EROSION/SEDIMENT YIELD PARAMETERS

The erosion/sediment yield component of **GLEAMS** has been changed only slightly from that in **CREAMS**. The principal changes include the fixing of some user-input variables for which default values were often used, and letting some be dynamically driven internally. Two updatable channel parameters (critical shear stress and depth to non-erodible depth at the side of the channel) are now driven internally in the model rather than user specified. The overland flow profile input was simplified by Dr. George Foster and Mr. Jim Ascough while Dr. Foster was at the USDA National Soil Erosion Lab. These changes reduce the user dependence for parameter file development.

Soil composition of sand, silt, clay, and organic matter is now entered in the hydrology component with other soil physical and chemical characteristics. Since clay content is needed by soil horizon for the plant nutrient component, silt content was added also, and the sand fraction is determined as residual.

The user-friendly parameter editor developed by Frank Davis is parcucularly helpful in establishing card sequence in the erosion parameter file. Generalized help tables from the **CREAMS** user manual are used in the software where possible.

* *

Cards 1-3: **TITLE**

TITLE Three 80-character lines of alphanumeric information that identifies the particular computer run. For example, the soil type, the crop rotation, the tillage practices, may be useful in identifying the file. This title will be printed on the erosion output file.

Card 4: **BYEAR, EYEAR, EROOUT, FLGSEQ, METFLG**

BYEAR Last two digits of the year when simulation begins, e. g. 73

EYEAR Last two digits of the year when simulation ends, e. g. 75

EROOUT Code for output

0 for abbreviated annual summary output;
1 for detailed annual summary output;
2 for abbreviated monthly and annual summary output;
3 for detailed monthly and annual summary output;
4 for abbreviated storm-by-storm and summary output;
5 for detailed storm-by-storm and summary output;

FLGSEQ This flag indicates the execution sequence of erosion- sediment submodels as follows:

1 overland;
2 overland-impoundment;
3 overland-channel;
4 overland-channel-channel;
5 overland-channel-impoundment;
6 overland-channel-channel-impoundment.

FLGSEQ determines whether certain groups of cards are read. Cards 6, 7, and 8 are always read once and once only. Cards 9 to 11 are read only if **FLGSEQ** is 3 or more; they are repeated for a second channel if **FLGSEQ** is 4 or 6. Card 12 is read only if **FLGSEQ** is 2, 5, or 6, and they are read only once.

METFLG Code for metrication

O if parameter data are in English units;
1 if parameter data are in metric units.

Card 5: **SSCLY**

SSCLY Specific surface area for clay particles (m^2/g) (suggested value of 20.0 for kaolinite and 800.0 for montmorillonite), e. g. 20.0

Card 6: **NPTSO, DAOVR**

NPTSO Number of points for overland flow profile slope, e. g. 5 (Maximum number is 10. Generally little advantage in using more than 5.)

DAOVR Drainage area represented by the overland flow profile, acres (hectares), e. g. 3.2 (1.30)

Card 7: **XOV(I), SLOV(I)** for I = 1 to **NPTSO** on Card 6

XOV() Distance from upper end of overland flow profile to the point where slope is given, ft (m), e. g. 140.0 (42.67)

SLOV() Slope of the overland flow profile at the **XOV()**, ft/ft (m/m), e. g. 0.02

NOTE: Up to 5 points can be given on one card. If 6 to 10 points are used, two Card 8's are required. It is possible to have two slopes given at the same distance to represent a sharp break. An example for an abrupt slope change is shown below

Card 6: 3 2.0
Card 7: 80.0 0.02 80.0 0.04 120.0 0.04

Card 8: **NXK, XSOIL(I), KSOIL(I)** for I = 1 to **NXK**

NXK Number (1 to 4) of slope segments differentiated by changes in soil erodibility factor, e. g. 1

XSOIL() Relative horizontal distance from the top of the slope to the bottom of the segment, e. g. 1.0

KSOIL() Soil erodibility factor for the slope segment just above **XSOIL**, ton/ac per English EI (t.ha.h/ha.MJ.mm), e. g. 0.23

Example: Assume a horizontal slope length of 200 ft (60.96 m), **KSOIL** = 0.20 for the first 150 ft (45.72 m), and **KSOIL** = 0.30 for the last 50 ft (15.24 m). Card 8 would be as shown below:

Card 8: 2 0.75 0.20 1.0 0.30

The last **XSOIL** on Card 8 must be 1.0.

Cards 9 to 11 contain the initial channel parameters. If **FLGSEQ** is 1 or 2 on Card 4, no Cards 9 to 11 are needed. If **FLGSEQ** is 4 or 6, two sets of Cards 9 to 11 are required for the two channels indicated. Channel profile plots should be developed before completing Cards 9 to 11.

Card 9: **NSC, CTLO, RA, RN, DACHL, DACHU, Z**

Card 9 applies to the field channel, standing at the upper end of the 1st or 2nd channel, whichever is being considered, looking downstream.

NSC Number of channel segments differentiated by changes in slope, e. g. 3 (Maximum of 5.)

CTLO Channel outlet control condition that affects flow depth:

1 if critical depth controls depth at the end of the channel;
2 if uniform flow controls depth at the end of the channel;
3 same as 2, except Manning's "n" for the outlet channel is the same as that for the lower segment of the field channel, that is, the field channel continues beyond the edge of the field;
4 if a rating curve controls depth at the end of the channel.

Critical discharge, Q, is computed as follows:

$$Q = RA * Y^{RN}$$

where
Q = critical discharge, ft /sec (m /sec),
RA = coefficient (Card 10),
Y = flow depth, ft (m),
RN = exponent (Card 10).

RA Coefficient in the rating equation, e. g. 2.4 (Leave blank if **CTLO** < 4)

RN Exponent in the rating equation, e. g. 2.25 (Leave blank if **CTLO** < 4)

DACHL Total drainage area at the lower end of the channel, ac (ha), e. g. 3.2 (1.30)

DACHU Drainage are at the upper end of channel, ac (ha), e. g. 0.20 (0.08)

Z Side slope of field channel cross-section expressed as horizontal-to-vertical distance, ft/ft (m/m), e. g. 20.0

Enter the value for Z that most closely approximates the channel shape.

Card 10: **XSLP(1), SSLP(1)** for I = 1 to **NSC** (Card 9)

XLSP() Distance from upper end of the channel to the bottom of segment I, ft (m), e.g. 46.0 (14.02)

SSLP() Slope of segment I directly above, ft/ft (m/m), e.g. 0.025

Card 11: **CTLZ, CTLN, CTLSL**

NOTE: Card 11 refers to the outlet control channel, that is, standing at the end of the channel looking downstream (at the end of the 1st channel looking at the 2nd channel, or at the end of the field channel looking beyond the edge of the field.

CTLZ Side slope of a cross-section of the outlet control channel, expressed as a ratio of horizontal-to-vertical e. g. 20.0

CTLN Manning's "n" for the outlet control channel, e. g. 0.03

CTLSL Slope of the outlet control channel, ft/ft (m/m), e. g. 0.002

Card 12 is for impoundment parameters. If **FLGSEQ** = 1, 3, or 4 (Card 4), skip card 12--do not leave blank line.

Card 12: **DAPND, INTAKE, FRONT, DRAW, SIDE, CTL, DIAO, C**

DAPND Total drainage area above the impoundment, same as **DACRE** in hydrology, ac (ha), e.g. 3.2 (1.30)

INTAKE Saturated soil-water intake rate or saturated conductivity within the impoundment, in/hr (cm/hr), e.g. 0.20 (0.51)

FRONT Embankment front slope (vertical to horizontal), ft/ft (m/m), e. g. 0.20

DRAW Slope (vertical to horizontal) along channel draining into the impoundment, ft/ft (m/m), e. g. 0.024

SIDE Side slope (vertical to horizontal) of land at impoundment toward **DRAW**, ft.ft (m/m) e. g. 0.01

CTL Code for type of impoundment outlet:

1 if the pipe outlet control is typical of impoundment-type terraces;
2 if an orifice coefficient, C, is to be entered.

DIAO Diameter of orifice in outlet pipe, in (cm), e. g. 3.0 (7.5) Leave blank if **CTL** = 2.

C Orifice coefficient, e. g. 3000.0 Leave blank if CTL=1.

The equation for C is:

$$\mathbf{C} = 3600\ Q/Y^{0.5}$$

where
Q = peak discharge of pipe outlet, cu ft /sec (cu m/sec),
Y = depth of water above orifice, ft (m).

Updatable Parameters

The remaining input, Cards 13 to 22, are updatable parameters that are time dependent. The program reuses the updatable parameters after a period of rotation (**NYEARS**, Card 13) is completed. The execution sequence flag (**FLGSEQ**, Card 4) determines the sequence in which Cards 13 to 22 are read. There are no updatable parameters for the impoundment. The updatable overland flow parameters are on Cards 15 to 18, and those for the channel are on Cards 20 to 22. An overland-channel-channel sequence (**FLGSEQ** = 4, Card 4) will have Cards 13 and 14 followed by Cards 15 to 18 for the overland flow, followed by Cards 19 to 22 for the 1st channel, followed by another set of Cards 19 to 22 for the 2nd channel.

Card 13: **NYEARS**

NYEARS The number of years in this rotation, e. g. 1

Card 14: **CDATE(J)** for J = 1 to 10

CDATE() The Julian days on which sets of parameters take effect, e. g. 001, 105, etc.

