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Adapting the CREAMS Model to Predict the Effect of Diversions on Soil Loss

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Adapting the CREAMS Model to Predict the Effect of Diversions on Soil Loss

Submitted to the DEC Task Force

by

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ABSTRACT

The CREAMS model was examined to determine if it could be used to estimate the reduction in soil loss associated with the construction of a diversion on sloping land. The model was then adapted to analyze two examples of diversion applications. In the first example a diversion was simulated between a sloping (2.0 to 12.0%) pasture and a relatively flat (0.5 to 2.0%) cropped bottomland. The simulated diversion reduced predicted annual soil losses by 1 to 20 t/ha. Most of this overall reduction resulted from less concentrated-flow erosion on the bottomland field.

For another field with a 180-m slope length at uniform 1 or 3 percent steepness, the predicted soil losses were 1 to 15 t/ha less with a diversion at midslope than without. A 3- or 9-m grass strip above the diversion reduced soil losses only slightly more.

Several other situations where the CREAMS model might be used to predict soil losses were presented in Appendix I. The application of the model to each of these situations was discussed.

The simulated soil losses obtained from the CREAMS model, adapted for uses such as these, provide useful information for evaluating diversions. However, CREAMS must be carefully used and the results thoroughly assessed to verify that they are reasonable.

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INTRODUCTION

Uncontrolled runoff flowing across a cropped, bottomland field is common in many areas of the United States. A diversion constructed above the bottomland field to intercept hillside runoff can be an effective soil-conserving practice for many of the fields. However, a method of estimating the soil-saving potential of such a diversion is needed, especially when concentrated-flow erosion occurs on the land below the diversion. Recognizing this need, the Soil Conservation Service and the Demonstration Erosion Control (DEC Project) task force requested a method to provide adequate estimates of soil saved by the installation of diversions. The research described in this report was conducted in response to that request.

Because soil loss predictions by the Universal Soil Loss Equation (Wischmeier and Smith, 1978) do not include concentrated-flow erosion or sediment deposition and the equation does not include variables to adequately describe complex slopes or diversions, the USLE is not suited for this application. The CREAMS (Chemicals, Runoff, and Erosion from Agricultural Management Systems) computer model (Knisel, 1980) is much more versatile than the USLE. It incorporates many more of the variables that are needed to describe and predict soil loss from fields without and with diversions. Therefore, the CREAMS model was studied to assess its usefulness in estimating how effective a diversion would be at reducing soil losses for several simplified field examples. This paper describes the way that the CREAMS model was applied for this purpose, reports the results from two test situations and discusses its suitability for these and similar applications.

PROCEDURE

Model Overview

The CREAMS model is described in detail in Conservation Research Report No. 26 (Knisel, 1980). Basically the model contains components to simulate the physical processes that control hydrology, erosion-sediment yield, and chemical movement on an individual field. Because this study was not concerned with chemical movement, only the first two components of the model (version 1.8) were used.

The CREAMS model has been applied to several land resource areas involving a range of management systems. Comparisons between simulated and observed data from the applications along with a complete user manual have been reported (Knisel, 1980). In addition, the model has been applied to some specific conservation practices (Foster and Ferreira, 1981; and Bingner et al., 1987).

Simulated values compared favorably with observed data, even though CREAMS was not intended to be a predictive (absolute quantity) model (DelVecchio and Knisel, 1982). The main intended use was to compare alternative management systems for given fields.

Model Application

In this study soil losses were estimated for a simplified 4.9 ha (12 ac) watershed (Fig. 1) which consisted of a 2.4 ha (6 ac) sloping (2.0 to 12.0%) pasture field above a relatively flat (0.5 to 2.0%) 2.4 ha bottomland field of soybeans. To determine the effect of a diversion, soil losses were estimated for the entire watershed without and with a diversion between the fields.

In the second application of the CREAMS model, soil losses were estimated for a 3.2 ha (8 ac) uniformly sloping (1 and 3%) soybean field (Fig. 2) without and with a diversion at midslope. For some runs, a 3- or 9-m (10- or 30-ft) grass strip was added immediately above the diversion channel to investigate its effect on predicted soil losses.

Because the diversion divided the watershed or field in half, two computer runs were required to determine the soil loss estimates from a watershed or field with a diversion. These estimates were determined by averaging the individual losses from the areas above and below the diversion. The averages were then compared with the corresponding soil loss estimates without a diversion.

Hydrology Component

The daily rainfall option of the CREAMS hydrology component (Smith and Williams, 1980) was chosen for all runs, using input of observed daily rainfall amounts for the 1982 and 1984 calendar years at raingage 11 on the Goodwin Creek watershed near Batesville, Mississippi. The total rainfall measured for these two years was 1700 and 1370 mm (70 and 54 in), respectively. This option employs the SCS curve number procedure to compute runoff. An SCS curve number between 80 and 90 was selected for each run, depending on the percentages of grass or soybeans present on the area being modeled.

