#224

Purchased By
U. S. Department of Agriculture
For Official Use

Use of the universal soil loss equation in the semiarid Southwest

H. B. Osborn, J. R. Simanton, and K. G. Renard

U. S. scientists have been developing methods for estimating erosion and sedimentation for several years. Recent increased awareness of the need for pollution abatement has accelerated these efforts. At the Southwest Watershed Research Center, emphasis has been placed on measuring and developing methods for estimating erosion and sedimentation on semiarid rangelands subjected to high intensity thunderstorms. Among the methods tested was the universal soil loss equation, developed to estimate average annual erosion losses from croplands in the Midwest (*12*, *13*).

For the past 3 years, good estimates of rainfall, bed load, suspended sediment, and channel aggradation and degradation have been made for five small waterhseds on the Walnut Gulch Experimental Watershed near Tombstone, Arizona. Preliminary findings (based on 1 year's data) from two of the five watersheds suggested that a channel erosion term, E_c, was needed in the universal soil loss equation to explain the different sediment yields from watersheds with different channel characteristics (*6*, *7*). This term might reflect both the efficiency of the channel transmission of eroded material from the watershed to the outlet and the erosion within the channel itself.

Now that we have collected 2 more years of data, we can make more definite conclusions and recommendations concerning possible applications and problems in using the equation to estimate soil losses in the Southwest.

Experimental Watersheds

Data in this report are based on 3 years of records from five very small (0.5 to 11 acres, 0.20 to 4.5 hectares) rangeland watersheds. Four watersheds, 101 (2.8 a, 1.1 ha), 103 (8.3 a, 3.4 ha), 104 (11 a, 4.5 ha), and 105 (0.6 a, 0.2 ha), are mainly brush covered (Figures 1, 2, and 3). The watersheds, except 105, were measured with broad-crested, V-notch weirs; runoff from watershed 105 was measured by a 3-foot (.9 meter) H-flume. We estimated bed loads with sediment traps that we cleaned and surveyed after

---

H. B. Osborn is a research hydraulic engineer, J. R. Simanton is an hydrologist, and K. G. Renard is a research hydraulic engineer at the Southwest Watershed Research Center, Agricultural Research Service, U.S. Department of Agriculture, Tucson, Arizona 85705.

Reprinted from *Soil Erosion: Prediction and Control*
Copyright © 1976
Soil Conservation Society of America
Ankeny, Iowa

Figure 1. Looking up the channel on watershed 103.

Figure 2. Looking up the channel on watershed 104.

Figure 3. Looking up the channel on watershed 105.

each runoff event. We sampled suspended sediment with a bottom pivot, slot-type Chickasha pump sampler, modified for sampling in flashy ephemeral streams.

Applying the Universal Soil Loss Equation

Wischmeier (*10*), in a discussion of the uses and misuses of the universal soil loss equation, indicated that the equation could be used to estimate average soil loss from a particular slope segment represented by the selective topographic factor. He also indicated possible sources of error in each of the five parameters, as well as in the varying, hard-to-quantify conditions affecting each parameter.

Rainfall Erosion Index Factor (R)

Estimating the rainfall erosion index factor, R, in the equation is very difficult in the western United States, where precipitation varies greatly in both time and space. Also, because most mountain ranges have wide orographic influences that add to rainfall variability, Wischmeier and Smith (*13*) concentrated on croplands east of the western mountain ranges. However, there have been several attempts recently to define R for conditions in the western United States.

The most recent effort was a joint Agricultural Research Service/Environmental Protection Agency manual (*9*) for controlling water pollution from croplands. Since sediment is the greatest pollutant, considerable effort was spent on estimating erosion and sediment production. The report has an isoerodent map with which to estimate R and gives tables of values for the other parameters in the equation. As indicated on the map, the R factor for the Walnut Gulch watershed is about 60.

Ateshian (*1, 2*), who also investigated the R factor for the western United States, estimated the annual rainfall erosion index using 2-year, 6-hour precipitation data from the