The first **CDATE** must be 001 for the first year of a rotation or simulation in order to have parameters for model operation to begin at the start of a year. The beginning **CDATE** of subseqent years does not have to be 001.

NOTE: The computer reads all 10 data fields on Card 14 but uses only values greater than zero. If, for example, only five **CDATES** are to be used in a year (J = 5), enter them in the first five fields of the card and leave the last five fields blank. The parameter editor automatically includes **CDATE** = 001 for the first year, and places **CDATE** in the appropriate fields.

Use one Card 14 for each year of rotation. The maximum number of **CDATES** possible in a rotation is 40. They may be spread out, such as 4 per year for a 10-year rotation (10 Card 14's); 10 per yr for a 4-yr rotation (4 Card 14's); or any combination between these. Each year does not require the same number of **CDATES**.

Card 13 and an appropriate number of Card 14's must always be the first cards in a set of updatable parameters.

Cards 15 to 18 contain the updatable parameters for the overland flow. Card 15 is read on the initial pass through the program, but not in subsequent reads of updatable parameters. This means that the **XFACT**'s initially entered on Card 15 will remain the same for every year of the rotation.

Card 15: **NXF, XFACT(I)** for I = 1 to **NXF**

NXF Number (1 to 4) of overland flow profile segments differentiated by changes in the overland flow updatable (annual) parameters, e. g. 1.0

XFACT() Relative horizontal distance from the top of the overland flow profile to the bottom of segment I (ratio of distance to bottom of segment to total profile length), e. g. 1.0

NOTE: A set of Cards 16 to 18 are needed for each overland flow segment, **NXF,** for each year of the rotation. For example, if **NXF** = 3 and **NYEARS** = 3 (Card 13), 9 sets of Cards 16 to 18 are needed. The last **XFACT** on Card 15 must be 1.0 The proper sequence of these sets and the last value are established automatically in the parameter editor.

Card 16: **CFACT(I,J)** for J = 1 to the number of updates per year

CFACT() Soil loss ratio for overland flow profile segment I, e.g. 0.56

Card 17: **PFACT(I,J)** for J = 1 to the number of updates per year

PFACT() Contouring factor for overland flow profile segment I, e.g. 1.0

Card 18: **NFACT(I,J)** for J = 1 to the number of updates per year

NFACT() Manning's "n" for overland flow profile segment I, e.g. 0.020

CAUTION: **NFACT** must never be less than 0.010 This lower limit is fixed in the parameter editor which will not accept a smaller value.

Cards 19 to 22 contain the updatable channel parameters. Card 19 is read on the initial pass through the program, but not in subsequent years of annual channel parameters. This means that the **XCHAN**'s entered initially will remain the same or every year of the rotation. The proper sequence of these updatable channel parameters is established automatically by the parameter editor.

Card 19: **NXC, XCHAN(I)** for I = 1 To **NXC**

NXC Number (1 to 4) of channel profile segments differentiated by changes in the channel parameters, e.g. 1

XCHAN() Relative horizontal distance from top of channel to the bottom of segment I, e.g. 1.0

NOTE: The last value of **XCHAN** on card 19 must be 1.0 This is automatically established by the parameter editor.

Card 20: **NCHAN(I,J)** for J = 1 to the number of updates per year

NCHAN() Manning's "n" for channel segment I, e.g. 0.045

CAUTION: **NCHAN** must not be less than 0.030 The parameter editor will not accept a smaller value.

Card 21: **DCHAN(I,J)** for J = 1 to the number of updates per year

DCHAN() Depth to nonerodible layer in the middle of the channel for segment I, ft (m), e. g. 0.33 (0.101)

Card 22: **WCHAN(I,J)** for J = 1 to the number of updates per year

WCHAN() Top width of channel for segment I, ft (m), e. g. 10.0 (3.05)

NOTE: A set of Cards 20 to 22 is repeated for each channel segment (**XCHAN**, Card 19). Similarly, a group of sets are repeated for each year of the rotation.

If **FLGSEQ** = 4 or 6 (Card 4), a similar set of Cards 20 to 22 are repeated for each segment and year for the second channel.

Parameters on Cards 21 and 22 have a feature none of the other parameters have: if negative values are assigned to any parameter--with one important exception described below--the model uses the computed value for **DCHAN** and **WCHAN**. For example, a -99.0 value on Card 21 tells the model to use the simulated value for **DCHAN** rather than update to some specified value, say 0.33 (0.10). Where a positive value, such as 0.33 (0.10) is given, it indicates that tillage occurred and the depth to nonerodible layer or plowpan is reset to 0.33 ft (0.10 m). The -99.0 is used to make it more prominent; any negative value serves the same purpose. These same conditions hold for **WCHAN** (Card 22), also.

There is one exception where negative values on Cards 21 and 22 have computational value, and that is on the first pass through the annual values. The first fields of **DCHAN** and **WCHAN** values are used as the absolute values. In subsequent reuse of the annual values, if a minus sign is present, computed values of **DCHAN** and **WCHAN** are used rather than the absolute value of the parameters.

Generalized tables for the erosion component (some help tables from the parameter editor) are given for user information.

EROSION PARAMETER DESCRIPTION

The erosion component has been changed only slightly from that described by Foster et al. (1980a; 1980b) and the USDA-SCS (1984). The changes mainly have been in slightly streamlining input to reduce user-dependence and allow more internal estimation of parameters. Some user choices have been eliminated since **GLEAMS** is a water quality loading model as opposed to state-of-the-art erosion model. For example, the user no longer has the option of specifying up to 10 sediment particle classes. This option was seldom, if ever, used in water quality considerations. There are five particle classes consisting of the primary sand, silt, and clay, and small and large aggregates with sizes estimated internally after Foster et al. (1985).

Input data describing the overland flow profile was significantly changed from that in **CREAMS**. Ascough and Foster[5] developed algorithms to take distances and slopes (tangents) along the overland flow profile, and fit parabolas tangent to the slope at the specified distances. This procedure greatly simplifies the user input, and the algorithms create smooth profiles described by the data.

Much of the following material describing the erosion parameters was taken from the above referenced publications. It is necessary to repeat the information here for user convenience in having the material in one publication when developing parameter files. A parameter editor developed for the erosion component is an extremely important software package, external to the model, to aid in creating and editing parameter files. Proper card sequences for different flow sequences, rotation cycles, and parameterized segments for overland flow and channel profiles are established automatically. The user is led through the parameterization process without having to think about order and sequence.

Although the parameter editor is a self-contained software package with convenient help tables, additional and more detailed description may be especially helpful to users who are not erosion specialists. The following material is intended to aid in the erosion component parameterization.

Initial General Parameters

BYEAR and EYEAR

The beginning and ending years of simulation were input in the hydrology component, and are used in the model to determine the number of years of rainfall data to read. These parameters are repeated here in the erosion component to facilitate writing an internal file that has complete parameters for all years of simulation rather than just for the rotation cycle as entered.

Designating Erosion Component Output--EROOUT

A separate output file is maintained for each component to give the user options for his specific problems and interests. Designation of EROOUT allows the user to obtain quite a range of output information from very brief summaries to very detailed storm output. EROOUT = 0 provides very abbreviated annual summaries only without data by flow element. EROOUT = 1 provides detailed annual summary data with information for each element, i. e. overland, channel 1, channel 2, and pond. EROOUT = 2 gives abbreviated monthly and annual summaries. Each higher level of output also includes the lower level. For EROOUT = 3, detailed monthly summaries also includes the detailed annual output. Likewise,

[5]Ascough, J. C., and G. R. Foster. USDA-National Soil Erosion Laboratory, Purdue University, West Lafayette, Indiana. Personal communication. October 3, 1985.

EROOUT = 4 provides abbreviated storm-by-storm output as well as the abbreviated monthly and annual summaries. EROOUT = 5 gives the most detailed storm-by-storm output and the detailed summaries.

Flow Sequence--FLGSEQ

The field, or natural drainage area, is represented by a combination of such elements as overland flow, channel, and temporary impoundment. The proper sequence of these elements determine the order in which data are read and computations made in the model. The six sequences represented in the model are:

Sequence No.	Sequence of Elements
1	Overland
2	Overland-Pond
3	Overland-Channel
4	Overland-Channel-Channel
5	Overland-Channel-Pond
6	Overland-Channel-Channel-Pond

The best representation of the field is needed to generate the best estimate of sediment yield at the edge of the field. Major field features must be identified before selecting the appropriate flow sequence. Site visits, aerial photographs, and topographic maps are needed to characterize the flow elements represented in the field. USGS topographic maps are generally too coarse for this purpose unless the slopes are very steep. Soil survey maps can be used to supplement the information.

All field drainage areas are assumed to be composed of an overland flow element. Natural topography causes overland flow to converge into major flow concentrations on many fields. These concentrations are readily distinguished from rills that may exist. Several rills may combine flow into the larger concentrations. Distinction between rills and flow concentrations is not necessarily based upon relative size, but how the behave hydraulically. Removal of a single rill has negligible effect upon hydraulics, but removal of a single concentration has a major effect upon the transport of sediment.