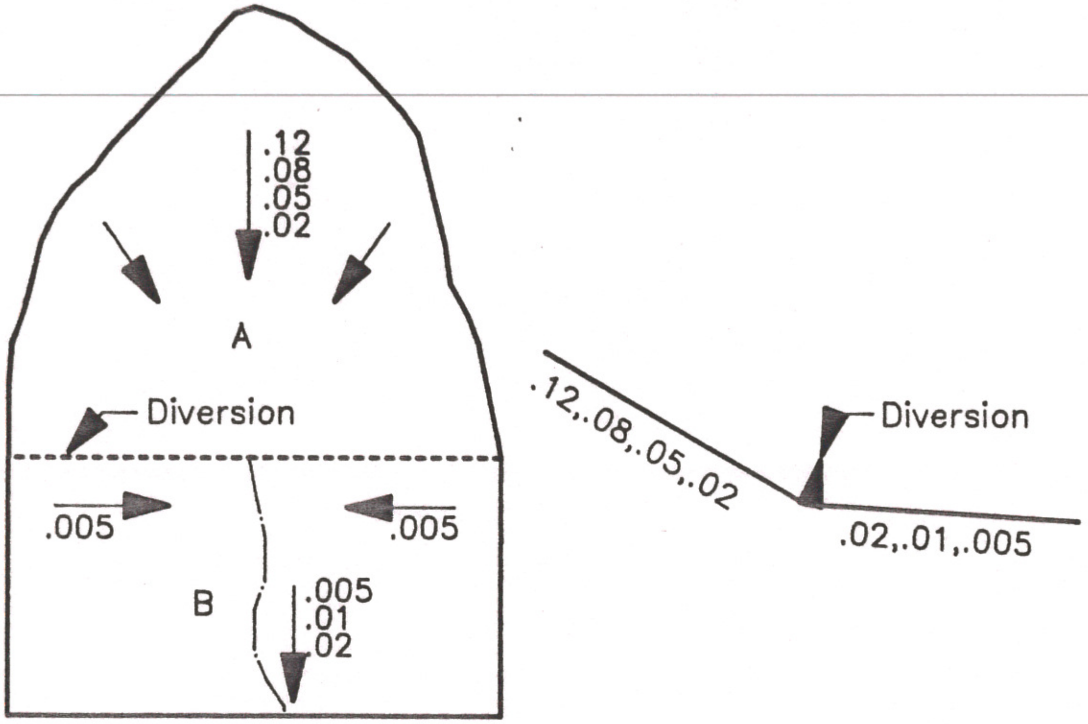

Fig. 1 Top and cross-sectional views of sloping pasture (A) above cropped bottomland (B) with concentrated flow channel across bottomland field.

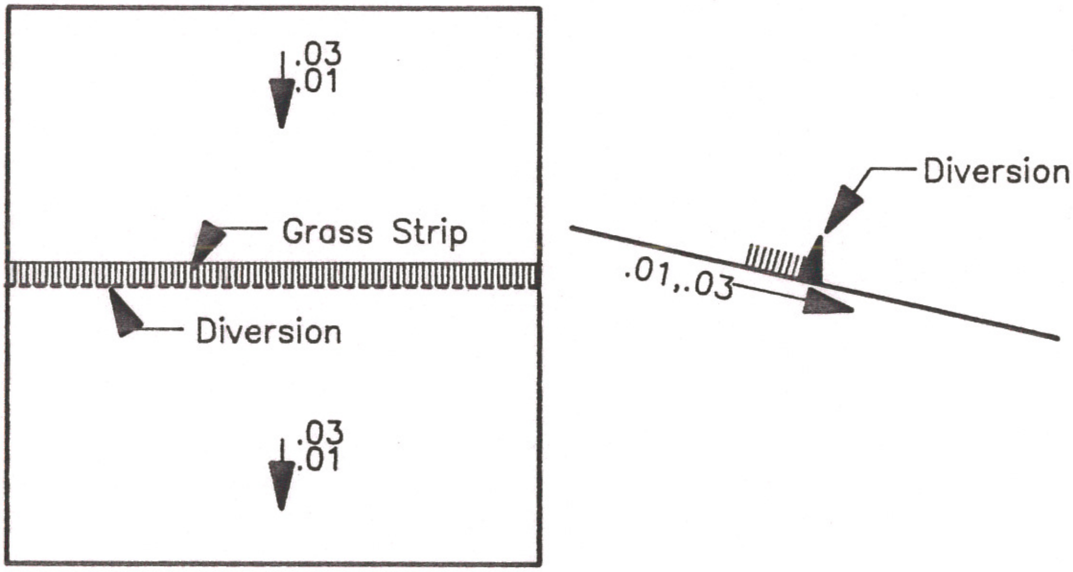

Fig. 2 Top and cross-sectional views of grass-strip-plus-diversion case.

The detailed inputs of climatic, soil, and crop data were obtained from suggested values given in the CREAMS user manual (Knisel, 1980). General information required to obtain these detailed inputs from the manual is given in Table 1. Because the watershed included both grass and soybeans and the hydrology component can only consider one set of crop parameters per run, crop data had to be weighted and averaged before being used as input for the runs without a diversion. Topographic inputs were computed from simplified field descriptions such as those shown in Figures 1 and 2. These descriptions do not represent an actual field, but were created for the purpose of testing the model. Soil inputs were determined from general characteristics of a Loring silt loam soil.

Erosion-Sediment Yield Component

The erosion-sediment yield component contains routines to predict interrill and rill erosion on overland flow areas, channel erosion on areas of concentrated flow, and net deposition in temporary impoundments. For most runs, the overland and channel routines were run in combination; however for runs involving areas without a concentrated flow channel or a diversion, only the overland flow routine was used.

Detailed crop-related data such as soil loss ratios and overland-flow Manning roughness coefficients were obtained from the CREAMS user manual (Foster et al., 1980). Some of the general information needed to obtain these inputs from the manual is given in Table 1.

Table 1. Examples of general CREAMS inputs.

Hydrology component	Erosion component
Field area[a]	Field area[a]
Average field slope[a]	Detailed slope profiles[a]
Daily rainfall data[a]	Channel data[a]
Crop[a]	Soils data (soil survey)[a]
Average crop rooting depth[a]	Tillage[a]
Soil porosity	Management system[a]
Average monthly temperatures	Soil loss ratios
Solar radiation	Depth of erodible soil
Leaf area index	Crop stages
SCS curve number	Channel outlet controls

[a] Denotes information required to determine inputs; other information can be determined from the CREAMS manual if not available.

All information shown in Table 1 must be supplied by the user; however, the nonsuperscripted input can be obtained by entering the user manual with the superscripted information. The model uses much of this information to create a representative overland flow profile for the entire area. However, for the watershed in Fig. 1, the overland flow profile changes from the upper field of pasture grass to the lower field of soybeans. Therefore, in order to represent the whole watershed as required for the runs without a diversion, the parameters associated with each field had to be weighted and averaged. In addition, since the average overland flow slope of the upper field was often much steeper than that of the lower field, the slopes had to be weighted and averaged also.

All diversions were treated as erodible, grassed concentrated flow channels with uniform gradients of 0.005; however, the diversion sideslope steepness input was decreased from the recommended 10 (10 to 1) for field channels, to 5 (5 to 1). The uniform depth control option was used to simulate the hydraulic conditions at the outlet of each diversion. The critical depth option would be used for eroding channels where flow goes through critical depth as it leaves the channel.

