APPENDIX B. CALCULATION OF EI FROM RECORDING-RAINGAGE RECORDS

The energy of a rainstorm can be computed from recording-raingage data. The storm is divided into successive increments of essentially uniform intensity, and a rainfall energy-intensity equation (for example, equations [B-3] and [B-5]) is used to compute the energy for each increment. Because the energy equation and energy-intensity table have been frequently published with energy expressed in ft · tonf · acre^{-1}, this unit was retained in table B-1. However, for computation of EI values, storm energy is expressed in hundreds of foot-tons per acre. Therefore, energies computed by the published formula or by table B-1 must be divided by 100 before multiplying by I_{30} to compute EI.

Soil-loss prediction with USLE does not require the computation of EI values by application personnel, but the procedure is included here for the benefit of those who may wish to compute them.

Mathematically, R is

$$R = \frac{1}{n} \sum_{j=1}^{n} \left[\sum_{k=1}^{m} (E) \left(I_{30}\right)_k \right] \qquad [B-1]$$

where
E = total storm kinetic energy,
I_{30} = maximum 30-min rainfall intensity,
j = index of number of years used to produce average,
k = index of number of storms in each year,
n = number of years used to obtain average R,
m = number of storms in each year, and
R = average annual rainfall erosivity.

$$EI = (E) \left(I_{30}\right) = \left(\sum_{k=1}^{m} e_r \, \Delta V_r \right) I_{30} \qquad [B-2]$$

where

e_r = rainfall energy per unit depth of rainfall per unit area ft · tonf · acre^{-1} · in^{-1}, and

ΔV_r = depth of rainfall for the rth increment of the storm hyetograph which is divided into m parts, each with essentially constant rainfall intensity (in).

Unit energy, e, is a function of rainfall intensity and is computed as

$$e_k = 1099 \left[1 - 0.72 \exp \left(-1.27 i_r \right) \right] \quad \text{[B-3]}$$

and

$$i_r = \frac{\Delta V_r}{\Delta t_r} \quad \text{[B-4]}$$

where

Δt_r = duration of the increment over which rainfall intensity is considered to be constant (h), and

i_r = rainfall intensity (in · h^{-1}).

The unit energy equation [B-3] was suggested by Brown and Foster (1987) as a replacement to the relationship used in Agriculture Handbook 537 because the equation not only includes more data for its development but also has a better functional form at low intensities. Equation [B-3] was used for the preparation of the isoerodent maps in the western United States whereas the isoerodent maps in the eastern United States were calculated using the following equation:

$$e_k = 916 + 331 \log_{10}(i_r) \quad \text{[B-5]}$$

We do not recommend using equation [B-5] for future calculations of unit energy.

The EI for a specified time period (such as the annual value) is the sum of the computed value for all rain periods within that time. Thus

$$R = \sum EI_{30}\left(10^{-2}\right) \qquad \text{[B-6]}$$

where

R = average annual rainfall erosivity in

$$\frac{\text{hundreds of ft} \cdot \text{tonf} \cdot \text{in}}{\text{acre} \cdot \text{h} \cdot \text{yr}}$$

and the division by 100 is made for convenience of expressing the units.

In the western United States, all storms were included in the calculation of R, except storms where the precipitation occurred as snow. Erosion index calculations in the eastern United States were computed for storms exceeding 0.5 in of precipitation. Rains of less than 0.5 in, separated from other showers by 6 h or more, were omitted as insignificant unless the maximum 15-min intensity exceeded 0.95 in $\cdot$ h^{-1}.

Sample Calculation of EI From Recording-Raingage Records

The kinetic energy of a given amount of rain depends on the sizes and terminal velocities of the raindrops, and these are related to rainfall intensity. The computed energy per inch of rain at each intensity is obtained by solving equations [B-3] and [B-4], or by using table B-1 and reading energy values for the intensity obtained from the recording raingage. The energy of a given storm depends on all the intensities at which the rain occurred and the amount that occurred at each intensity. A recording-raingage record of the storm will provide this information. Clock time and rain depth are read from the chart at each point where the slope of the pen line (from a cumulative record) changes, and are tabulated as shown in the first two columns of the sample computation in table B-2. Clock times (col. 1) are subtracted to obtain the time intervals given in column 3, and the depths (col. 2) are subtracted to obtain the incremental amounts tabulated in column 4. The intensity for each increment (col. 5) is the incremental amount times 60, divided by column 3.