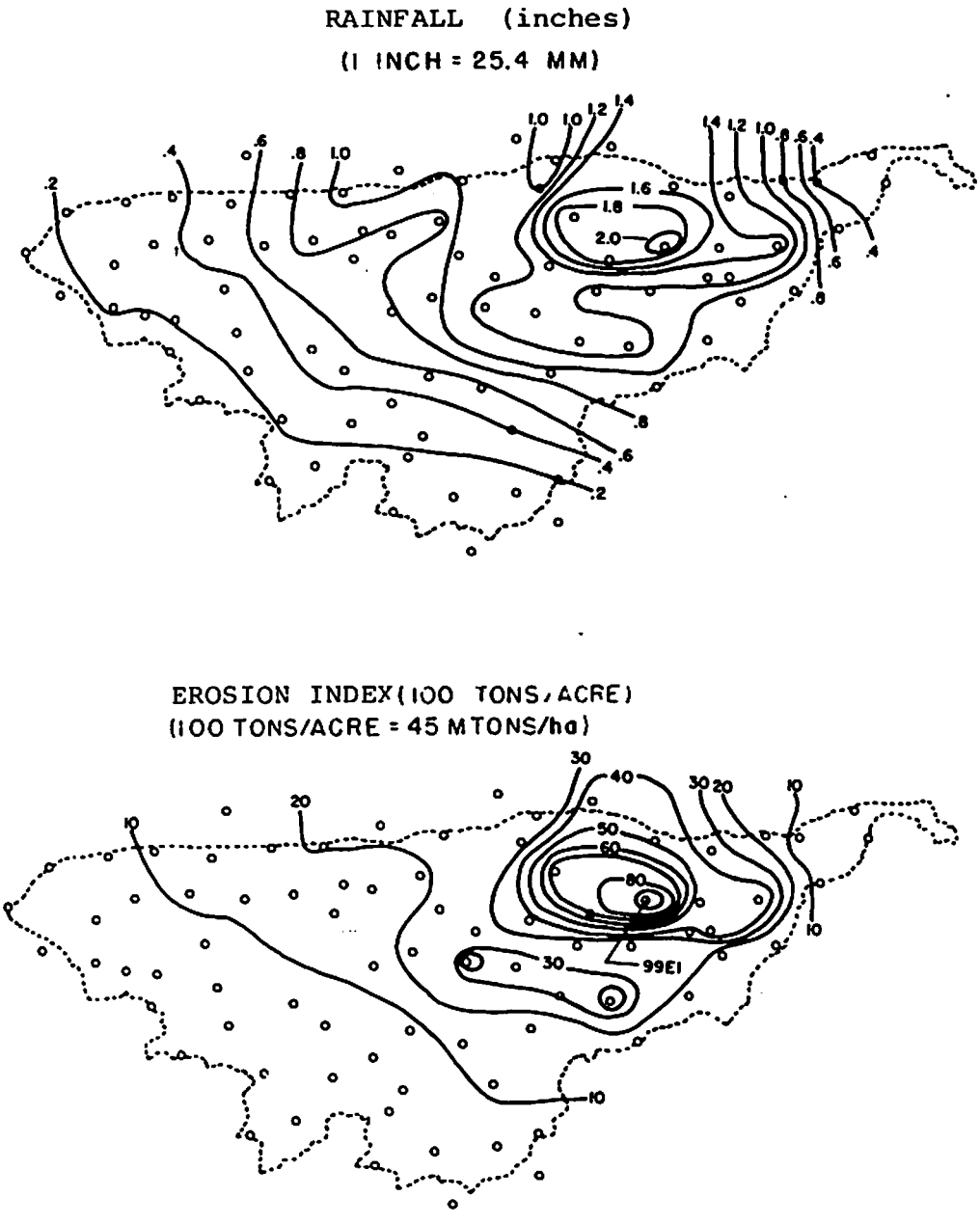

Figure 4. Isophyetal and isoerodent index maps for the July 22, 1964, storm on the Walnut Gulch Experimental Watershed. Each small circle represents the location of a recording rain gage.