Other flow concentrations that may exist within fields other than these natural ones are terrace channels, grass waterways, and diversion ditches. Ridges developed by tillage at the edge of a field may confine overland flow into the turn-row area and result in a major flow concentration. Ridge-furrow systems such as in potato production or in high water table areas result in major flow concentration. The furrows have more affect than rills, but the removal of one furrow may not have a major affect for the field. Each ridge and furrow behaves like a mini-terrace, and the flow concentration may require consideration.

Pond elements in the erosion/sediment yield component results in temporary ponding of water as opposed to any permanent storage of water such as a farm pond or floodwater retarding structure. Impoundment terraces pond water temporarily until it can be drained by the pipe outlet. Pipe culverts through roadways and through field berms also create temporary impoundment of water resulting in deposition of the coarse sediment fractions. Natural drainage of water through a break in a ridge around a field may result in temporary ponding. Debris and sediment basins may be considered as the pond element if there is not a permanent storage of water.

Examples of each of these flow sequences may be helpful for the user in representing specific sites.

1. If overland flow drains into a stream (of channel) which also contains water drained from areas other than the field of concern.

2. Overland flow converges into an impoundment such as an impoundment terrace, or into a culvert through a roadway.

3. The field may be overland flow converging into a single concentration down the center of the field, or overland flow draining along a turn-row caused by a ridge at the field edge, or overland flow intercepted by a diversion terrace.

4. Fields with a terrace system draining into a grassed waterway typify FLGSEQ 4. Overland flow enters the terrace channel which in turn drains into a grassed outlet channel. This sequence might also represent overland flow from the side of a row ridge draining into a furrow and the furrows drain into a waterway or a turn row at the edge of a field.

5. If overland flow from the inter-terrace area drains into a terrace channel before flowing into the pond of an impoundment-type terrace, the overland-channel-pond sequence is appropriate. Overland flow converging into a central concentration of flow that drains through a road culvert also represents sequence 5.

6. The overland-channel-channel system of sequence 4 (the terrace system) that drains through a road culvert typifies sequence 6.

Only one "representative" overland flow profile is accepted by the erosion component of **GLEAMS**. This will be discussed in detail later. Branching channels, such as two concentrations of flow merging into a single is not considered a channel-channel sequence and is not permitted in the model. Selection of the one that gives the best representation must be made by the user. The best overall representation is desired to give the best estimate of sediment yield at the edge of the field.

Metrication--FLGMET

FLGMET is used in the hydrology parameter file to designate that all input and output is in metric. However, it is repeated in the erosion component merely for the parameter editor to specify the correct values and ranges of parameter values.

Specific Surface Area for Clay--SSCLY

Specific surface area of soil particles is used to estimate an enrichment ratio (ER) for sediment delivered to the edge of the field. Phosphorus and ammonia are adsorbed onto the clay fraction of the soil, and pesticides are adsorbed onto the organic carbon in the soil. Transport capacity of overland and concentrated flows determine which particles can be carried, and deposition of the sands occur first, followed by large aggregates and then small aggregates. Deposition of the coarser heavier fraction occurs in impoundments, also. The sand and silt fractions do not contain plant nutrients and pesticides. Therefore, it is necessary to estimate a measure of the increase (enrichment) of soil fines in the sediment leaving the field. One measure is an enrichment ratio, i. e. the ratio of the specific surface area of the sediment to the specific surface area of the residual soil

$$ER = \frac{SS_{sed}}{SS_{soil}} \qquad \textbf{[5]}$$

Sediment is routed through the delivery system (sequence) allowing deposition, and the composition of sediment by primary particles (sand, silt, clay, and organic matter) is known. The specific surface area is also calculated for the residual soil.

Specific surface area of sand and silt are given by Baver (1965) as 0.05 and 4.0 m^2/g, respectively. Organic matter surface area active in pesticide adsorption is generally accepted as 2,000 m^2/g. Specific surface area of clay particles depends upon the mineralogy. Specific surface areas of 20 and 800 m^2/g are given (Baver, 1965) for kaolinite and montmorillonite clay particles, respectively.

The specific surface areas for sand, silt, and organic matter given above are fixed in **GLEAMS**. Since there is such a difference for the two clay minerals, the user must specify the specific surface for clay particles, SSCLY.

Description of Overland Flow Area

Profile and Soil Erodibility

It was stated in the discussion of FLGSEQ above that only one representative overland flow profile can be entered in **GLEAMS**. It is not the longest, shortest, steepest, or the flatest, but is the most representative of the entire overland flow area. The entire area of the field is generally considered contributing overland flow, DAOVR (see FLGSEQ above). A special application where DAOVR is less than the field area would be the ridge-furrow system described in the discussion of FLSEQ. In this case, DAOVR would be the area of an individual furrow, i. e. row width (spacing) times the row length. The total area of the field would be the drainage area at the outlet of the last channel or pond.

Before entering data for the overland flow profile, it is recommended that the user obtain a topographic map of the field (USGS topo map is not sufficiently detailed). Mark about 10 overland flow paths on the map, and plot the profiles on x-section paper. After plotting the profiles, select what appears to be the most representative of the group. This requires professional judgement and it is somewhat subjective, but objectivity is urged. The overland flow shape, length, and slope are sensitive input since they control the delivery of sediment to the channel, pond, or field outlet. Their sensitivity decreases with other flow elements in the sequence. Channels and a pond may reduce the sensitivity depending upon channel slope and impoundment characteristics.

The overland flow profile is described by giving distances and slopes along the flow path to the end of the profile. Beginning at the upper end or top (topographically highest point) of the profile as the zero distance, select up to 10 points where the slope is to be given. Although some would say there cannot be a slope of a point, the slope of a curved surface at a point is a tangent to the curve. The last point must be the total slope length. Ascough and Foster[6] considered up to 20 points along the profile and found that little accuracy was gained by more than about 5 points, and essentially none was gained with more than 10. Thus, the limit in **GLEAMS** was fixed at 10.

A uniform slope can be represented by one point at the end of the profile, or by a point at the beginning and one at the end. For example, a 100 ft (30.5 m) long flow path with a slope of 0.02 ft/ft (m/m) could be given as

100.0   0.02

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[6] Op cit.

or it may be entered as

0.0	0.02	100.0	0.02

Both representations will give the same results.

One point on the overland flow profile may given two slopes if theres is an abrupt change. An example of this representation is in the Strawberry Hills area in California. Strawberries are grown on high beds (approximately 1 ft or 0.33 m) on a very sandy soil. When the ridges are shaped with almost vertical side walls, trickle irrigation tubing is placed in the ridge, a plastic cover is placed on top of the ridge, and the edge of the plastic is forced into the side of the ridge near the top. A relatively sharp break in the slope occurs at the edge of the ridge. This slope could be represented as follows:

Distance (XOV)	Slope (SLOV)
(ft)	(ft/ft)
0.75	0.002
0.75	2.00
1.25	2.00
1.25	0.005
1.50	0.005

The first two points (0.75 ft) is the top edge of the ridge, and the next two points (1.25 ft) is the bottom edge of the ridge. The last point (1.50 ft) is the end of the overland flow profile which is the middle of the bottom of the furrow. This is an extreme example of a short, steep overland flow profile that can be represented simply in this version of **GLEAMS**.

The above example for the strawberry beds represents a complex slope shape: convex-concave. When describing other complex shapes that are smooth in transition rather than the abrupt changes in slope, careful attention should be given to the curved sections. Any rapidly changing slope, other than the abrupt breaks, require more closely spaced points.

Zero (flat) slopes are not permitted in **GLEAMS**. Zero slope will result in a fatal run-time error, divide by zero. If a slope segment is perfectly flat, such as the top of the strawberry bed described above, some small value of slope should be entered. For example, a slope = 0.0005 is practically negligible, but will prevent division by zero.

Soil erodibility is considered a non-updatable parameter in **GLEAMS**. Although alternate freezing and thawing, wetting and drying, or tillage versus no-till systems change the erodibility, the changes are considered small. Also, for relative comparisons of management systems, a constant value of erodibility is entirely satisfactory. If the model is used for absolute prediction for individual storms, a constant erodibility is much less desirable.

Erodibility of soil varies within a series just as water retention characteristics. Likewise, prior erosion and sediment transport in an overland flow region may change erodibility from one area on the flow path to another, i. e. from a flat upper slope with a normal soil plow layer to a steep mid slope where significant erosion and transport of a sand-size fraction to the flattened slope at the bottom of a concave section where deposition has occurred. Signif-icant differences in the soil erodibility (KSOIL) along the overland flow path can be distinguished in the model. Up to four segments can be represented with different erodibility factors. Even though a field is mapped as the same soil series, and the soil database gives only one value of erodibility, the user can objectively change KSOIL on the representative overland flow profile.

The example of the strawberry beds given above is one in which two KSOIL parameters should be entered. The plastic cover extending across the ridge (from 0.0 to 0.75 ft) would have an erodibility factor of 0.00, while that from 0.75 to 1.5 ft might have KSOIL = 0.30. A zero value for KSOIL will not result in a run-time error since KSOIL is a multiplicative parameter.

Soil erodibility is determined the same as for the Universal Soil Loss Equation (Wischmeier and Smith, 1978). It can be estimated using the nomograph in the handbook. Also, it has been included in the information on the Soils-5 database. If neither the database nor the handbook are available, an estimate can be made using average particle size-distribution data from the textural classification. This may be a useful feature in countries where good soil databases are not available.