The drainage area at the upper end of each diversion was assumed to be zero. The drainage area at the upper end of the bottomland concentrated flow channel was equal to the area of the pasture (2.4 ha) for the runs involving the pasture-above-cropped-bottomland (Fig. 1) without a diversion, and equal to zero for the corresponding runs with a diversion. These inputs assume the diversion intercepted all the runoff generated on the pasture, thereby preventing it from contributing to flow in the bottomland channel. Thus, the diversion greatly decreased the quantity of, and therefore the erosiveness of, flow in the channel.

For the second case (Fig. 2) in which 3- and 9-m grass strips were included in combination with a diversion, the grass strips were assumed to have average growth and density and to be located below the cropped area and above the diversion channel. Because the overall slope length remained constant, the addition of the strips decreased the cropped area of the upper field slightly.

RESULTS

Pasture-Above-Cropped-Bottomland Case

The CREAMS simulated soil losses for a sloping pasture (2 to 12%) above a cropped bottomland (0.5 to 2.0%) for 1982 rainfall are shown in Table 2. All soil losses except those in column 7 represent the combined net of overland flow erosion (USLE-type), and channel erosion/deposition. The predicted soil losses in column 7 are for the pasture (upper field) with no diversion (W/o dv) or eroding concentrated-flow channel; therefore, only overland erosion was computed. Thus, all soil losses, except those in column 7, represent soil leaving the field area through the end of a channel.

Table 2. Predicted soil losses for the Pasture-Above-Cropped-Bottomland case using 1982 and 1984 rainfall data.

Slope[a] sequence (1)	Watershed average W/o dv (2)	W/dv (3)	Cons[b] (4)	Lower field W/o dv (5)	W/dv (6)	Upper field W/o dv (7)	W/dv (8)
(%)	(t/ha)[c]	(t/ha)	(t/ha)	(t/ha)	(t/ha)	(t/ha)	(t/ha)
			1982				
2-0.5	2.2	0.7	1.5	4.4	1.2	0.2	0.1
2-1.0	2.8	1.4	1.4	5.4	2.7	0.2	0.1
2-2.0	6.7	5.3	1.4	13.2	10.5	0.2	0.1
5-0.5	6.7	0.7	5.9	12.8	1.1	0.5	0.3
5-1.0	7.9	1.7	6.2	15.3	3.0	0.5	0.3
5-2.0	11.6	5.6	6.0	22.6	11.0	0.5	0.3
8-0.5	9.2	0.8	8.4	17.6	1.0	0.9	0.5
8-1.0	13.4	1.8	11.7	26.0	3.0	0.9	0.5
8-2.0	17.1	5.8	11.3	33.3	11.0	0.9	0.5
12-0.5	12.5	1.1	11.4	23.4	1.2	1.6	1.0
12-1.0	22.7	2.2	20.6	43.8	3.4	1.6	1.0
12-2.0	26.1	6.1	20.1	50.6	11.2	1.6	1.0
			1984				
2-0.5	2.0	0.6	1.4	3.8	1.0	0.2	0.1
2-1.0	3.1	1.2	1.9	6.0	2.2	0.2	0.1
2-2.0	7.1	4.5	2.6	14.0	8.8	0.2	0.1
5-0.5	4.3	0.6	3.7	8.1	1.0	0.5	0.2
5-1.0	8.3	1.3	7.0	16.1	2.3	0.5	0.2
5-2.0	12.3	4.6	7.7	24.1	8.9	0.5	0.2
8-0.5	7.3	0.7	6.6	13.7	1.0	0.9	0.4
8-1.0	14.1	1.4	12.7	27.4	2.4	0.9	0.4
8-2.0	18.1	4.7	13.3	35.3	9.0	0.9	0.4
12-0.5	10.7	0.9	9.8	19.7	1.0	1.6	0.8
12-1.0	22.6	1.7	20.9	43.6	2.6	1.6	0.8
12-2.0	27.2	5.0	22.2	52.8	9.2	1.6	0.8

[a] The percent slopes of the pasture and bottomland (upper and lower fields) respectively.

[b] Difference in soil losses without (W/o dv) and with (W/dv) a diversion.

[c] Metric tons per hectare; t/ha ÷ 2.24 = ton/acre.

In Table 2, the first column (Slope sequence) contains the respective slope steepnesses of the upper and lower fields in the direction perpendicular to the diversion. The average steepness of the bottomland field is also the steepness of all but the upper 23 m of the concentrated flow channel. For this section, the beginning channel slope was assumed to be equal to the slope of the pasture and then to gradually decrease until reaching the slope of the bottomland. Columns 2 and 3 of Table 2 contain estimated soil losses for the combined 4.9 ha watershed without a diversion (W/o dv) and with a diversion (W/dv) respectively. The soil losses in the "Without diversion" column were determined by considering the entire area as one field in which all runoff and sediment is routed to the end of the concentrated flow channel. The soil losses in the "With diversion" column are the averages of the soil losses of the pasture and bottomland fields (columns 6 and 8) with a diversion. The differences between the soil losses for the watershed without and with a diversion, shown on column 4 (Cons), were considered soil conserved.

The quantities of soil conserved increased with increasing upper field slope steepness, ranging from less than 2 t/ha at 2 percent to about 20 t/ha for some conditions at 12 percent. This increase in soil conserved was attributed to greater quantities of the predicted runoff being diverted around the lower field. With increased upper field steepness, the model generates greater quantities and higher peak rates of runoff, which in the absence of a diversion, increase the predicted soil loss on the cropped bottomland.

Except for deposition in the diversion, all of the overall soil conserved as a result of the diversion (column 4) occurred on the cropped bottomland. Thus, the differences between the bottomland soil losses without and with a diversion (columns 5 and 6) were approximately twice the soil conserved shown in column 4 (Cons). This occurred because the effect of a diversion on soil losses of the upper field (deposition in the diversion) was much smaller than that of the bottomland. Therefore, when the soil losses of both fields were averaged, the resulting watershed soil conserved was approximately half the soil loss reduction of the bottomland field alone.