The energy per inch of rain in each interval (col. 6) is obtained by entering table B-2 with the intensity given in column 5 or by solving equations [B-3] and [B-4]. The incremented energy amounts (col. 7) are products of columns 4 and 6. The total energy for this 90-min rain is 1,254 ft $\cdot$ tonf $\cdot$ $acre^{-1}$. This is multiplied by a constant factor of 10^{-2} to convert the storm energy to the dimensions in which EI values are expressed.

The maximum amount of rain falling within 30 consecutive minutes was 1.08 in, from 4:27 to 4:57. I_{30} is twice 1.08, or 2.16 in · h^{-1}. The storm EI value is 12.54(2.16) = 27.1. When the duration of a storm is less than 30 min, I_{30} is twice the amount of rain.

Comparison of the new unit energy relationship (eq. [B-3]) with the one from Agriculture Handbook 537 (eq. [B-5]) shows less than a 1% difference in the energy of some sample storms (see tables B-3 and B-4).

Table B-1.
Kinetic energy of rainfall expressed in ft · tonf · acre^{-1} · in^{-1}

Intensity (in/h)	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	308	318	328	337	347	356	366	375	384	393
0.1	402	411	420	428	437	445	453	461	469	477
.2	485	493	501	508	516	523	530	537	545	552
.3	558	565	572	579	585	592	598	604	611	617
.4	623	629	635	641	646	652	658	663	669	674
.5	680	685	690	695	700	705	710	715	720	725
.6	730	734	739	743	748	752	757	761	765	770
.7	774	778	782	786	790	794	798	801	805	809
.8	813	816	820	823	827	830	834	837	840	843
.9	847	850	853	856	859	862	865	868	871	874
1.0	877	903	927	947	956	981	995	1,008	1,019	1,028
2.0	1,037	1,044	1,051	1,056	1,061	1,066	1,070	1,073	1,076	1,079
3.0	1,081									

Table B-2.
Sample calculation of storm EI_{30}

Chart readings		For each increment			Energy	
Time	Depth (in)	Duration (min)	Amount (in)	Intensity ($in \cdot h^{-1}$)	Per inch	Total
4:00	0.00					
:20	.05	20	0.05	0.15	445	22
:27	.12	7	.07	.6	730	51
:36	.35	9	.23	1.53	985	227
:50	1.05	14	.7	3	1081	757
:57	1.2	7	.15	1.29	945	142
5:50	1.25	8	.05	.38	611	31
:15	1.25	20	0	0	308	0
:30	1.3	15	.05	.2	485	24
Total		90	1.30			1,254

Total storm $EI_{30} = 1{,}254(10^{-2})(2.16) =$ 27.09 hundred $ft \cdot tonf \cdot in \cdot acre^{-1} \cdot h^{-1}$.

Table B-3.
Sample calculation of storm EI for storm of July 22, 1964, at raingage 63.056, using revised equation [B-3] for computing rainfall energy

Chart readings		For each increment			Energy	
Time	Depth (in)	Duration (min)	Amount (in)	Intensity ($in \cdot h^{-1}$)	Per inch	Total
18:15	0					
:19	.35	4	0.35	5.25	1,081	378
:22	.47	3	.12	2.4	1,061	127
:27	1	5	.53	6.36	1,081	573
:30	1.62	3	.62	12.4	1,081	670
18:45	2.06	15	.44	1.76	1,015	447
Total		30	2.06			2,195

Table B-4.
Sample calculation of storm EI for storm of July 22, 1964, at raingage 63.056, using original equation [B-5] for computing rainfall energy

Chart readings		For each increment			Energy	
Time	Depth (in)	Duration (min)	Amount (in)	Intensity ($in \cdot h^{-1}$)	Per inch	Total
18:15	0					
:19	.35	4	0.35	5.25	1,074	376
:22	.47	3	.12	2.4	1,042	125
:27	1	5	.53	6.36	1,074	569
:30	1.62	3	.62	12.4	1,074	666
18:45	2.06	15	.44	1.76	997	439
Total		30	2.06			2,175