Table E-1 was developed for the average sand, silt, and clay contents of each of the 21 textural classifications in Table H-5. Wischmeier and Smith (1978) gave an expression for soil erodibility

$$KSOIL = \frac{2.1\ TF^{1.14}\ 10^{-4}\ (12 - OM) + 3.25\ (SF - 2) + 2.5\ (PF - 3)}{100} \qquad \textbf{[6]}$$

where OM is percent organic matter, SF is a soil structure code, and PF is a soil profile permeability class. TF is a texture factor given as

$$TF = (SI + VFS)\ (100 - CL) \qquad \textbf{[7]}$$

where SI is percent silt, VFS is percent very fine sand, and CL is percent clay. The values of TF given in Table E-1 assumes that one-half of the sand fraction is VFS. The soil structure code is

1 very fine granular,
2 fine granular,
3 medium or coarse granular,
4 blocky, platy, or massive.

The profile permeability class is

1 rapid,
2 moderate to rapid,
3 moderate,
4 slow to moderate,
5 slow,
6 very slow.

The relationship given in equation [6] is valid where the fraction of silt does not exceed 70 percent. Only the silt texture listed in Table E-1 exceeds the 70% limit. The soil erodibility, KSOIL, is estimated by the relation

$$KSOIL = TF\ (12 - OM) + SF + PF \qquad \textbf{[8]}$$

where SF and PF are approximate generalized structure and permeability factors, respectively.

Erodibility of soil in concentrated flow (channels) is calculated in the model as 0.39 times KSOIL for overland flow (Foster et al., 1980a). This allows adjustment internally for different soils.

Soil erodibility is a sensitive parameter since it is a multiplicative factor in estimating rill and interrill erosion. However, if the flow sequence contains a channel and/or pond, the sensitivity of sediment yield at the edge of the field to erodibility may be very slight. This would result for a transport- limited systems.

Initial Channel Parameters

Description of channel characteristics and controls are required to supply enough information for the model to consider flow conditions affecting sediment transport and/or deposition. Channel slope, shape, and width affect flow velocity, and controls may cause backwater that results in sediment deposition. The user must be careful when selecting parameter values to distinguish between "outlet control channel" and "field channel". Outlet control channel places the user at the edge of the field (or outlet of channel 1) looking downstream at those conditions or characteristics that may cause backwater. The field channel places the user at the edge of the field (or at the outlet of channel 1) looking back up the channel into the field. These are keys in knowing which channel or what condition is being parameterized. If there is a channel-channel in the flow sequence, channel 2 is the outlet control channel for channel 1, and channel 1 is the field channel. For channel 2, the outlet control channel is what lies beyond the edge of the field, and the field channel is channel 2.

Just as for the overland flow profile, it is necessary to indicate the number of slope segments in the field channel. A maximum of 5 slope segments can be entered. If the channel has a continuously steepening or flattening from the upper end of the channel, 5 segments may be needed. Also, if soil or geologic layers cause a stair-step profile, the maximum number may be used. A uniform slope could be represented with only one slope segment for the entire channel length.

Field Channel

A field channel is defined as a concentration of flow, such as where several rills converge or well-defined grass waterways, terrace channels, of diversions. The length of a natural concentration of flow extends from its origin, or rill convergence, to the outlet at the field edge or where it drains into another channel. The length of a constructed waterway, terrace channel, or diversion is well defined. These determinations should be made from a site visit and topographic map before assigning parameter values.

Number of Channel Slope Segments--Channel slope is specified for a maximum of five segments beginning from the upper end, or channel origin. The distance from the origin to the bottom of each successive segment and the slope of the respective segment is entered (see distance and slope below). The number of segments, NSC, denotes how many values distance and slope are to be entered.

Outlet Control--Some type of control at the field channel outlet may affect the flow condition that either increases velocity (causes a draw-down of water surface) or causes backwater in the channel. Either condition affects the transport and/or deposition of sediment near the end of the field channel. For example, an overfall from a terrace channel into a roadside ditch would cause critical flow at the point of overfall. The flow velocity and sediment transport capacity would increase. There would not be a well defined stage discharge relation because channel geometry would be irregular. Conversely, a weir, flume, or some type of water-level control structure in the channel would have a regular geometrical shape with a constant rating equation. Table E-2 gives the four types of control for different defined conditions that may be specified by code as CTLO.

Channel Outlet Control: Rating Coefficient and Exponent--Channel control structures that are stable and constant in time can be represented by discharge-to-depth relationships. If the shape of a berm or the shape of an overfall (nickpunct) remains stable, ratings can be developed and used flow controls. Weir and flume or other ratings can be expressed as

$$Q = RA\ (Y)^{RN} \qquad \textbf{[9]}$$

where Q is discharge, m^3/sec (ft^3/sec), and Y is depth of flow over the control, m (ft). RA and RN are discharge coefficient and exponent, respectively, the values of which depend upon the rating and units of Y and Q.

Drainage Area of the Channel at the Lower End--If the flow concentration (channel) is the main stem of a watershed or field, the drainage area at the outlet, DACHL is the total area of the field. It is the same as DACRE in hydrology. If the channel is a terrace channel, it is the area of the terrace interval selected as the representative channel. This area is smaller than the drainage area of the overland flow, DAOV, which is the total field area. If the channel is a furrow between two crop rows, the area is the product of row length and spacing, and is less than the field area.

Drainage Area of the Channel at the Upper End--The main stem of a watershed generally does not extend to the field boundary or divide. Natural drainage converges from a pie-slice shaped area into the upper end of the channel. The area of this pie slice is the drainage area of the channel at the upper end, DACHU. The runoff from this area may contain some sediment, and the discharge and sediment load is greater than zero at the upper end. The area is used to extend the channel back, at the same slope as the upper segment and same drainage density as for the main channel, to a point of zero flow. This fictitious length is added to the channel length entered to give an "effective" channel length that becomes an output.

A terrace channel or a grassed waterway that serves only as a terrace outlet channel does not have a drainage area at the upper end, i. e. DACHU = 0.0. Discharge and sediment load begins at zero at the upper end of the channel. It is necessary to begin channel computations with zero water and sediment inflow at the beginning of the top computational segment. Computations progress down the channel as spatially varied, uniformly increasing discharge.

The **CREAMS** model operated as three separate computer programs with an intermediate pass-type file. It was simple to select a specific storm from the hydrology passfile to operate as input to the erosion component. The USDA-SCS irrigation engineer at the West National Technical Center, Portland, Oregon, wanted to use **CREAMS** to compute erosion from furrow irrigation. Since the model could consider a row furrow as a channel, this was a feasible application. However, furrow irrigation begins with flow at the upper end greater than flow at the lower end, i. e. spatially varied uniformly decreasing flow--the opposite that in the model. The erosion component was modified by Dr. G. R. Foster to accept a DACHU greater than DACHL, representing more inflow at the upper end than at the outlet. A hydrology passfile was created artificially with the runoff volume equal to the equivalent depth of irrigation water applied, a zero rainfall energy, and a characteristic discharge rate (at the lower end of the furrow) equal to an estimated tailwater flow rate. This permitted erosion/sediment yield calculations for an individual furrow.

GLEAMS also accepts DACHU greater than DACHL, but since erosion is simulated simultaneously, natural rainfall events and furrow irrigation events cannot be simulated in the same run. It would require the model to stop simulation and re-configure the DACHU and DACHL between the events. This is not feasible. If it is desired to consider erosion by furrow irrigation, **CREAMS** is recommended for use. Likewise, if pesticides are of concern with the irrigation event, then the **CREAMS** chemistry component is recommended.

Field Channel Sideslope--The sideslope, Z, of the field channels vary with type of channel. Sides of terrace channels are generally not symmetrical, but a sideslope of 5:1 (horizontal-to-vertical) is recommended. A value of 10:1 would be appropriate for a natural concentration of flow unless better information is available. A value of 20:1 is recommended for concentrated flow caused by a ridge or berm at the edge of a field. Constructed trapezoidal shaped waterways generally degrade to a parabolic shape before grass is established, and a value of 25:1 or 30:1 is recommended depending upon width and depth of the designed channel.

Field Channel Distance and Slope--The channel segment distance and slope description is entered into the model for a maximum of five segments. The distance from the upper end (origin) of the channel to the bottom of the segment, and the slope at the bottom of the segment in entered for all segments, NSC. All distances, measured in ft or m, are measured from the top of the channel, and the last distance entered is the total channel length.

A uniform channel slope can be represented with one segment (NSC = 1), with the distance, XSLP, equal to the total channel length, and the slope, SSLP, equal to the average slope, expressed in ft/ft or m/m.

If a channel continually steepens or flattens from the beginning to the outlet, the entire five segments may be needed to describe the slope adequately.

Outlet Control Channel

Considering the outlet control channel, that is standing at the end of channel 1 looking at channel 2, or standing at the end of the field channel looking beyond the edge of the field, describe the channel characteristics. These characteristics affect the flow velocity and sediment transport capacity.

<u>CTLZ</u>--CTLZ is the approximate side slope of the control channel. If the field channel continues beyond the edge of the field with the same shape, slope, and etc, CTLZ may be the same as that for the field channel. If a channel is regularly tilled, side slopes ranging from 10:1 to 15:1 (horizontal:vertical) may be appropriate. For naturally eroded channels or concentrations of flow caused by a field boundary ridge, 20:1 may more nearly approximate the side slopes. Foster et al. (1980a) expressed side slope of a rectangular channel related to a function of bottom width divided
by discharge weighted over a range of rates. This assumes the user knows in advance the anticipated flow rates. An a priori estimate of 20:1 to 25:1 would be an acceptable value. Side slopes for terraces were recommended as 5:1.