In order to determine how the predicted soil losses change with respect to slope sequences, the slope steepness of the upper field was held constant at 2, 5, 8, or 12 percent while the slope of the lower field was increased from 0.5 to 1.0 to 2.0 percent. For constant upper field steepnesses of 2 and 5 percent, the watershed soil conserved (column 4) remained relatively similar over the range of bottomland slopes. However, for upper field slopes of 8 and 12 percent, the soil conserved increased as the slope of the lower field increased from 0.5 to 1.0 percent. Therefore, the model indicates that the simulated diversion was generally more effective at steeper upper-lower field slope combinations.

The soil losses for the upper field (pasture) without (W/o dv) and with (W/dv) a diversion are shown in columns 7 and 8 of Table 2. The decrease in soil loss from 7 to 8 resulted from predicted deposition in the diversion. These decreases were generally less than 1 t/ha, and therefore contributed little to the overall soil conserved shown in column 4.

Because the rainfall distribution of 1982 was nontypical (25% of the annual rainfall occurred in December), soil losses were also predicted using 1984 rainfall data. The 1984 soil losses, shown in the bottom half of Table 2, are more similar to those obtained using 1982 rainfall than the rain data would suggest. However, some of the soil loss trends for 1984 are more consistent than those of 1982, particularly the increase in soil conserved as the slope of the lower field increases for each upper field slope. Further analyses of additional years should be made, since two years of soil loss predictions are inadequate to confidently determine the effects of a diversion. The CREAMS model can simulate up to 50 years in one run depending on computer size and time constraints.

Grass-Strip-Plus-Diversion Case

The soil losses for the grass-strip-plus-diversion case using 1982 rainfall data are shown in Table 3. The first column (Field slope) is the slope steepness of this field (Fig. 2) which was uniform over the entire 180-m slope length. The second column (Grass strip) contains the widths of the grass strips.

The soil losses for the field without a diversion (W/o dv), shown in column 3, decreased slightly with the inclusion and widening of a grass strip. The differences between the soil losses without and with a 3-m grass strip (column 3) were at least half those of the 9-m strips.

Table 3. Predicted soil losses for the Grass-Strip-Plus-Diversion case using 1982 and 1984 rainfall data.

Field slope (1)	Grass strip (2)	Field average W/o dv (3)	Field average W/dv (4)	Field average Cons[a] (5)	Lower area W/o dv (6)	Lower area W/dv (7)	Upper area W/o dv (8)	Upper area W/dv (9)
(%)	(m)	(t/ha)[b]	(t/ha)	(t/ha)	(t/ha)	(t/ha)	(t/ha)	(t/ha)
				1982				
1.0	0	6.9	4.8	2.1	7.8	6.0	6.0	3.6
1.0	3	6.6	4.3	2.4	9.9	6.0	3.5	2.6
1.0	9	6.4	4.0	2.3	9.9	6.0	2.9	2.0
3.0	0	39.3	24.4	14.9	42.8	35.8	35.8	13.0
3.0	3	34.7	22.8	11.9	51.8	35.8	17.7	9.9
3.0	9	34.5	22.2	12.3	53.8	35.8	15.3	8.6
				1984				
1.0	0	4.4	3.4	1.0	4.8	4.0	4.0	2.8
1.0	3	4.4	3.2	1.2	5.5	4.0	3.2	2.3
1.0	9	4.4	3.0	1.4	6.0	4.0	2.8	2.0
3.0	0	26.8	17.2	9.6	28.4	25.1	25.1	9.3
3.0	3	25.3	16.4	8.9	33.8	25.1	16.8	7.8
3.0	9	25.2	16.0	9.2	35.4	25.1	15.1	7.0

[a] Difference in soil loss rates without (W/o dv) and with (W/dv) a diversion.

[b] Metric tons per hectare; t/ha ÷ 2.24 = ton/acre.

This indicates that the first 3 m of the grass strips were at least as effective at reducing soil loss as the next 6 meters.

Soil losses from the field with a diversion are shown in column 4 (W/dv). These losses are the average of the losses from the areas above and below the diversion (columns 7 and 9). The differences between the soil losses without and with a diversion, termed soil conserved (Cons), are shown in column 5. The magnitude of soil conserved increased greatly as the field slope increased from 1 to 3 percent. However, soil conserved increased only slightly with increasing grass strip width. Thus, for the conditions examined, the model indicates that the grass strips increased the soil conserving effects of the diversions relatively little.

The soil losses that were predicted using 1984 rainfall data are shown in the bottom half of Table 3. The trends of the soil losses were similar to those of 1982, although the amounts were generally less. Average annual soil losses for some runs of the grass-strip-plus-diversion case were also computed using the Universal Soil Loss Equation (Wischmeier and Smith, 1978). The soil losses, shown in Table 4, were computed using R = 510.6 $\mathrm{MJ \cdot mm \cdot ha^{-1} \cdot h^{-1} \cdot yr^{-1}}$ (300), K=.053 $\mathrm{t \cdot h \cdot MJ^{-1} \cdot mm^{-1}}$(0.4), C=0.27, and P=1.0 (typical U. S. units), the same values used in the CREAMS analysis except for R and C. The soil losses without a diversion were computed using the entire slope length, while the losses with a diversion were computed using half this length.

The predicted soil loss for the example field at 1 percent slope (LS = 0.22) without a diversion was greater using the USLE (16 t/ha) than

Table 4. Average annual soil losses for the Grass-Strip-Plus-Diversion case predicted using the USLE.

Field Slope (1)	Grass Width (2)	Field Average W/o dv (3)	Field Average W/dv (4)	Field Average Cons[a] (5)	Lower Area W/o dv (6)	Lower Area W/dv (7)	Upper Area W/o dv (8)	Upper Area W/dv (9)
(%)	(m)	(t/ha)[b]	(t/ha)	(t/ha)	(t/ha)	(t/ha)	(t/ha)	(t/ha)
1.0	0	16.0	13.1	2.9	18.9	13.1	13.1	13.1
3.0	0	35.6	29.0	6.6	42.2	29.0	29.0	29.0

[a] Difference in soil loss rates without (W/o dv) and with (W/dv) a diversion.

[b] Metric tons per hectare; t/ha ÷ 2.24 = ton/acre.