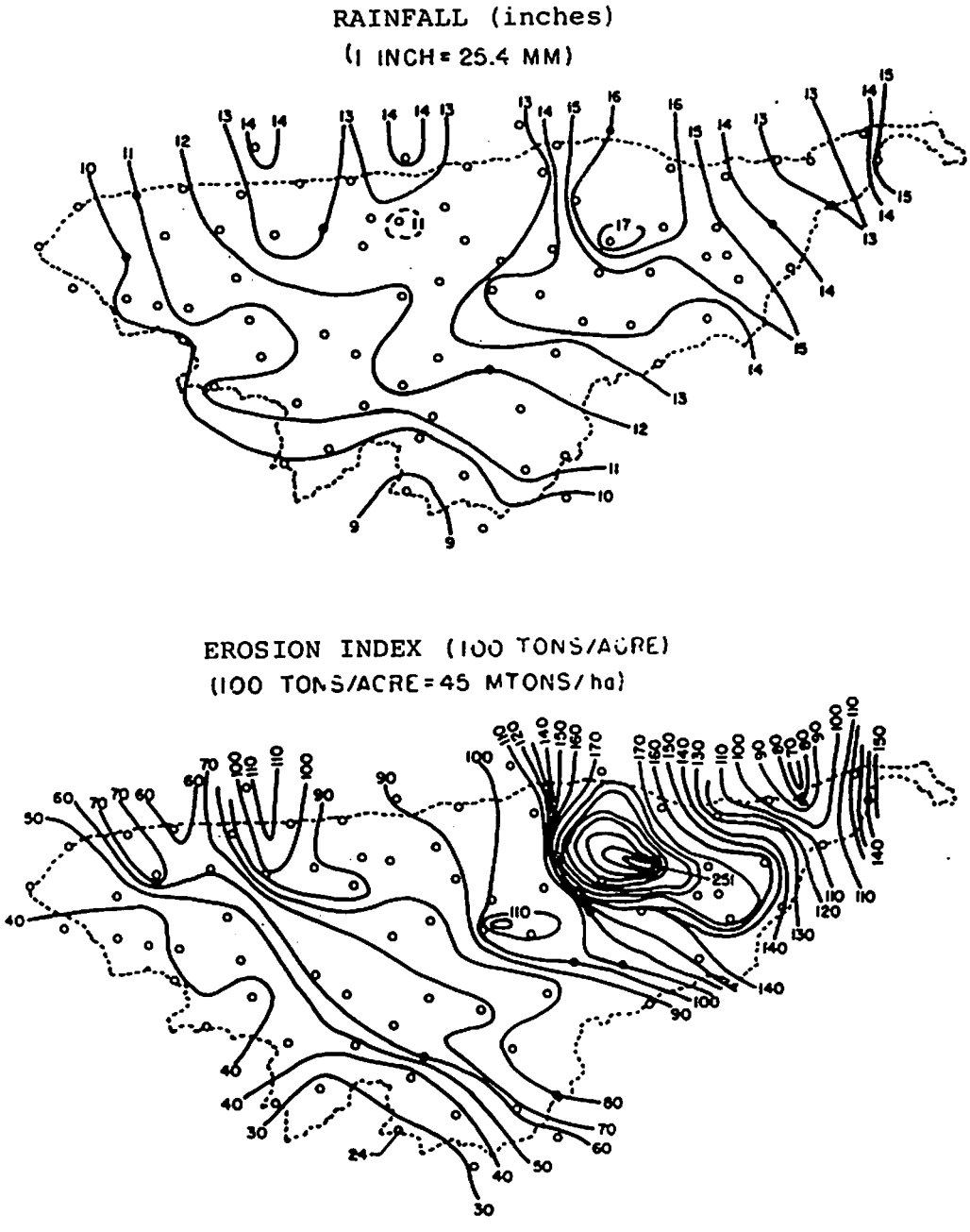

Figure 5. Isophyetal and isoerodent index maps for 1964 annual totals on the Walnut Gulch watershed.

National Weather Service. He calculated an R factor of about 85 for Walnut Gulch, compared with 70 based on 15 years of Walnut Gulch rainfall data.

Renard (*4*) and Renard and Simanton (*5*), who discussed Ateshian's 1974 article, pointed out that the 2-year, 6-hour precipitation values may not be a good measure of R for the Southwest, where short-duration thunderstorms dominate runoff. Also, Renard and Simanton (*6*) showed the extreme spatial and temporal variability in the rainfall erosion index associated with a typical thunderstorm rainfall (Figures 4 and 5).

Thunderstorm rainfall is highly variable, intense, and of limited areal extent. Point estimates of R should be used only in the immediate area surrounding them for estimating seasonal erosion (*6*). Estimates of R based on point measurements can be used for a wider area in estimating average annual erosion. For a small complex of watersheds, like Lucky Hills (four watersheds covering about 20 a, 8 ha), seasonal R values probably vary less than 10 percent over the area [based on a precipitation-gaging study by Osborn, Lane, and Hundley (*3*)]. Therefore, the EI index does not explain differences in measured sediment yield from the four watersheds.

Soil Erodibility Factor (K)

The soil erodibility factor, K, initially seems to be the most consistent factor in the equation. In the Southwest, however, surface soil conditions vary during the season because of both moisture distribution and watershed land use (e.g. whether the watershed is grazed). Because of the paucity of data on K values for soils in the Southwest, we used the soil nomograph procedure (*11*) to determine the K factor for soil types on the five watersheds.

