain composite P-factor value.

[2]Values for closed-outlet terraces also apply to terraces with underground outlets and to level terraces with open outlets.

[3]Channel grade is measured on the 300 ft of terrace closest to outlet or 1/3 of total length, whichever distance is less.

Table 6-16.
Sediment delivery subfactor (P_y) for terraces[1]

Terrace grade	Sediment delivery subfactor
%	
Closed outlet	[2]0.05
0 (level)	.10
.1	.13
.2	.17
.4	.29
.6	.49
.8	.83
.9	1
[3]>1	1

[1]Includes terraces with underground outlet.
[2]From Foster and Highfill 1983. All other values from $P_y = 0.1e^{2.64g}$, where e = natural logarithm and g = terrace grade (%).
[3]Potential for net erosion in terrace channels, depending on flow hydraulics and soil erodibility in the channels. If net erosion occurs, $P_y > 1$.

Source: Foster and Highfill (1983).

Table 6-17.
Runoff and erosion effects from mechanical practices on rangelands

Rangeland treatment	Data source	Runoff and erosion changes after treatment for indicated years[1]		
		Runoff (%)	Erosion (%)	Years
Pitting	Hickey and Dortignac (1963)	-18 -10	-16 0	1 3
Ripping	Hickey and Dortignac (1963)	-96 -85	-85 -31	1 3
Moldboard plowing	Gifford and Skau (1967), Blackburn and Skau (1974)	+U 0	0 0	1 5
Contour furrowing (model B)	Branson et al. (1966), Wein and West (1973)	-U -U	-U -U	1 10
Root plowing	Simanton et al. (1977)	+50 -80	-54 -45	1 4
Land imprinting	Unpublished, Walnut Gulch Experimental Watershed (1978)	0	-90	1

[1]Relative to pretreatment level; (-) = decrease, (+) = increase, and U = unknown.

Source: Simanton (1988, personal communication).

Table 6-18.
Ratings[1] of possible effects of rangeland treatment and implement use

Possible effect	Treatment or implement[2] LP	PT	CH	BP	RP	RI	CF	BR	RD	TR	FL	BU
Incr. infiltration	3	3	1	2	3	1	3	2	1	3	1	0
Incr. percolation	2	2	1	1	3	3	3	1	0	3	0	0
Incr. pore space	2	2	1	2	2	3	3	1	0	1	0	0
Incr. water holding cap.	3	3	1	2	2	3	3	2	1	3	1	0
Incr. surface porosity	1	2	0	2	3	1	2	2	1	1	0	0
Incr. surface stability	3	2	1	2	2	1	1	3	1	1	1	0
Incr. roughness	3	3	1	2	2	1	2	3	1	1	0	0
Incr. seedling establish.	3	2	0	1	2	0	2	1	2	1	0	1
Decr. surface compaction	0	2	0	3	3	1	2	0	2	1	0	0
Decr. soil water evap.	2	1	1	1	1	0	1	2	0	0	3	0
Decr. surface runoff	2	2	1	1	2	1	3	1	1	2	1	0
Decr. erosion	2	2	1	1	3	2	2	1	1	2	1	0
Decr. canopy cover	3	2	2	2	2	1	1	3	0	0	3	3
Decr. competition	1	1	2	2	3	0	1	1	0	0	1	2
Treatment or implement used on:	**LP**	**PT**	**CH**	**BP**	**RP**	**RI**	**CF**	**BR**	**RD**	**TR**	**FL**	**BU**
Steep slopes	3	1	3	1	2	3	1	3	2	3	3	3
Rocky soils	3	1	3	1	2	1	2	3	2	3	3	3
Clay soils	2	2	3	1	3	3	2	2	3	3	3	3
Shallow soils	3	3	3	3	3	2	3	3	3	3	3	3
Woody shrubs	3	2	3	2	3	3	2	3	1	3	3	3
Herbaceous plants	3	3	0	3	0	0	3	0	1	3	0	3
Treatment longevity	3	1	3	2	3	3	2	1	1	3	0	2
Return/cost	3	1	3	1	2	1	2	1	3	3	1	2
Treatment or implement totals:	53	43	34	38	51	34	46	39	27	43	28	28

[1]LP = Land imprinter, broadcast seeding
PT = Pitting, broadcast seeding
CH = Chaining, cabling
BP = Brushland plow
RP = Rootplow, rangeland drill seeding
RI = Ripping
CF = Contour furrow, broadcast seeding
BR = Brush roller
RD = Rangeland drill (seeding)
TR = Terrace, broadcast seeding
FL = Flail
BU = Burning
[2] Ratings range from 0 = no effect, to 3 = greatest effect.