CREAMS (4 to 7 t/ha). The corresponding USLE soil loss of 35.6 t/ha for a 3 percent slope (LS = 0.49) was within the range of the CREAMS 1982 and 1984 soil losses (39.3 and 26.8 t/ha). These annual soil losses cannot be directly compared because the USLE is based on a long term average and the CREAMS model on a given year; however, estimates of the same magnitude would be expected. The soil-conserved values were slightly lower for CREAMS at 1 percent slope, but at 3 percent slope, the CREAMS-predicted soil conserved was 1.5 to 2.3 times the corresponding USLE soil conserved. Much of this was attributed to the CREAMS model predicting deposition in the diversion.

DISCUSSION

Because the CREAMS model has the capability to consider specific site characteristics and to estimate sediment deposition and concentrated flow erosion, it has the potential for predicting the soil loss reduction resulting from such practices as the installation of a diversion. Also, because crop parameters can be changed at given distances along the overland flow length, the CREAMS model can be used to analyze the effects of practices such as grass strips. Other useful features of CREAMS include the capability to simulate erosion processes on complex slopes, thereby predicting where soil deposition and erosion will occur and their effects on sediment-size distributions. The model can also simulate soil loss by storm or month.

Results from the CREAMS model as with any model need to be examined to determine if they predict soil losses that are realistic for the conditions studied. Although individual soil losses predicted in these examples seem reasonable, the difference between the soil losses without and with a diversion was the main purpose of the analysis. This difference will help to evaluate a proposed diversion's effectiveness at reducing soil loss on the area under consideration.

The CREAMS model was not designed for the applications described, yet it is versatile enough to be adapted for these and additional purposes. This paper describes one approach for evaluating the effect of diversions and grass strips using CREAMS, and reports the results of several examples using the approach. It also identifies some of the problems and questions that need to be addressed as the model is developed further and applied to conditions peripheral to its primary intended uses.

SUMMARY

The CREAMS model was used to evaluate the effect of installing a diversion on annual soil losses for several typical cropping and topographic conditions. For the pasture-above-cropped-bottomland case, predicted soil loss reductions resulting from a diversion ranged from 1 to 20 t/ha for pasture steepnesses of 2 to 12 percent. Most of the reduction in soil loss occurred on the bottomland field of soybeans, because the diversion prevented pasture runoff from contributing to concentrated-flow erosion on the bottomland.

In the grass-strip-plus-diversion case, a 3- or 9-m grass strip was combined with a diversion to examine their combined effects on predicted soil losses from a 180-m long field of 1 and 3 percent uniform slopes. The reduction in the overall soil losses ranged from 1 to 15 t/ha. For the conditions examined, the grass strips added relatively little to the reduction on soil losses resulting from a diversion.

Soil losses for the grass-strip-plus-diversion case were also estimated using the USLE. The USLE-predicted soil losses were generally similar to those predicted by CREAMS. Differences that did occur were attributed to the inability of the USLE to predict deposition and single-year soil losses.

The focus of this paper was to describe a procedure that was developed to evaluate the effects of a diversion on soil loss and to report the type of results obtained from several examples. Further development of the procedure and evaluation of more conditions will be necessary to provide a comprehensive evaluation on the capability of CREAMS to predict the effect of diversions on soil loss.

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REFERENCES

1. Bingner, R. L., C. E. Murphree, and C. K. Mutchler. 1987. Comparison of sediment yield models on various watersheds in Mississippi. ASAE Paper #87-2008, Presented ASAE Summer Meeting, Baltimore, MD.

2. DelVecchio, J. R. and W. G. Knisel. 1982. Application of a field-scale nonpoint pollution model. p. 227-236. Proceedings of the specialty conference on environmentally sound water and soil management. ASCE, Orlando, FL.

3. Foster, G. R. and V. A. Ferreira. 1981. Deposition in uniform grade terrace channels. p. 185-197. Proceedings of the conference on crop production with conservation in the 80's. ASAE, St. Joseph, MI.

4. Foster, G. R., L. J. Lane, and J. D. Nowlin. 1980. A model to estimate sediment yield from field-sized areas: selection of parameter values. p. 193-281. In W. G. Knisel (ed.) CREAMS: A field scale model for Chemicals, Runoff and Erosion from Agricultural Management Systems. Conserv. Res. Rep. 26. USDA-ARS, Washington, D. C.

5. Knisel, W. G. (ed.) 1980. CREAMS: a field scale model for Chemicals, Runoff and Erosion from Agricultural Management Systems. Conserv. Res. Rep. 26. USDA-ARS, Washington, D. C.

6. Smith, R. E. and J. R. Williams. 1980. Simulation of the surface water hydrology. p. 13-35. In W. G. Knisel (ed.) CREAMS: a field

scale model for Chemicals, Runoff, and Erosion from Agricultural Management Systems. Conserv. Res. Rep. 26. USDA-ARS, Washington, D. C.

7. Wischmeier, W. H. and D. D. Smith. 1978. Predicting rainfall erosion losses -- a guide to conservation planning. USDA Agricultural Handbook No. 537. U. S. Government Printing Office, Washington, D. C.

APPENDIX I

Example Applications

In addition to the situations examined in the foregoing report, the following cases were presented by representatives of the Mississippi Soil Conservation Service as examples of typical applications of diversions. Some general comments and recommendations regarding the adaptation of the CREAMS model to these additional situations are given.

Diversion at the Base of a Cropped Slope

The CREAMS model can easily be applied to predict soil losses resulting from basically overland flow erosion on the slopes (Fig. 3) without and with a diversion. The model can also consider stripcropping on the slopes when the primary direction of overland flow is perpendicular to the boundary between the field(s). However, if the primary direction of overland flow is parallel to the field boundary (on the contour) and 2 or more crops are simulated, either a separate run for each crop, or a single run with overland parameters averaged should be made.

A wide range of crops, slope steepnesses, and slope lengths can be simulated by CREAMS. Also, parallel terraces, grass strips, strip cropping, and minimum tillage can be included for selected situations.