Slope Length and Steepness (LS)

Slope length and steepness, LS, is also a difficult parameter to evaluate because slopes tend to be badly broken on rangeland watersheds. On Walnut Gulch, we attempted to be consistent in determining slope lengths, but 100 percent errors were possible.

Cover and Management Factor (C)

Possibly the greatest uncertainty in using the universal soil loss equation in the Southwest is in determining C, the cover and management factor. If only rangeland vegetation is considered, ground cover is very low, and C is very high. However, watersheds, such as Walnut Gulch, have erosion pavements that protect the soil from direct raindrop impact and surface runoff erosion (Figure 6). The erosion pavement is extensive on all Lucky Hills watersheds. In places it almost completely covers the surface. Such pavements, however, allow runoff to be concentrated between pebbles, thus possibly increasing the erosion potential wherever water reaches the soil surface.

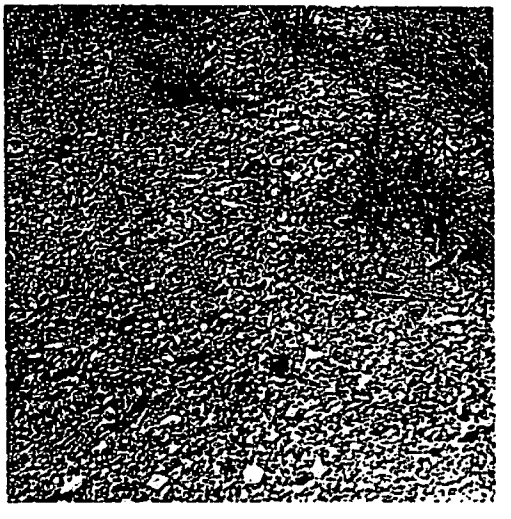

Figure 6. Erosion pavement on watershed 105.

For Lucky Hills (centrally located on Walnut Gulch), we assumed from measured rock and gravel cover that the erosion pavement was a part of the cover. This provided about 60 percent ground cover on all four watersheds, which led to an estimate of C = 0.038 (*8*). More research is needed here because, if the erosion pavement provides only 40 percent ground cover, for example, the estimated soil loss more than doubles.

With our estimated values for the parameters (Table 1), we predicted the sediment yields from the five watersheds (Table 2).

Table 1. Universal soil loss equation parameters for five very small rangeland watersheds in southeastern Arizona.

Site	K	LS	C	P
101	0.09	0.8	.038	1
103	0.10	1.2	.038	1
104	0.085	1.2	.038	1
105	0.12	0.9	.038	1
112	0.085	2.8	.012	1

Results

For all watersheds, except 104, there seems to be very little actual sediment accumulation in the channels above the sampling stations. For 1973 to 1975, about 7 tons (6.3 MT) accumulated at the intersection of two channels immediately above the sediment traps at watershed 104, thus adding an average 0.21 tons per acre per year (0.09 metric tons/ha/yr) to that actually measured.

The actual sediment yields for 3 years on watersheds 103 and 104 were, respectively, seven and three times that of watershed 101, compared with predicted values of 1.7 and 1.4 times that of watershed 101.

Based on 1 year (1975) of data, watersheds 103 and 104 had actual sediment yields about 5.3 and 1.8 times that of watershed 101, although the predicted yields were 1.2 and 1.1 times those of watershed 101. For 1975 the equation underestimated the sediment yield for watershed 105--1.5 times that predicted for watershed 101, compared with a measured sediment yield of 5.2 times.

In spite of Wischmeier's warning about using the equation to predict single storm erosion (*10*), we examined actual versus predicted sediment yields during individual events (Figure 7). In general, predicted and actual sediment yields varied similarly for individual events, suggesting that the channels pass sediment efficiently; therefore, the relatively short data record for Walnut Gulch may provide a better-than-expected measure of erosion from these small semiarid watersheds.

In general, the universal soil loss equation seemed to overpredict sediment yields from brush-covered watersheds for years with only smaller events, as suggested by data from watershed 101. Years with larger events seem to be underpredicted. On the grass-covered watershed (112), predicted values were higher than actual values, but both the number and intensities of rainfall events were less than those on the brush-covered watersheds (101 to 104). The annual R values were considerably higher on the brush-covered watersheds for the 3 years of data, but a longer rainfall record (over 15 years) on Walnut Gulch indicated that the average annual values would be the same.