Source: Simanton (1988, personal communication).

Table 6-19.
Common mechanical practices applied to rangelands

Practice	Degree of disturbance	Surface configuration	Estimated duration of effectiveness (yr)	Runoff reduction
Rangeland drill	Minimal tillage except in furrow	Low ridges (<2 in) and slight roughness	1–2	None to slight
Contour furrow/pitting	Major tillage 8-12 in deep	High ridges, about 6 in	5–10	Slight to major
Chaining	Severe surface but shallow	Slight to moderate random roughness	3–5	Slight to moderate
Land imprinting	Moderate-sized shallow depressions	Short channels (40 in) and small to moderate	2–3	Slight to moderate
Disk plows, offset disks	Major tillage, about 4-8 in deep	Moderate ridges 2-4 in	3–4	Slight to moderate
Ripping, grubbing, root plowing	Minimal but often deep, 8+ in	Slight to very rough, especially when done at right angles	4–7	Moderate to major

Table 6-20.
Definition of cover-roughness conditions for rangeland

Condition identification	Description
R1	Very rough; plant plus rock cover greater than 50%
R2	Very rough; plant plus rock cover less than 50%
R3	Rough; plant plus rock cover greater than 50%
R4	Rough; plant plus rock cover less than 50%
R5	Moderately rough; plant plus rock cover less than 50%
R6	Moderately rough; established vegetation; plant plus rock cover less than 40%
R7	Slightly rough; plant plus rock cover less than 25%
R8	Slightly rough; established vegetation; plant plus rock cover less than 35%
R9	Smooth; established vegetation; plant plus rock cover less than 25%

Table 6-21.
Runoff indices for cover-roughness conditions at disturbance in areas dominated by thunderstorms

Cover-roughness condition[1]	Hydrologic soil group				Manning's n_t	Roughness index (in)
	A	B	C	D		
R1	47	50	53	56	0.10	2.0
R2	52	55	58	61	0.08	2.0
R3	57	60	63	66	0.07	1.4
R5	62	65	68	71	0.04	0.9
R7	67	70	73	76	0.023	0.5

[1]Defined in table 6-20

Table 6-22.
Runoff indices for cover-roughness conditions at disturbance in areas dominated by frontal activity

Cover-roughness condition[1]	Hydrologic soil group A	B	C	D	Manning's n_t	Roughness index (in)
R1	32	35	38	41	0.20	2.0
R2	37	40	43	46	0.10	2.0
R3	42	45	48	51	0.07	1.4
R5	47	50	53	56	0.04	0.9
R7	52	55	58	61	0.023	0.5

[1]Defined in table 6-20

Table 6-23.
Runoff indices after consolidation for cover-roughness conditions at disturbance in areas dominated by thunderstorms

Cover-roughness condition[1]	Hydrologic soil group				Manning's n_t	Roughness index (*in*)
	A	B	C	D		
R3	67	70	73	76	0.10	1.4
R4	72	75	78	81	0.08	1.4
R6	77	80	83	86	0.07	0.9
R8	82	85	88	90	0.04	0.5
R9	87	90	92	94	0.023	0.2

[1]Defined in table 6-20

Table 6-24.
Values for runoff index after consolidation for cover-roughness conditions in areas dominated by frontal activity

Cover-roughness condition[1]	Hydrologic soil group				Manning's n_t	Roughness index (in)
	A	B	C	D		
R3	47	50	53	56	0.10	1.4
R4	52	55	58	61	0.08	1.4
R6	57	60	63	66	0.07	0.9
R8	62	65	68	71	0.04	0.5
R9	67	70	73	76	0.023	0.2

[1]Defined in table 6-20

Table 6-25.
Description of cropland cover-management conditions used in RUSLE for estimating P-factor values in the Northwestern Wheat and Range Region.