Outlet channel sideslope is not generally a sensitive parameter, but some channel characteristics may result is significant sensitivity. The user is urged to give careful attention the this value.

<u>CTLN</u>--Manning's "n" for the outlet control channel, CTLN, is a relatively sensitive parameter since it affects flow velocity. The velocity is used to calculate transport capacity and shear stress, and thus erosion or deposition.

For outlet control channels within a field, "n" values may be obtained from Table E-3. Cover included in the table represents a moderate range for grassed channels and channels that are tilled and cropped. If the outlet control channel is an extension of the field channel, the values in Table E-3 are appropriate. However, if the outlet control channel has brush and trees along the banks, or boulders and cobbles, other data sources should be consulted. Such sources include Ree and Palmer (1961), Chow (1959), and Barnes (1967). If these or other sources are not readily available, reasonable estimates can be made by extension from values in Table E-3. Data in the table for very dense grass and a good cover of small grain in 7-in (18-cm) rows show Manning's "n" values of 0.30, the largest values in the table. It would be reasonable to expect that channels with brush and weeds might have values in the range of 0.40 to 0.60 depending upon density and size. These are merely guidelines in absence of data, but good references are recommended since the parameter may be relatively sensitive.

<u>CTLSL</u>--Slope of the outlet control channel, CTLSL, is another relatively sensitive parameter since it affects sediment transport at or near the edge of the field. In an overland-channel-channel sequence where the second channel occurs within the field, the second channel is the outlet control channel. CTLSL is the slope of the first (upper) segment of that channel. The outlet control channel for the second channel is beyond the edge of the field (standing at the field edge looking downstream). In an overland-channel sequence, the outlet control channel is beyond the edge of the field, also. In both of these cases, CTLSL is the slope immediately beyond the edge of the field, within 15-20 m (45-60 ft). Changes farther downstream probably has little affect.

If the outlet control channel beyond the edge of the field is an extension of the field channel, the same parameters for side slope, bottom slope, and Manning's "n" are the same as for the last segment of the field channel.

These considerations mainly apply to site-specific situations. Since channel conditions beyond the edge of the field may have significant affect on sediment yield, it is very important to visit the site before developing parameters and applying the model. This cannot be overstressed. Less concern may be justified for more generalized applications where relativity is more important.

Pond (Impoundment) Element

The pond element in **GLEAMS** represents temporary impoundments of sediment-laden water that allows deposition of the coarse, heavy particles (aggregates and sand). Infiltration occurs at the bottom of the impoundment, and it is assumed to drain within the day on which inflow occurs. It was developed to represent impoundment-type terraces with pipe outlets, temporary ponding of runoff water behind ridges and culverts, and debris or sediment basins. All of these are designed expressly to remove sediment load for runoff water before it enters streams or other receiving bodies.

Design of impoundments must consider ratio of runoff area to pond volume, and the time required for drainage. These two factors determine the sediment removed from the release water. Impoundment characteristics do not change during a simulation, and sediment deposition is accumulated in the pond for all inflow events. If the storage volume is filled to maximum capacity during the simulation, the pond becomes ineffective and un-attenuated sediment-laden flow continues to pass through the impoundment. Any changes in pond characteristics such as pipe size, basin size, or etc, the simulation must be stopped and the new system described.

Control

Two types of control are included in the model: (1) a pipe riser typical of parallel terraces, and (2) an equivalent orifice coefficient. Designation of control type tells the model what data are needed, i. e. pipe diameter (DIAO) or orifice coefficient (C).

Impoundment Characteristics

<u>Drainage Area</u>--The pond element is always the last (lowest) element in the flow sequence, i. e. overland-pond, overland-channel-pond, etc. Thus, the drainage area into the pond, DAPND, is generally the total drainage area of the field (DACRE in hydrology). If a representative impoundment terrace is being represented, the field area is generally taken as the drainage area contributing to the terrace rather than the entire field. Little is to be gained by the model simply adding the discharge, sediment yield, and chemical yield from several pipe outlets where deposition/attenuation does not occur.

<u>Intake</u>--The infiltration rate, or saturated hydraulic conductivity, of the pond bottom may be significant in transmitting water into the profile of light-textured soils. High intake rates add to the effectiveness of the pond for sediment deposition, but it may adversely affect ground water quality if the inflow contains soluble, mobile chemicals. The INTAKE parameter may be specified the same as SATK for the top horizon in hydrology, or as the final infiltration rate if information is available.

<u>Pond Storage Relations</u>--The impoundment surface area and storage volume are needed for the model to estimate the deposition of sediment in the pond and that fraction that flows out. The surface area, that is the area of soil over which infiltration occurs, is needed. The surface area, SA (ft^2), is expressed as

$$SA = F_s \ (y)^B \qquad \textbf{[10]}$$

where F_s is a coefficient, B is an exponent, and y is water depth in the pond in ft. (English units only are given here since the relationship is expressed in these units internally in the model.) The surface area:depth relationships are design criteria, and design information is needed for accurate assessment. Values of F_s for impoundment terraces in Iowa (Laflen et al., 1972) and Alabama (Rochester and Busch, 1974) were found to range from 4,500 to 9,500. Corresponding values of the exponent B ranged from 1.10 to 1.77.

If design data are not available, a value of B = 2 is assumed, and F^s is estimated from physical characteristics of the pond. The relation in the model is

$$F_s = \frac{\left[\frac{(f + d)}{f}\right]^2}{(d)\ (s)} \qquad \textbf{[11]}$$

where f is front slope (FRONT) of the embankment, d is the draw slope (DRAW) along the line of flow toward the embankment, and s is the side slope (SIDE) along the embankment. FRONT, DRAW, and SIDE are expressed in ft/ft (m/m).

<u>Diameter of the Orifice in the Pipe Outlet</u>--DIAO is the diameter of the orifice (hole) in the pipe riser that allows unrestricted drainage from the pond. DIAO should not be mistaken as the diameter of the pipe. The pipe may be 1 m (3 ft) in diameter, but if the orifice is only 2 in (5 cm) in diameter, the orifice controls the outflow. Foster et al. (1980a) suggests a value of DIAO = 3 in (7.5 cm) for impoundment terraces if a better value cannot be found. Unfortunately, some model users take this suggestion for a pond with a drainage area (DAPND) of 100 acres (40 ha) giving an infinite stage, and this results in a model run-time error (math overflow). Caution and sound professional judgement are urged. DIAO is a sensitive parameter since it is used to estimate the sediment deposition and sediment discharge through the pone. Sediment enrichment ratio is dependent upon DIAO, and sediment yield and ER affect nutrient and pesticide adsorption.

<u>Orifice Coefficient</u>--An orifice coefficient, C, is required in the model, but if it is not known, C can be left blank and the model will estimate a value from the relation

$$C = 3600\ \frac{Q}{\sqrt{Y}} \qquad \textbf{[12]}$$

where Q is discharge (ft^3/sec), Y is depth (ft) of water above the control, and 3600 is constant to convert seconds to hours. (Only English units are given since the equation is used in English units internally in the model). The discharge coefficient is a sensitive parameter for sediment yield and enrichment ratio, and for nutrient and pesticide transport.

Updatable Parameters

Some parameters change with tillage, crop growth, and harvest. Tillage that makes or eliminates ridge/furrow systems changes direction of flow. Tillage also changes the surface roughness, it may incorporate crop residue, and it destroys crop root systems that would otherwise help resist erosion by concentrated flow. Change in crop canopy with a growing crop affects the rainfall energy that reaches the soil surface. Those parameters affected must be updated periodically for the model to adequately represent erosion and sediment transport. Updatable parameters occur in the overland flow and concentrated flow elements, but not in the pond element. The shape of the pond that affects depth-area-volume relations does not change during a simulation.

Just as parameters change in time, they may also vary in space. For example, even though two crops cannot be represented hydrologically, if runoff can be assumed to be uniform from two crops, spatial changes in erosion protection and tillage must be
represented in the overland flow element. Also, part of a field channel may be tilled, and another segment may have side slopes too steep for tillage. These conditions can be represented in the erosion component of the model.

Years in Rotation Cycle

Updating parameters can be made throughout the crop rotation cycle, and then the parameters are re-used in subsequent cycles in the simulation period. The rotation cycle is specified in the hydrology component, but it is repeated here as NYEARS to aid in establishing updates. NYEARS should be the same as IROT in the hydrology component.