Influence of Channels

Watersheds 103 and 104 are similar in size, soils, and cover, but their channels differ markedly. Watershed 103 has a straight, incised central channel (Figure 1), whereas 104 has a meandering channel with more gently sloping stabilized banks (Figure 2). Exposed roots along the channels of watershed 103 suggest much higher soil losses than along the channels of

Table 2. Average annual soil loss (tons/acre) from five very small Walnut Gulch watersheds (1 ton/acre X 0.446 = metric tons/hectare).

Year	R	101 (2.8 Acres) Predicted	101 (2.8 Acres) Actual	103 (8.3 Acres) Predicted	103 (8.3 Acres) Actual	104 (11 Acres) Predicted	104 (11 Acres) Actual	105 (0.6 Acres) Predicted	105 (0.6 Acres) Actual	R	112 (4.6 Acres) Predicted	112 (4.6 Acres) Actual
1973	64	.18	.10	.29	1.00	.25	.34	-	-	22	.06	.00
1974	79	.22	.06	.36	2.10	.30	.82	-	-	77	.22	.02
1975	185	.51	.72	.85	3.83	.72	1.29	.76	3.52	53	.15	.04
Average	110	.30	.29	.50	2.31	.42	.82	-	-	50	.14	.02
ARS/EPA	60	.16		.27		.23		.25			.17	

watershed 104. Renard, Simanton, and Osborn (7) hypothesized that the apparent difference in sediment yield between these two watersheds was because of watershed 103's greater channel bank erosion; and they introduced a sixth parameter, the channel factor, E_c, to account for the differences. The same approximate difference was evident after 3 years of data; there was still about three times more sediment from 103 than from 104. In 1975 we collected sediment for the first time from watershed 105, which does not have an incised channel, and found that this watershed also apparently produced about three times more sediment than did watershed 104. Watershed 105 has a very clean, efficient channel system. The differences between adjacent watersheds in Lucky Hills may possibly be due, at least in part, to the efficiency of the channels in moving the eroded material, rather than the direct contribution of soil from the channel banks. A precise survey of the channels on watersheds 103, 104, and 105, before and after the 1976 runoff season, might help explain these differences and determine whether a channel factor is warranted or useful.

Conclusions

Since rangelands comprise the largest single land classification, results from predicting sediment yields from them would have wide application. The relatively small but well-instrumented effort at Walnut Gulch indicated that the universal soil loss equation has possible applications for predicting sediment yields from small rangeland watersheds. For 3 years of record on five small watersheds, predicted versus measured sediment yields varied similarly with different rainfalls.

The equation was developed for ungullied rangelands. Gullies (channels) apparently play a strong role in sediment yield on even the smallest rangeland watersheds, and

a channel factor (E_c) has been suggested to account for this role. Current records indicate that such a factor can reduce the differences between predicted and measured sediment yields. However, more data are needed to establish the necessity for such a factor and to determine its actual role.

Recommendations

1. Continue experimental studies on the five small instrumented watersheds at Walnut Gulch.
2. Consider establishing several similar stations on the Alamagordo Creek watershed to take advantage of a different climatic regime.
3. Make very precise channel surveys on the Walnut Gulch watersheds before and after the 1976 runoff season to determine the role of channel character in sediment production and movement and to evaluate and apply the parameter, E_c, to the universal soil loss equation.
4. Study the effects of erosion pavement on the C parameter to assist in parameter value assignments.

REFERENCES CITED

1. Ateshian, K. H. 1974. *Estimation of rainfall erosion index.* Am. Soc. Civil Eng., J. Irrigation and Drainage Div., 100 (IR3): 293-307.