Categories of conditions	Description of condition
C1. Established sod-forming grass (very dense cover)	The grass is dense and runoff is very slow; about the slowest under any vegetative condition. When moved and baled, this changes to condition 2.
C2. Standing stubble, 1st year grass, or meadow to be cut for hay (moderately dense cover)	The stubble is from a good stand with few rills or flow concentrations. The hay is a mixture of grass and legumes just before cutting. When mowed and baled, this becomes condition 4.
C3. Heavy (dense) cover or very rough or both	Ground cover is about 75 to 95%. Roughness depressions appear to be 5 or more inches deep (Random Roughness >2 ½ inches). Vegetative hydraulic roughness is like that of a good legume crop that has not been mowed.
C4. Moderate cover or roughness or both	Ground cover is about 40 to 65%. Roughness depressions appear to be about 3 to 5 inches deep (Random Roughness 1 ½ to 2 ½ inches), and vegetative hydraulic roughness is like that of a good stand of winter small grain at full maturity.
C5. Light cover or moderate roughness or both	Ground cover is from 10 to 30%. Roughness depressions appear to be 1 to 3 inches deep (Random Roughness ½ to 1 ½ inches), and the vegetative hydraulic roughness is like that of a typical stand of spring small grain at 3/4 maturity.
C6. Minimal cover or minimal roughness or both	Ground cover is 5 to 10% and the roughness is that of a moderately tilled seedbed. The surface is rougher than that of a finely pulverized seedbed for seeding vegetables. Roughness depressions appear to be ½ to 1 inch deep (Random Roughness 1/4 to ½ inch).
C7. Clean, tilled, smooth, fallow	The surface is essentially bare, with less than 5% cover. A crop has not been grown for some time so that the residual effects of previous cropping have disappeared. The surface is smooth, similar to that of a finely pulverized seedbed exposed to one or more intense rainfalls. Roughness depressions appear to be less than ½ inch deep (Random Roughness < 1/4 inch). This condition is most likely found in a fallowed field, but could exist in a vegetable field as well.
VR. Very rough primary tillage	Very rough primary tillage across slope that leaves the soil fractured below normal frost depth. The fractures are expected to last through the winter erosion season, preventing surface sealing and formation of impermeable frost, thus allowing a high rate of infiltration. Roughness depressions are greater than 7 inches deep (Random Roughness > 3 inches).

Table 6-26.
Values for runoff index used to compute runoff to estimate P-factor values for cropland in the Northwestern Wheat and Range Region for conditions where frost in soil significantly reduces infiltration

Cropland cover-management condition	Hydrologic soil group			
	A	B	C	D
C1	40	67	78	86
C2	65	76	84	88
C3	69	82	85	89
C4	75	92	92	92
C5	81	93	93	93
C6	85	94	94	94
C7	89	95	95	95
VR	30	58	71	78