Dates of Parameter Changes

When the rotation feature was implemented in the erosion component of **CREAMS** (USDA-SCS, 1984), the number of updates were limited to a maximum of 40 during a rotation period. This feature was retained for the **GLEAMS** model. Generally 40 updates (CDATE) is sufficient. The ten 8-character fields on an 80-column card (image) was used as a convenient limit of CDATE per year. Thus, a maximum of 10 updates can be specified in a year. If the rotation cycle is 4 years, there can be a maximum of 10 updates each year for a total of 40 for the rotation cycle. If the rotation cycle is 2 years, only 20 CDATEs can be entered, 10 per line on two lines. If a 5-year rotation is simulated, there are 5 lines (cards) for CDATE. There can only be a total of 40 updates, but the number per year does not have to be the same. For example, there may be 10 updates the first year, 6 the second year, 7 the third year, 5 the fourth year, and 9 the fifth year for a total of 34. It is not necessary to have updates every year. For example, a 5-year rotation may be corn-soybeans-meadow-meadow-meadow and the meadow is not mowed or grazed. The 1st-year of meadow obviously would be planted and have some growth increase, and the 3rd-year meadow would be harvested and/or plowed. The 2nd-year meadow may have a relatively constant forage/cover and updates may not be needed. In this case, a blank card is needed for the fourth year of the rotation. Calendar year or rotation year is not included as part of the CDATE, only the Julian date. A continuous crop, i. e. a 1-year rotation, would have 1 card for CDATE with a maximum of 10 updates.

The first year of a rotation cycle must have a CDATE on Julian day 001. This is necessary to have values for the updatable parameters when simulation begins on January 1 of the first year. It is not necessary to have CDATE = 001 on subsequent rotation years because the model will wrap around the year's end, and keep the same parameter values until they are updated during the year. An update on day 001 on each year (even specifying the same parameter values as on the previous update) does not cause a problem other than reduce by one the number of additional updates each year. If observed data were available for the 5-yr rotation cited above, and the record began in the 4th year, the rotation would appear as meadow-meadow-corn-soybeans-meadow. Then if the middle meadow year really did not justify updates, a CDATE = 001 would be required in order to have initial parameter values when simulation begins.

The user should consider the entire rotation cycle as well as the flow elements before beginning parameterization. Only one set of CDATEs are specified to include updates of both overland flow and concentrated flow elements. Parameters are not necessarily changed in the channel element when an update is made in the overland flow element, and vice versa.

Overland Flow

Segments for Different Updatable Parameters--Up to four segments can be differentiated with changes in parameter values on the overland flow profile. A grass buffer strip at the bottom of the overland flow profile would have different parameters than those for the cropped portion of the field. This would justify two differentiated segments (NXF = 2). If parameters are assumed to be uniform along the profile, only one segment (NXF = 1) is required. For every NXF, a set of the three updatable parameter cards are needed in the overland flow element. For example, if NXF = 3, and the rotation cycle is two years, a set of 3 updatable parameter cards are needed for each of the 3 segments differentiated for each of the two rotation years, a total of 18 cards for the overland flow.

The location of the different overland flow segments must be given. The segments do not have to be equal in length. The total overland flow length is given in the initial parameters. Here, the segments are given in relative distances (XFACT) from the beginning (top) of the profile to the bottom of the segment. The relative distances are the actual length divided by the total length. For example, assume a 100 ft (30.5 m) overland flow profile length has two segments (NXF= 2) with different parameters. The top segment is 30 ft (9.1 m) long. Then $XFACT_1 = 0.3$, and $XFACT_2 = 1.0$ which is the bottom of the overland flow profile. The last XFACT must always be 1.0, representing the entire overland flow length.

The erosion parameter editor automatically sets card sequence and number of cards when NYEARS and NXF are selected. The editor shows which parameter on what segment in which year to aid in parameterization without the user having to remember what goes where and when.

Soil Loss Ratio--The soil loss ratio (CFACT) represents the crop factor (C-factor) in the Universal Soil Loss Equation (Wischmeier and Smith, 1978) for a specific part of a year. CFACT is not averaged over the rotation period in **GLEAMS** to give an annual estimate of erosion, but individual C-factors for some shorter period of time for storm erosion. CFACT is a fraction (not a percentage) ranging from 0 to 1. In the USLE, C-factors are step functions, but this rarely is the real situation except at harvest or for a major tillage. In **CREAMS** (Foster et al., 1980a) and **GLEAMS** CFACT is a step function. With the limited updates (CDATE) each year, it is impossible to approach a continuous function for CFACT.

A sub-factor method of calculating CFACT daily is employed internally in the WEPP model (Lane and Nearing, 1989). However, one of the sub-factors is residue, and if the **GLEAMS** user does not opt to run the plant nutrient component, data are not available internally for residue on the surface and other factors. A good biomass generation with nutrient uptake and stress is required, and users who do not want to run that component, such as those with agricultural chemical companies, would be at a disadvantage. For this reason, external user-defined CFACT continues in **GLEAMS**.

Soil loss ratios for a number of management conditions and selected crops was published by Wischmeier and Smith (1978). The tables were reproduced by Foster et al. (1980a) for **CREAMS** and are included in the appendix of this publication for user convenience. Values in the tables are good references, and can be used as guides for estimating CFACT for crops and conditions other than those included in the tables.

CFACT is a sensitive parameter in the model depending upon the overland flow profile and the flow sequence. If FLGSEQ = 1, overland flow only, and the representative profile has a uniform slope or is convex (steepening along the slope), CFACT is very sensitive. If the slope shape is concave (flattening along the slope), or is complex (convex-concave), CFACT is not nearly as sensitive. If the flow sequence includes a channel, or channels, with slopes flatter than the last segment of the overland flow profile, CFACT is not a very sensitive parameter. If the flow sequence contains a pond as the last element, CFACT becomes relatively insensitive for sediment yield at the edge of the field. For these conditions, the system is generally transport-limited, i. e. the flow cannot transport the sediment load and deposition of the coarser fraction(s) of sediment occurs until the fine particles can be transported. The convex shape overland flow profile is generally detachment-limited, i. e. the flow volume and rate can transport more sediment than that detached by raindrop impact. In this case, additional soil will be detached to supply the load. Thus, parameter sensitivity is site specific.

Management Practice Factor--The main strength of the USLE that causes it to be modified for application in other models is the impact of management. The discussion of CFACT above indicates how management (crop, tillage, etc) affect the soil loss ratio. The same is true for the practice factor (PFACT).

Direction of tillage may significantly influence erosion and sediment yield. Contour furrows may store most rainfall in excess of soil water storage for most small storms. Large storms may exceed the furrow storage and cause breakover of ridges that results in more erosion and sediment yield from subsequent small storms than may have occurred without contouring. Contour tillage loses its effectiveness for long slopes or as slope steepens. Wischmeier and Smith (1978) gave some guidelines for PFACT based upon slope length and steepness, and the values are reproduced here in Table E-4. If overland flow slope length exceeds those shown in the table for average slope within the ranges given, a contouring factor (PFACT) of 1.0 should be used.

Representing the side of a row ridge as the overland flow profile (such as for the Strawberry Hills application in California cited above) results in a short, steep profile. Since tillage is not performed on the profile, but the ridge was made by the tillage, tillage is assumed to be up-and-down slope. PFACT should always be given a value of 1.0 for these applications.

The topography of a field is seldom uniform with contours parallel to the field boundary except where land forming has been performed. Conventional management systems generally have tillage and row directions parallel to the longest field boundary. Unless contour tillage, parallel to terraces or contour lines, PFACT will change from point-to-point along the row. The overland flow profile crosses the contours at right angles, but only one profile can be represented. Among all of the infinite number of profiles in the field, tillage direction varies considerably. Up to four contouring factors can be represented on the overland flow profile, and this can aid in the best representation.

Just as tillage direction relative to the contour changes around the field, it also changes from time to time during the cropping system. For example, planting and tillage of row crops may be on the approximate contour, but tillage for a small grain may be parallel to the long axis of the field. Updating PFACT must be represented on the appropriate CDATE.

A nonlinear adjustment of the contour factor can be made when tillage is other than on the contour or up-and-down hill. The adjusted PFACT is

$$PFACT = P_{cont} + AF(1.0 - P_{cont}) \qquad \textbf{[13]}$$

where AF is the adjustment factor, and P_{cont} is PFACT from Table E-4. AF can be expressed as

$$AF = 5.14X - 14.91X^2 + 18.80X^3 - 8.03X^4 \qquad \textbf{[14]}$$

where X is the fraction off the contour. The fraction for up-and-down hill is 1.0.

Sensitivity of the contouring factor is similar to that for CFACT. Both CFACT and PFACT are multiplicative factors from USLE.

Hydraulic Roughness--Soil cover and roughness slow overland flow and reduce its sediment transport capacity. The reduction in velocity depends upon the depth of flow, the type of material on the surface, and its density. Manning's "n" value is a measure of the resistance to flow, that is, the higher the "n" value the greater the resistance and lower the flow velocity. Table E-5 contains estimates of Manning's "n" for different cover and amount in the overland flow path. Values in Table E-5 are based on n = 0.01 for overland flow over bare soil. It represents a smooth bare surface over which flow has occurred following tillage.

Flow velocity and sediment transport capacity are inversely related to Manning's "n"--NFACT. As seen in Table E-5, NFACT increases significantly from bare soil with little or no surface depressions to good and very dense grass cover. There is a factor of 40 from smooth bare soil to very dense grass. It is easy to see why well maintained grass buffer strips reduce sediment transport capacity and sediment yield compared with that from a cropped area.

NFACT is a sensitive parameter for sediment yield from uniform or convex slope shapes. If the overland flow drains into a channel of lesser slope or into a pond, the system is transport-limited, and sediment yield at the edge of the field is not sensitive to NFACT.

Concentrated Flow

Channel Segment Differentiation--Up to four channel segments can be designated for different updatable parameters, just as in the overland flow profile. This allows different channel top width in different segments, some segments tilled and some not tilled, and etc.

