4 Theoretical Basis for SAM.yld Calculations

Purpose

Sediment yield is the total sediment outflow from a watershed or drainage basin, measurable at a cross section of reference and in a specified period of time (ASCE, 1975). Sources of the total sediment yield include the watershed surface, rills and gullies, streambanks, and degrading streambeds. Sediment yield can be subdivided based on the method of transport. The finer portion of the sediment yield is continuously maintained in suspension by flow turbulence and is called the washload. The coarser fraction of the sediment yield is actively exchanged with the sediment on the bed and is called the bed-material sediment yield. SAM.yld provides hydraulic design engineers a systematic method for rapidly calculating sediment yield. If sediment transport is calculated using sediment transport *equations*, only the bed-material sediment yield is calculated. If sediment transport is determined from total load *measurements*, then the total sediment yield (washload and bed-material load) is calculated.

General

SAM.yld calculates sediment yield passing a cross-section during a specified period of time. The time period considered can be a single flood event or an entire year. In SAM.yld the flow can be specified by either a flow duration curve or a hydrograph. The sediment discharge curve can be specified as either sediment discharge versus water discharge or as sediment concentration versus water discharge. Calculations are based on the flow-duration sediment-discharge rating curve method.

Flow-Duration Sediment-Discharge Rating Curve Method

This is a simple integration of the flow duration curve with the sediment discharge rating curve at the outflow point from the drainage basin. This method is widely used in the Corps of Engineers for two reasons. First, both the flow duration curve and the sediment discharge rating curve are process-based and can be changed from the historical values needed for hindcasting to values needed for forecasting water and sediment yield in the future. Also, the curves can be defined to reflect specific components of the sediment runoff process, i.e., a sediment discharge rating curve can be calculated for sand and gravels when those are the types of sediment of most interest to project performance.

Sediment discharge rating curve

The sediment discharge rating curve is a relationship between water discharge and sediment discharge as discussed in chapter 3. SAM.sed calculates the bed-material sediment discharge rating curve needed for SAM.yld. SAM.sed will create this rating curve in terms of sediment concentration. However, the sediment discharge rating curve may be described in terms of tons/day by direct input to SAM.yld. If total sediment yield is required, the sediment discharge rating curve must be determined from measurements and directly input to SAM.yld.

Flow duration curve

The flow duration curve is a relationship between water discharge and the cumulative frequency each discharge occurs over a given time. It is a graphic description of a hydrologic event. The discharge magnitudes are plotted as the ordinates with the corresponding percents of time exceeded as the abscissas. Care should be taken in developing this curve.

Often the flow duration curve is calculated from historical databases containing the USGS mean daily records. If this data is used as the basis for a flow duration curve, efforts must be made to ensure that the peak flows are represented. This may be important in smaller streams where peak flow durations are considerably shorter than one day. Discharge durations for events larger than those in the mean daily record can be determined by one of several methods. If there are flood hydrographs on record, they can be the basis for calculating the discharge duration for the high flow events. If there is no recorded hydrograph for a flood event that has a published peak discharge, then the discharge durations can be determined assuming that the hydrograph had the same shape as a flood hydrograph of record or as a synthetic hydrograph calculated using HEC-1 or another hydrologic method. In any case, to ensure reasonable results the peak discharges of record should be incorporated into the flow duration curve, or the hydrograph, used in SAM.yld.

Calculations

Class intervals of water discharge are used in the integration of the flow-duration and sediment discharge rating curves. The percent exceedance is tabulated at each ordinate in user-defined increments that should be sufficiently small so the exceedance curve is approximated by straight line segments. The value of the discharge at the midpoint of each segment and its incremental time in percent is then calculated. The representative value of the sediment discharge is calculated as the geometric mean of the sediment discharges corresponding to the water discharges that bound the increment. The daily average discharge is calculated by multiplying the water discharge by the incremental exceedance fraction and summing all increments. The daily average sediment discharge is calculated similarly, by summing all results of multiplying the incremental sediment load by the incremental exceedance fractions. The average annual sediment yield is the product of the mean daily value times 365 days.

Points of caution

The sediment discharge rating curve is plotted as water discharge (Q) versus sediment discharge (QS) on a log-log grid. The typical scatter in such plots demonstrates that sediment discharge is not a simple function of water discharge. When the water discharge in cfs is plotted versus the sediment concentration in ppm, scatter is more apparent than when water discharge is plotted versus sediment discharge in tons/day. This is due to the spurious correlation between Q and QS resulting from the dependency of QS on Q. The engineer should investigate and evaluate any regional and watershed characteristics which might contribute to scatter. This can be accomplished by testing for homogeneity with respect to season of the year, systematic changes in land use, type of sediment load, and type of erosive mechanisms. A multiple correlation approach coupled with good engineering judgement may be employed to establish the dominant factors influencing historical concentrations. It is important to predict how these factors might change in the future and how such changes would impact sediment concentrations and particle sizes.

Additional factors contributing to scatter include washload concentration and temperature. The percent of the sediment load that is washload influences the amount of scatter in the data because the washload depends on its availability from source areas and not upon hydraulics of flow at the point of interest. Also, as the concentration of fines increases above 10,000 ppm, the transport rate of sands and gravels increases significantly. Water temperature may cause a significant variation in transport capacity of the bed material load. Thus water temperature variations, when coupled with seasonal changes in land use, may require that separate warm and cold weather sediment discharge rating curves be used to achieve acceptable accuracy in the calculated results.

It is usually necessary to extrapolate the sediment discharge rating curve to water discharges well above the range of measured data. Straight-line extrapolations typically over-estimate sediment load at high discharges. Extrapolating the relationship for total concentrations does not guarantee the proper behavior of individual size classes. Typically, the rating curves for finer size classes tend to flatten with increasing discharge.

Flow Hydrograph Method

This modification of the flow-duration--sediment discharge rating curve method substitutes water discharges from a hydrograph for the flow-duration curve. Those ordinates are integrated with the sediment discharge rating curve to produce the sediment yield for that event.