Diversion Above the Steepest of a Three-Slope Field

Because of the complex slope capability of the model, the topography of the three-slope field in Fig. 4 can be simulated with only minor simplifications. If only overland flow erosion in the downslope direction is considered,

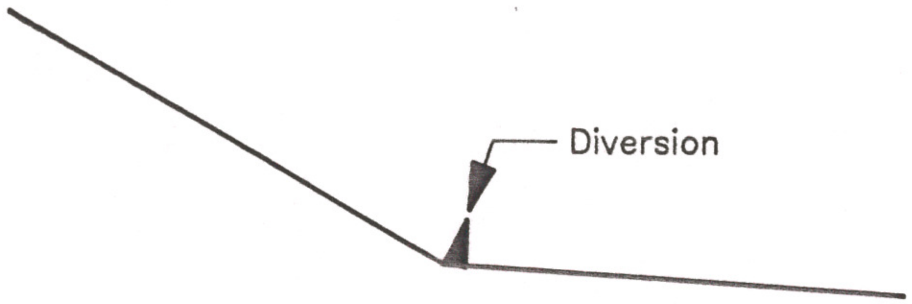

Fig. 3 Example cross-section of a diversion between a sloping hillside and a relatively flat bottomland field.

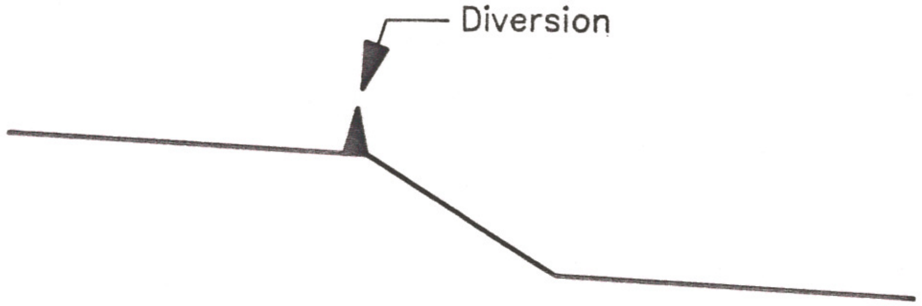

Fig. 4 Example cross-section of a diversion above the steep midsection of a complex slope.

many combinations of crops planted on the contour of each of the three slopes can be input; however, like the previous case, if the primary direction of overland flow is parallel to the crop boundaries, parameter averaging or separate runs would be required. Regardless of the direction of overland flow, the model can predict the quantities and locations of net deposition and erosion occurring on the slopes.

Concentrated Flow on Both Upper and Lower Fields

The situation shown in Fig. 5, where concentrated flow channels begin on the upper field and continue across the bottomland, cannot be simulated as a whole by CREAMS. The model can only simulate one concentrated flow channel per field as was the situation for the pasture-above-cropped-bottomland case reported previously. The model could be used on a representative channel; however, this would exclude combined effects such as when two channels joined into one. Also, channel parameters such as critical shear and Manning roughness can be changed at given distances down the channel. Thus the model can simulate one continuous channel originating on the upper field and continuing across the bottomland, but not two or more of them.

Accelerated Sheet and Rill Erosion

The situation shown in Fig. 6 can be simulated using CREAMS; however, problems occur in determining a representative overland flow slope length, particularly for the runs without a diversion. This problem occurs because the concentrated flow channel is not perpendicular to the primary direction of overland flow, and does not extend over the

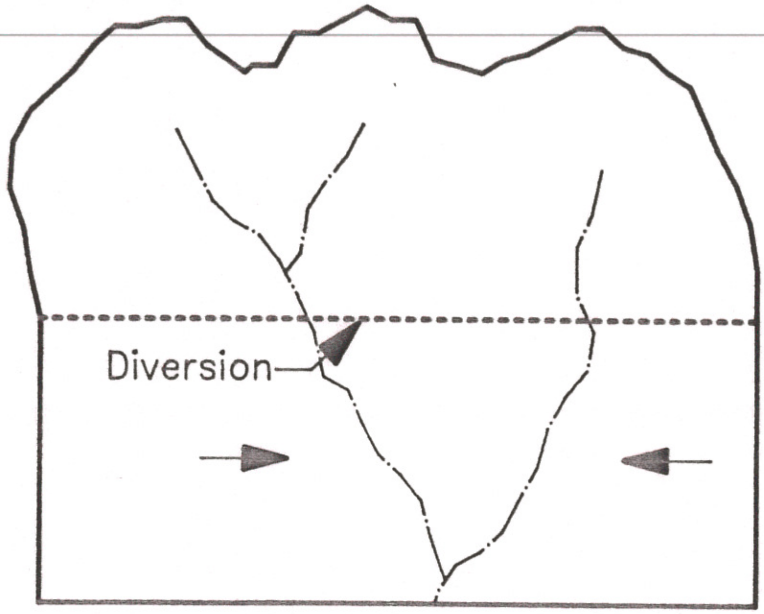

Fig. 5 Top view of example watershed with concentrated flow channels beginning on upper field and continuing across bottomland.

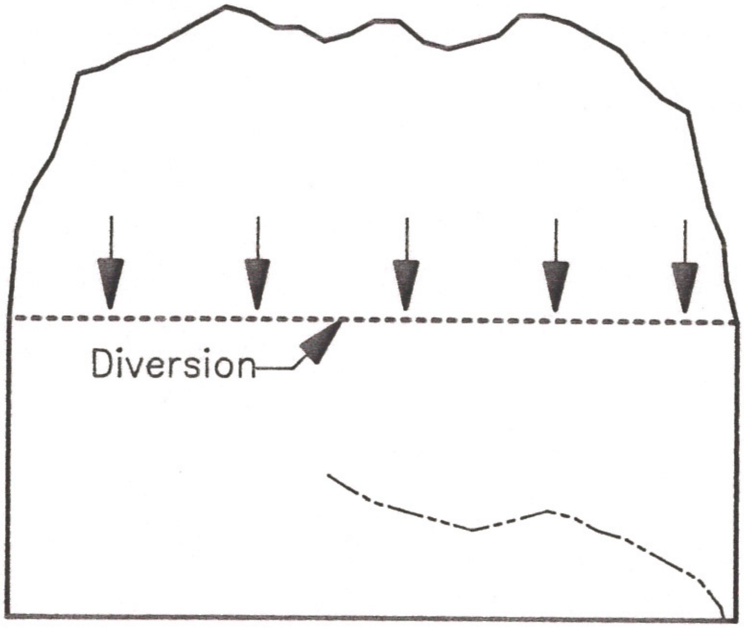

Fig. 6 Top view of example watershed with upper field contributing only overland flow and short concentrated flow channel on bottomland.

entire length of the field; therefore, overland flow lengths vary from one end of the field to the other.