The number of channel segments, NXC, must be positioned by fractions of the channel, XCHAN, just as that in the overland flow profile. The relative distance for the top of the channel to the bottom of each segment must be input. XCHAN for the last segment must be 1.0, representing the total length of the channel.

Terrace channels rarely, if ever, need more than one segment for updatable parameters. These channels generally are tilled and cropped the same as in the field. Terraces are generally constructed uniformly, and the top width of flow is the same throughout its length. Terrace outlet channels, i. e. grassed waterways, are vegetated throughout their length. A grassed terrace outlet channel may be stair-stepped in width to reduce the area that would be taken out of crop production by a full width channel for the entire length.

Channel Hydraulic Roughness--Hydraulic roughness, or resistance to flow, in a channel changes in time with tillage and crop growth in a tilled channel, and changes with grass growth and mowing in grassed waterways. Ree and Palmer (1949) show that Manning's "n" varies over a considerable range of the product of velocity and hydraulic radius of the channel. However, "n" is assumed to be constant for discharges in a channel in **GLEAMS**. This assumption does not reduce the effectiveness of the model.

Manning's "n" values (NCHAN) are tabulated in Table E-3 for a range of channel cover and conditions. The values in the table are generally for VR products (velocity x hydraulic radius) of 1.0 to 1.5. For high flows that submerge the vegetation, the NCHAN values in the table are too high. For example, submerged unmowed dense lovegrass might have an NCHAN value of 0.06.

NCHAN is a sensitive parameter for sediment yield since it used to calculate sediment transport capacity. If the channel under consideration is the last element in the sequence, the relative sensitivity is greater than if another channel or a pond follows.

Depth to Nonerodible Layer--Tillage in a concentrated flow area destroys the root system that binds the soil together and resists erosion. Also, primary tillage loosens the soil and makes it easier to detach by the concentrated flow, and erosion occurs down to the depth of tillage. After a severe erosion-producing storm, marks made by the tillage equipment (moldboard, disk, chisel, etc) are clearly visible on the nontilled sub-soil layer. This untilled layer is relatively nonerodible, and further erosion does not occur in the field, nor is it permitted in the model. Subsequent tillage of the concentrated flow area establishes a new nonerodible at the depth of tillage. The model keeps account of the erosion out of the concentrated flow zone, deepening to the nonerodible layer then widening to the full top with of the channel (Foster et al., 1980b). The concepts for nonerodible layer are valid for ephemeral gullies and other tilled concentrated flow areas.

Depth to nonerodible layer in a tilled channel element (DCHAN) is an updatable parameter, and should be updated on CDATEs for primary tillage. It should not be updated for secondary tillage such as a row or field cultivator, planter, or grain drill. Depth of secondary tillage is generally not more than about 2 in (5 cm), and it is not considered sufficient for resetting DCHAN. This might unduly reduce DCHAN in a short time even without significant rainfall.

If one segment of a channel element is tilled and another segment has a permanent grass cover, two channel segments are needed to represent the element. DCHAN in the tilled segment would be updated with primary tillage, and the grass segment would not be updated.

A very important feature is included in **GLEAMS** for updating DCHAN. DCHAN must be defined on Julian day 001 of the first year of a crop rotation cycle. However, in a channel segment that is not tilled, depth to nonerodible layer should not be updated on day 001 of the first year of the next rotation cycle (the updatable parameters are reused for subsequent cycles of the simulation period). By including a minus sign in front of DCHAN for day 001, the model uses the absolute value initially, and when the parameters are re-used, it is not updated. On other CDATEs, a large negative number, e. g. -99.0, signals not update of DCHAN. For example, assume a grassed channel in a field on which there are six CDATEs in the first year of a 2-yr rotation. Also assume that the depth to nonerodible layer was established as 0.4 ft (0.12 m) well before simulation begins, and the grass cover will not be plowed. DCHAN for CDATE 001 should be -0.4 (-0.12), that is minus 0.4, and DCHAN for the other 5 CDATEs should be -99.0 (minus 99.0). This signals the initial setting of DCHAN to 0.4 ft, it would not be updated throughout the 2-yr rotation, and it would not be updated on day 001 of the next rotation cycle. This is important in erosion accounting between updates, particularly for tilled channel segments.

Updating DCHAN has another important aspect, and that is for resetting the critical shear internally in the model. Critical shear increases in time after primary tillage, but is reset to its lowest value on the date of tillage. This done in the model, and the **GLEAMS** user does not have to externally set critical shear as was done in the **CREAMS** model (USDA-SCS, 1984).

The depth to nonerodible layer is not a sensitive parameter for vegetated channels. If tilled concentrated flow segments occur at the bottom of a channel element, DCHAN may be relatively sensitive depending upon the slope of the segment. If the sequence is transport-limited, then DCHAN may not be sensitive. If the sequence is detachment-limited, it may be relatively sensitive for total sediment yield and enrichment ratio. This would also affect adsorbed nutrient and pesticide losses as well. Thus, it is rather site-specific.

Channel Top Width--The top width of channel elements do not generally change during a simulation period. There is a very significant management system which does require updating channel top width, WCHAN.

Updating channel top width was developed in **CREAMS** for the specific model application of a ridge-furrow system. The ridge-furrow systems at Stawberry Hills, in land-formed cotton fields of the

Mississippi delta, and in potato growing areas, all have channel top width equal to the row spacing during the crop growing period. After harvest of the cotton and potato crops, and at the end of the 2nd year's strawberry crop, tillage obliterates the ridges. If WCHAN is updated to 33 ft (10 m), the channel appears to the model to be infinitely wide with a very shallow depth approximating shallow overland flow. Computationally the transport capacity decreases and deposition of detached soil particles occurs. This is conceptually realistic, and the results closely approximate observed sediment yield.

The same feature of negative value for DCHAN on CDATE 001 of the first rotation year applies to WCHAN as well. Also, the subsequent negative values applies for WCHAN, i. e. -99.0 signifies no update of WCHAN.

WCHAN is not a sensitive parameter except in the overland-channel representation of the ridge-furrow system. When WCHAN is updated to represent an infinitely wide channel, any sensitivity is lost.

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Table E-1. Texture, structure, and permeability factors for estimating erodibility by soil textural classification.

Soil Texture	Clay	Silt	Sand	Texture Factor (TF)	Struct. Factor (SF)	Permeab. Factor (PF)
	%	%	%			
Coarse sand	5	5	90	0.00827	0.0325	-0.050
Sand	5	5	90	0.01481	0.0325	-0.050
Fine sand	5	5	90	0.02173	0.0000	-0.050
Very fine sand	5	5	90	0.04401	-0.0325	-0.050
Loamy coarse sand	8	8	84	0.00982	0.0325	-0.025
Loamy sand	8	8	84	0.01624	0.0325	-0.025
Loamy fine sand	8	8	84	0.02301	0.0000	-0.025
Loamy very fine sand	8	8	84	0.03726	-0.0325	-0.025
Coarse sandy loam	15	25	60	0.01914	0.0325	0.000
Sandy loam	15	25	60	0.02549	0.0325	0.000
Fine sandy loam	15	25	60	0.03205	0.0000	0.000
Very fine sandy loam	15	25	60	0.03877	-0.0325	0.000
Loam	20	35	45	0.03618	0.0325	0.025
Silt loam	20	60	20	0.04259	0.0650	0.025
Silt	10	85	5	0.05845	0.0650	0.025
Sandy clay loam	25	20	55	0.02778	0.0650	0.050
Clay loam	35	30	35	0.02360	0.0650	0.050
Silty clay loam	35	50	15	0.02606	0.0650	0.050
Sandy clay	40	10	50	0.01714	0.0650	0.075
Silty clay	45	45	10	0.01870	0.0650	0.075
Clay	50	30	20	0.01287	0.0650	0.075

KSOIL = TF * (12. - OM) + SF + PF

Table E-2. Field channel outlet-control conditions and codes, CTLO. [From Foster et al., 1980a.]

Condition	Control	CTLO
For terrace, diversion, or other channel when depth of flow in outlet channel has no restricting effect.	Critical depth controls flow at the end of the field channel.	1
For a channel with a reach at the lower end that sets the depth of flow, i. e. heavy vegetation at the outlet.	Uniform flow controls depth at the end of the field channel.	2
The model will choose the greater of 1 or 2. Note the distinction of "field" and "outlet" channel.	Same as 2, except Manning's "n" for the outlet channel is the same as that for the lower segment of the field channel.	3
A control structure such as a weir, flume, or culvert controls flow depth according to a known rating curve.	A rating curve controls flow depth at the end of the field channel with critical discharge computed by: $Q = RA\ (Y)^{RN}$	4

Table E-3. Manning's "n", CTLN and NCHAN, for channel flow with typical cover (does not include effects of submergence). [From Foster et al., 1980a.]