[1]Defined in table 6-25

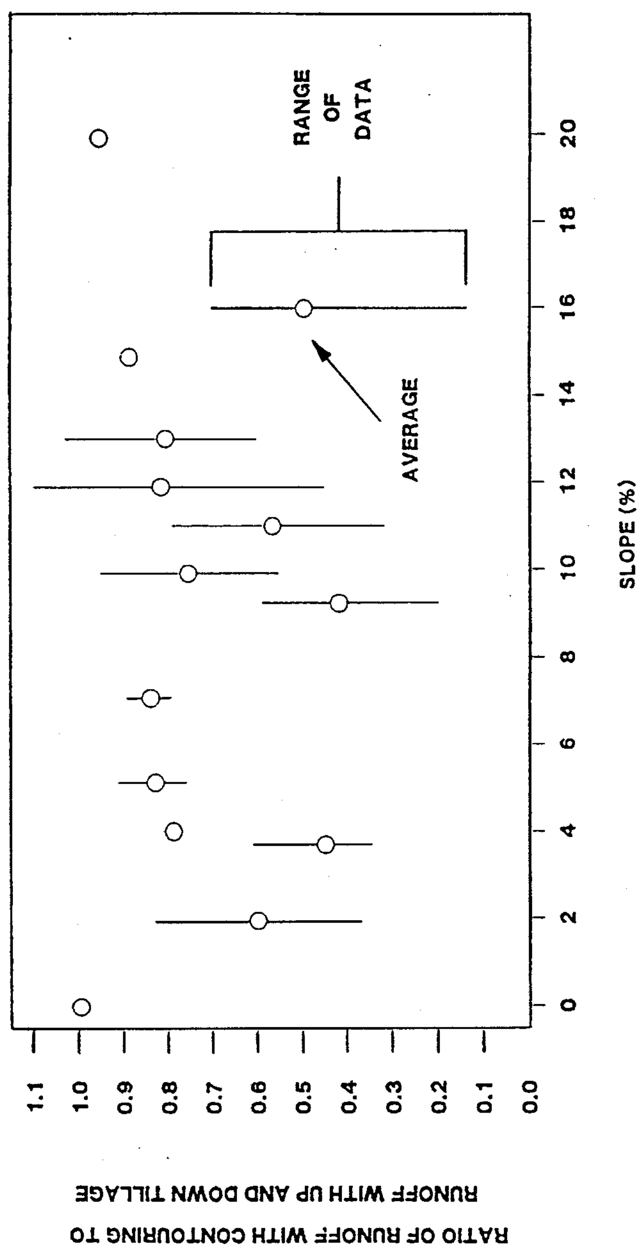

Figure 6-1. Effect of contouring on runoff.

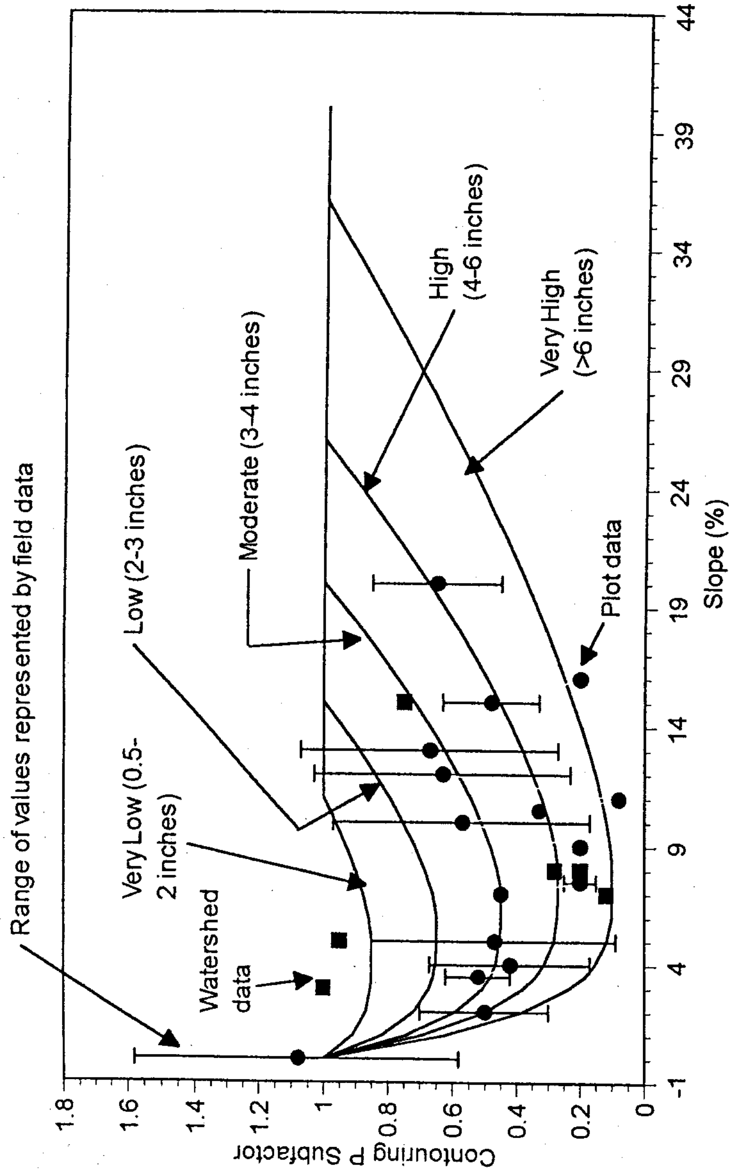

Figure 6-2. Effect of contouring on soil loss.