The model has the capability to change sets of crop parameters in the direction of overland flow, which would be required to simulate different crops in the upper and lower fields. Thus, in this situation, parameter averaging is not needed, but averaging of the overland flow lengths to obtain a representative overland flow profile for the entire area would be required.

Diversion Failure or Overtopping

The CREAMS model does not have the capability to simulate the situation in Fig. 7. Although the model can predict overtopping when the quantity of runoff in the diversion channel exceeds its capacity, it lacks the capability to estimate the erosion that would result from this excess runoff flowing across the bottomland field. Physical parameters of the diversion can be changed throughout the year to perhaps simulate a break in the diversion; however, like overtopping, the erosion caused by this could not be estimated.

Outlet Conditions

The CREAMS model has several options to simulate conditions at the outlet of a field channel. For the condition of free overfall, shown in Fig. 8, the critical depth option, which specifies that flow goes through critical depth as it leaves the field channel, should be used. Also, a relatively steep sideslope of the outlet channel could be used to simulate the dropoff at the end of the field.

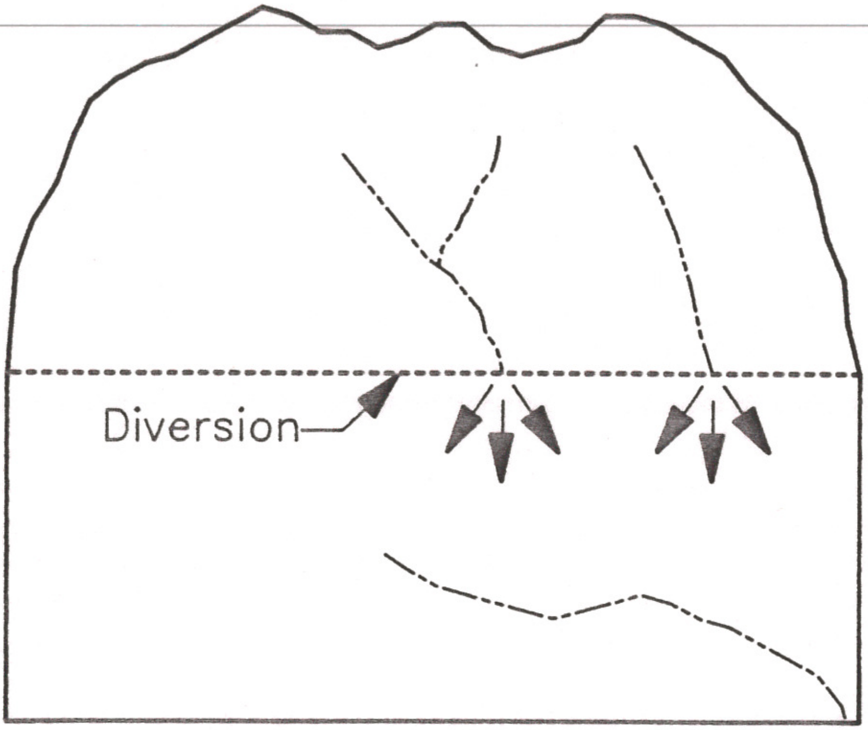

Fig. 7 Concentrated runoff from upper field overtopping or breaking diversion.

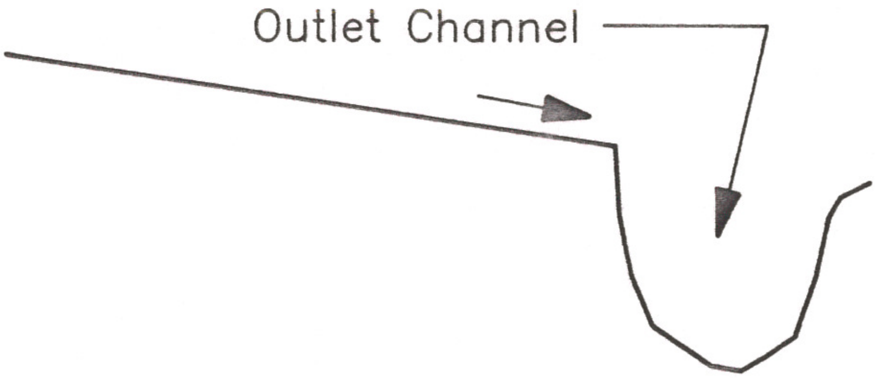

Fig. 8 Free overfall outlet condition.

The second situation (Fig. 9), which involves only overland flow, can be somewhat simulated. The grass buffer can be input and the overfall condition can be simulated by specifying a deep outlet channel with steep sideslopes as in the previous situation. In relation to this situation, the CREAMS model does not predict sloughing of the channel sideslopes.

The third outlet condition (Fig. 10) in which a field channel continues across the field boundary can be simulated by setting the slope of the outlet channel equal to the slope of the field channel. Also, a rating curve or a Manning roughness coefficient can be specific for the outlet channel, thereby approximating backwater conditions at the outlet. A variation of this option was used for the pasture-above-cropped-bottomland example given earlier. In that example, the Manning roughness coefficient was slightly higher and the slope of the outlet channel slightly steeper than those of the field channel.

In some cases, flow depth in the field channel may be less than critical depth before it reaches the outlet. In these cases, the option chosen will have little effect on the estimated soil loss, unless a backwater condition is predicted. However, when flow depth above the outlet of the channel is deeper than critical, choosing the critical depth option will often result in significantly greater predicted soil loss.