Cover	Cover density	Manning's n
Smooth, bare soil; roughness elements	Less than 1" (2.5 cm)	0.030
	1-2" (2.5-5 cm) deep	0.033
	2-4" (5-10 cm) deep	0.038
	4-6" (10-15 cm) deep	0.045
Corn stalks (assumes residue remains in place and is not washed away)	1 t/ac (2.24 t/ha)	0.050
	2 t/ac (4.48 t/ha)	0.075
	3 t/ac (6.72 t/ha)	0.100
	4 t/ac (8.96 t/ha)	0.130
Wheat straw (assumes residue remains in place and is not washed away)	1 t/ac (2.24 t/ha)	0.060
	1.5 t/ac (3.36 t/ha)	0.100
	2 t/ac (4.48 t/ha)	0.150
	3 t/ac (6.72 t/ha)	0.200
	4 t/ac (8.96 t/ha)	0.250
Grass (assumes that grass is erect and that flow depth does not exceed height of grass)	Sparse	0.040
	Poor	0.050
	Fair	0.060
	Good	0.080
	Excellent	0.130
	Dense	0.200
	Very dense	0.300
Small grain (20% to maturity)		
7" (18 cm) rows with flow	Poor	0.130
	Good	0.300
14" (36 cm) rows with flow	Poor	0.100
	Good	0.200
Rows across flow	Good	0.300
Sorghum and coton	Poor	0.070
	Good	0.090
Soybeans	Good	0.080
Sudangrass	Good	0.200
Lespedeza	Good	0.100
Lovegrass	Good	0.150

Table E-4. Contour factor values (PFACT) and slope-length limits for contouring. [From Wischmeier and Smith, 1978.]

Land Slope (%)	Contour factor	Maximum length (ft)	Maximum length (m)
1 to 2	0.60	400	122
3 to 5	0.50	300	91
6 to 8	0.50	200	61
9 to 12	0.60	120	36
13 to 16	0.70	80	24

17 to 20	0.80	60	18
21 to 25	0.90	50	15

Table E-5. Manning's "n" values for overland flow element (NFACT). [From Foster et al., 1980a.]

Surface condition	n	Surface condition	n
Cornstalk residue:		Wheat straw mulch:	
Applied to fallow surface			
		0.25 t/ac (0.56 t/ha)	0.015
1 t/ac (2.24 t/ha)	0.020	0.5 t/ac (1.12 t/ha)	0.018
2 t/ac (4.48 t/ha)	0.040	1 t/ac (2.24 t/ha)	0.032
4 t/ac (8.96 t/ha)	0.070	2 t/ac (4.48 t/ha)	0.070
		4 t/ac (8.96 t/ha)	0.074
Disk-harrow incorporated			
		Crushed stone mulch:	
1 t/ac (2.24 t/ha)	0.012		
2 t/ac (4.48 t/ha)	0.020	15 t/ac (33 t/ha)	0.012
4 t/ac (8.96 t/ha)	0.023	60 t/ac (135 t/ha)	0.023
		135 t/ac (304 t/ha)	0.046
Small grain-20% to maturity:		240 t/ac (540 t/ha)	0.074
Across slope		375 t/ac (844 t/ha)	0.074
Poor stand	0.018	Grass:	
Moderate stand	0.023		
Good stand	0.032	Sparse	0.015
Dense stand	0.046	Poor	0.023
		Fair	0.032
Up-and-down slope		Good	0.046
		Excellent	0.074
Poor stand	0.012	Dense	0.150
Moderate stand	0.015	Very dense	0.400
Good stand	0.023		
Dense stand	0.032		
Rough surface depressions:			
No depressions	0.010		
1-2" (2.5-5 cm) deep	0.014		
2-4" (5-10 cm) deep	0.023		
4-6" (10-15 cm) deep	0.046		

Footnotes for Table E-6.

[1]Symbols: B, soybeans; C, corn; conv till, plow, disk and harrow for seedbed; cot, cotton; F, rough fallow; fld cult, field cultivator; G, small grain; GS, grain sorghum; M, grass and legume meadow, at least 1 full year; pl, plant; RdL, crop residues left on field; RdR, crop residues removed; SB, seedbed period; sprg, spring; TP, plowed with moldboard; WC, winter cover crop; ---, insignificant or an unlikely combination of variables.

[2]Dry weight per acre after winter loss and reductions by grazing or partial removal: 4,500 lbs represents 100 to 125 bu corn; 3,400 lbs, 77-99 bu; 2,600 lbs, 60-74 bu; and 2,000 lbs, 40-59 bu; with normal 30% winter loss. For RdR or fall-plow practices, these four productivity levels are indicated by HP, GP, FP, and LP, respectively (high, good, fair, and low productivity:. In lines 79 to 102, this column indicates dry weitht of the winter-cover crop.

[3]Percentage of soil surface covered by plant residue mulch after crop seeding. The difference between spring residue and that on the surface after crop seeding is reflected in the soil loss ratios as residues mixed with the topsoil.

[4]The soil loss reatios, given as percentages, assume that the indicated crop sequence and practices are followed consistently. One-year deviations from normal practices do not have the effect of a permanent change. Linear interpolation between lines is recommended when justified by field conditions.

[5]Cropstage periods are defined as: F, rough fallow--inversion plowing to secondary tillage; SB, seedbed--secondary tillage for seedbed preparation until the crop has developed 10 % canopy cover; 1, establishment--end of SB until crop has developed a 50% canopy cover (35% for cotton); 2, development--end of period 1 until canopy cover reaches 75% (60% for cotton); 3, maturing crop--end of period 2 until crop harvest. This period was evaluated fro three levels of final crop canopy; 4, residue or stubble--harvest to plowing or new seeding. The 3 columns for cropstage 3 are for 80, 90, and 96-100% canopy cover at maturity.

[6]Column 4L is for all residues left on field. Corn stalks partially standing as left by some mechanical pickers. If stalks are shredded and spread by picker, select ratio from table E-9. When residues are reduced by grazing, take ratio from lower spring-residue line.
[7]Period 4 values in lines 9-12 are for corn stubble (stover removed).
[8]Inversion plowed, no secondary tillage. For this practice, residues must be left and incorporated.
[9]Soil surface and chopped residues for matured preceding crop undisturbed except in narrow slots in which seeds are planted.
[10]Tof of old row ridge sliced off, throwing residues and some soil into furrow areas. Reridging assumed to occur near end of cropstage 1.
[11]Where lower soil loss ratios are listed for rows on the contour, this reduction is in addition to the standard field contouring credit. The P value for contouring is used with these reduced loss ratios.
[12]Field-average percent cover; probably about three-fourths of percent cover on undisturbed strips.
[13]If again seeded to WC crop in corn stubble, evaluate winter period as a winter grain seeding (lines 132-148). Otherwise, see table E-9.
[14]Select the appropriate line for the crop, tillage, and productivity level and multiply the listed soil loss ratios by sod residual factors from table E-10.
[15]Spring residue may include carryover from prior corn crop.
[16]See table E-9.
[17]Use values from lines 33-62 with appropriate dates and lengths of cropstage periods for beans in the locality.
[18]Values in lines 109-122 are best available estimates, but planting dates and lengths of cropstages may differ.
[19]When meadow is seeded with the grain, its effect will be reflected through higher percentages of cover in cropstages 3 and 4.
[20]Ratio depends on percent cover. See table E-9.
[21]See item 12, table E-8.

Table E-9. Soil loss ratios (percent) for cropstage 4 when stalks are chopped and distributed without soil tillage (From Wischmeier and Smith, 1978).

Mulch Cover[1]	Corn or Sorghum		Soybeans		Grain Stubble[4]
	Tilled seedbed[2]	No-till	Tilled seedbed[2]	No-till corn rd[3]	
20	48	34	60	42	48
30	37	26	46	32	37
40	30	21	38	26	30
50	22	15	28	19	22
60	17	12	21	16	17
70	12	8	15	10	12
80	7	5	9	6	7
90	4	3	--	--	4
95	3	2	--	--	3

[1]Part of a field surface directly covered by pieces of residue mulch.
[2]This column applies for all systems other than no-till.
[3]Cover after bean harvest may include an appreciable number of stalks carried over from the prior corn crop.
[4]For grain with meadow seeding, include meadow growth in percent cover and limit grain period 4 to 2 months. Thereafter, classify as established meadow.

Table E-10. Factors to credit residual effects of turned sod[1] (From Wischmeier and Smith, 1978).

Crop	Hay Yield	Factor for cropstage period:				
		F	SB or 1	2	3	4
	Tons					
First year after meadow:						

Row crop or grain	3-5	0.25	0.40	0.45	0.50	0.60
	2-3	.30	.45	.50	.55	.65
	1-2	.35	.50	.55	.60	.70
Second year after meadow:						
Row crop	3-5	.70	.80	.85	.90	.95
	2-3	.75	.85	.90	.95	1.00
	1-2	.80	.90	.95	1.00	1.00
Spring grain	3-5	-	.75	.80	.85	1.00
	2-3	-	.80	.85	.90	1.00
	1-2	-	.85	.90	.95	1.00
Winter grain	3-5	-	.60	.70	.85	.95
	2-3	-	.65	.75	.90	1.00
	1-2	-	.70	.85	.95	1.00

[1]These factors are to be multiplied by the appropriate soil loss percentages selected from table E-6. they are directly applicable for sod-forming meadows of at least 1 full year duration, plowed not more than 1 mo before final seedbed preparation.

When sod is fall plowed for spring planting, the listed values for all cropstage periods are increased by adding 0.02 for each additional month by which the plowing precedes spring seedbed preparation. For example, Sept. plowing would precede May disking by 8 mo. and 0.02(8-1), or 0.14, would be added to each value in the table. For nonsod-forming meadows, like sweetclover or lespedeza, multiply the factors by 1.2. When the computed value is greater than 1.0, use as 1.0.