

Environmental Hydrology Chapter 9 Equations:

The Universal Soil Loss Equation, Downstream Sediment Yields, Single Event Sediment Yields

The Universal Soil Loss Equation

The USLE continues to be a widely accepted method of estimating sediment loss despite its simplification of the many variables involved in soil loss prediction. It is useful for determining the adequacy of conservation measures in resource planning, and for predicting nonpoint sediment losses in pollution control programs. The average annual soil loss, as determined by Wischmeier and Smith (1978) can be estimated from the equation

$$A = R K L S C P \quad (9.1)$$

where

- A = average annual soil loss in tons/acre,
- R = rainfall and runoff erosivity index for a geographic location,
- K = soil-erodibility factor,
- LS = slope steepness and length factor,
- C = cover management factor,
- P = conservation practice factor.

In this text, English units are used for *A*, *R*, and *K*. Readers should ensure that if using other sources of information for the USLE, that units are consistent (Foster et al., 1981). Although developed for use in the United States, the procedure is used in many countries and has been the focus of considerable study during the past 30 years. Methods for determining each of the input parameters for the USLE and examples of their use follow.

Downstream Sediment Yields

Sediment delivery ratio (SDR). The USLE estimates gross sheet and rill erosion, but does not account for sediment deposited enroute to the place of measurement, nor for gully or channel erosion downstream. The sediment delivery ratio is defined as the ratio of sediment delivered at a location in the stream system to the gross erosion from the drainage area above that point. This ratio varies widely with size of area, steepness, density of drainage network, and many other factors. For watersheds of 6.4, 320, 3200, and 64,000 acres, ratios of 0.65, 0.33, 0.22, and 0.10, respectively, were suggested as average values by Roehl (1962). The development of new process-based erosion models in GIS environments will enhance the prediction of sediment delivery from watersheds.

Renfro (1975), for the Blackland Prairie Area in Texas, developed the SDR equation:

$$\log_{10} \text{SDR} = 1.8768 - 0.14191 \log_{10} 10A \quad (9.2)$$

where SDR is the sediment delivery ratio (percent of annual erosion) and A is the drainage area in square miles ($A < 100 \text{ mi}^2$).

Numerous other models have been developed. For example the Soil and Water Assessment Tool (SWAT) (Arnold, et al. 1996) considers storm runoff and uses the equation:

$$\text{SDR} = \left[\left(\frac{q_p}{P_r} \right) \left(0.78285 + 0.21716 \frac{Q}{P} \right) \right]^{0.56} \quad (9.3)$$

where SDR is the sediment delivery ratio (fraction of the gross erosion for the event), q_p is the peak runoff rate, and P_r = the peak rainfall rate, P is the rainfall and Q is the runoff depth (all units are mm or mm/hr, although in and in/hr can be used provided a consistent set of units is used for all quantities).

Single Event Sediment Yields

A method called the Modified Universal Soil Loss Equation (MUSLE) (Williams, 1975) illustrates how sediment yields for individual storm events might be obtained:

$$Y = 95(Qq)^{0.56} K LS CP \quad (9.4)$$

where Y is the single storm sediment yield in tons, Q is the storm runoff volume in acre-ft, q is the peak discharge in cfs, and the other terms are the standard USLE factors discussed earlier. The approach has seen widespread application, but should be used with caution as it was developed empirically based on limited data for Texas and the southwestern United States. The procedure should only be used on small watersheds, and considerable judgment is required in selecting an appropriate slope length when determining the *LS* topographic factor. A delivery ratio should not be included if the sediment yield is determined at the outlet of the watershed used to obtain the runoff volume, Q, and the peak discharge, q. However, if a sediment yield estimate is required downstream of the watershed evaluated with the MUSLE, then a delivery ratio would also need to be used. Estimates of Q and q can be obtained by using the procedures presented in chapter 5.