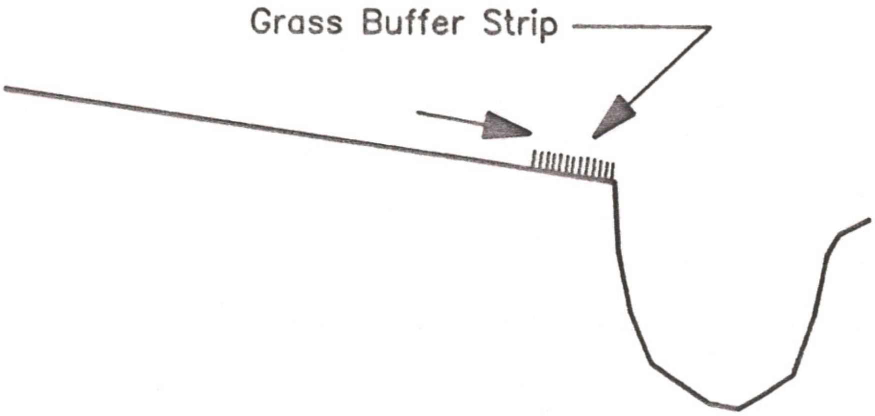

Fig. 9 Free overfall with a grass buffer strip.

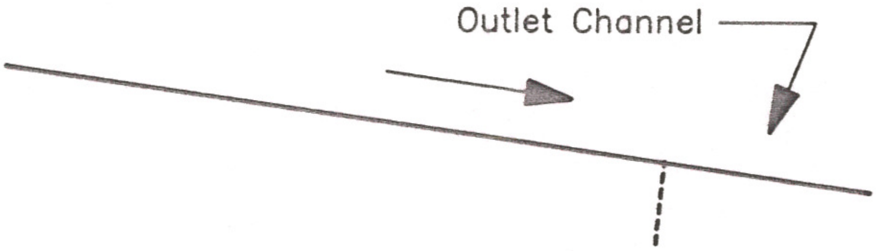

Fig. 10 Outlet channel on same slope as field channel.

APPENDIX II

Example CREAMS Output

```
         C R E A M S  NONPOINT SOURCE POLLUTION MODEL (EROSION/SEDIMENT YIELD)

                           VERSION 1.8/PC MAY 1, 1985

***********************************************************************
 GRASS STRIP PLUS DIVERSION CASE /10' GRASS STRIP BUT NO DIVERSION
 600' UNIFORM 3.0% SLOPE OF SOYBEANS ON LORING SILT LOAM SOIL
 R.F. DATA USED CONSISTED OF ONLY 1 STORM.
***********************************************************************
CARD   4:
     82      82       6       0       0       1       0       0
CARD   5:
   .000    .010    .000    .170    .000    .000
CARD   6:
   .100    .850    .050    .005    .000    .000    .000    .000
CARD   8:
  8.000 600.000    .030    .030    .030    .030 600.000    .000 600.   0

CARD   9:
      1   1.000    .400
CARD  16:
      1
CARD  17:
      1     132     140     161     191     274     300
CARD  18:
      3    .483    .500   1.000
CARD  19:
   .380    .450    .680    .600    .430    .220    .250
CARD  20:
  1.000   1.000   1.000   1.000   1.000   1.000   1.000
CARD  21:
   .025    .046    .010    .012    .012    .032    .025
CARD  19:
   .004    .003    .003    .003    .003    .003    .003
CARD  20:
  1.000   1.000   1.000   1.000   1.000   1.000   1.000
CARD  21:
   .030    .035    .046    .046    .046    .030    .030
CARD  19:
   .380    .450    .680    .600    .430    .220    .250
CARD  20:
  1.000   1.000   1.000   1.000   1.000   1.000   1.000
CARD  21:
   .025    .046    .010    .012    .012    .032    .025
```

```
                    INITIAL CONSTANTS
                    -----------------

     BEGINNING YEAR FOR THIS RUN     82
     WT. DENSITY SOIL (IN PLACE)   96.0     LBSF/FT**3
     WT. DENSITY WATER             62.4     LBSF/FT**3
     MASS DENSITY WATER             1.94    SLUGS/FT**3
     ACC. DUE TO GRAVITY           32.2     FT/SEC**2
     KINEMATIC VISCOSITY         .121E-04   FT**2/SEC
     MANNING N BARE SOIL (OVER)     .010
     MANNING N BARE SOIL (CHAN)     .030
     CHANNEL ERODIBILITY FACTOR     .170
                (LBS/FT**2 SEC)/(LBS/FT**2)**1.05
     YALIN CONSTANT (ALL PART.)     .635
     MOMENTUM COEFF. FOR
     NONUNIFORM VELOCITY
     IN CROSS SECTION              1.56    (NO UNITS)
  +++++++++++++++++++++++++++++++++++++++++++++++++++++++

       AND ORGANIC MATTER IN THE ORIGINAL SOIL MASS
       --------------------------------------------
          TYPE        FRACTION      SPECIFIC SURFACE
       ----------     --------      ----------------
                                    (M**2/G OF SOIL)
          CLAY          .100             20.000
          SILT          .850              4.000
          SAND          .050               .050
                                (M**2/G OF ORGANIC CARBON)
      ORGANIC MATTER    .005           1000.000

          (ORGANIC CARBON = ORGANIC MATTER/1.73)

  INDEX OF SPECIFIC SURFACE    8.27 M**2/G OF TOTAL SOIL,


                  PARTICLE SPECIFICATIONS
                  -----------------------

TYPE      DIA.     EQSAND DIA.  FALL VEL.    SPGRAV.    FRAC. IN
 NO.       MM          MM        FT/SEC     GM/CM**3  DETACH. SED.
----     ------      ------    ----------    ------     -------
  1       .002        .002      .102E-04      2.60        .02
  2       .010        .010      .263E-03      2.65        .11
  3       .030        .020      .125E-02      1.80        .20
  4       .200        .115      .341E-01      1.60        .63
  5       .200        .201      .759E-01      2.65        .04
                   PARTICLE COMPOSITION
                   --------------------

   TYPE              PRIMARY PARTICLE FRACTIONS
    NO.      CLAY        SILT        SAND      ORGANIC MATTER
   ----     ------      ------      ------     --------------
     1      1.000        .000        .000           .050
     2       .000       1.000        .000           .000
     3       .105        .895        .000           .005
     4       .093        .888        .018           .005
     5       .000        .000       1.000           .000
```