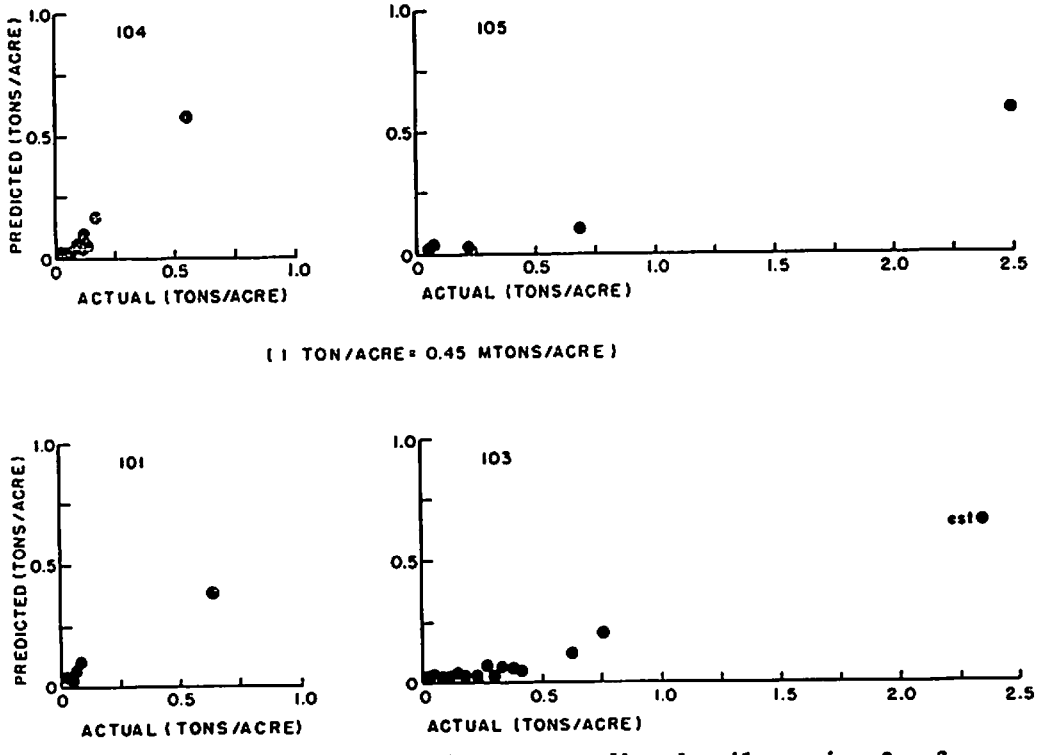

Figure 7. Actual sediment yield versus predicted soil erosion for four small brush-covered semiarid rangeland watersheds.

2. Ateshian, K. H. 1975. *Cooperative costs of erosion and sedimentation control measures.* Proc., Third Fed. Interagency Sedimentation Conf. Sedimentation Comm., Water Resources Coun., Washington, D. C. pp. 2.13-2.23.
3. Osborn, H. B., L. J. Lane, and J. F. Hundley. 1972. *Optimum gaging of the thunderstorm rainfall in southeastern Arizona.* Water Resources Res. 8(1): 259-265.
4. Renard, K. G. 1975. *Discussion of paper "Estimation of rainfall erosion index."* Am. Soc. Civil Eng., J. Irrigation and Drainage Div. 101 (IR3): 240-241.
5. Renard, K. G., and J. R. Simanton. 1975. *Discussion of paper "Estimation of rainfall erosion index."* Am. Soc. Civil Eng., J. Irrigation and Drainage Div. 101 (IR3): 242-247.
6. Renard, K. G., and J. R. Simanton. 1975. *Thunderstorm precipitation effects on the rainfall-erosion index of the universal soil loss equation.* Proc., Ariz. Sec., Am. Water Resources Assoc., Hydrol. Sec. Ariz. Acad. Sci. 5: 47-54.
7. Renard, K. G., J. R. Simanton, and H. B. Osborn. 1974. *Applicability of the universal soil loss equation to semiarid rangeland conditions in the southwest.* Proc., Ariz. Sec., Am. Water Resources Assoc., Hydrol. Sec. Ariz. Acad. Sci. 4: 18-32.
8. Soil Conservation Service, U.S. Department of Agriculture. 1972. *Procedures for computing sheet and rill erosion on project areas.* Tech. Rel. No. 51, Geol. Washington, D. C. 14 pp.
9. Stewart, B. A., D. A. Woolhiser, W. H. Wischmeier, J. H. Caro, and M. H. Frere. 1975. *Control of water pollution from cropland.* Vol. 1. U.S. Environmental Protection Agency, Washington, D. C. 111 pp.
10. Wischmeier, W. H. 1976. *Use and misuse of the universal soil loss equation.* J. Soil and Water Cons. 31(1): 5-9.
11. Wischmeier, W. H., C. B. Johnson, and B. V. Cross. 1971. *A soil erodibility nomograph for farmland and construction sites.* J. Soil and Water Cons. 26(5): 189-192.
12. Wischmeier, W. H., and D. D. Smith. 1958. *Rainfall energy and its relationship to soil loss.* Trans., Am. Geophys. Union 39(2): 285-291.
13. Wischmeier, W. H., and D. D. Smith. 1965. *Predicting rainfall-erosion losses from cropland east of the Rocky Mountains.* Agr. Handbook 282. U.S. Dept. Agr., Washington, D. C. 47 pp.