CE 5361 Surface Water Hydrology
Hydrographs and Baseflow

Contents

1 Hydrographs

A hydrograph is a plot of a hydrologic variable versus time. Typically the variable of interest is discharge or stage (depth). A hydrograph over a long time frame (days-weeks) is a continuous hydrograph. A hydrograph during an event (storm) is called a storm hydrograph (some times episodic or event hydrograph is how such plots are titled). Figure 1 is an example of an idealized event hydrograph.

The hydrograph is comprised of two principal parts: a base flow (background) component and a storm flow component. The storm flow component is called the direct runoff hydrograph (DRH). The DRH is the hydrograph resulting from excess precipitation over the watershed after the losses (abstractions) are removed. It is believed that the lag time from beginning of precipitation to the peak of the DRH, the shape of the DRH) and the decay pattern of the DRH are related to the characteristics of the basin as well as the rainfall pattern. Various approaches to model such relations are in common use. The NRCS TR-20 and the HEC-I; HEC-HMS and HEC-RAS all employ similar methods to relate excess precipitation to direct runoff.

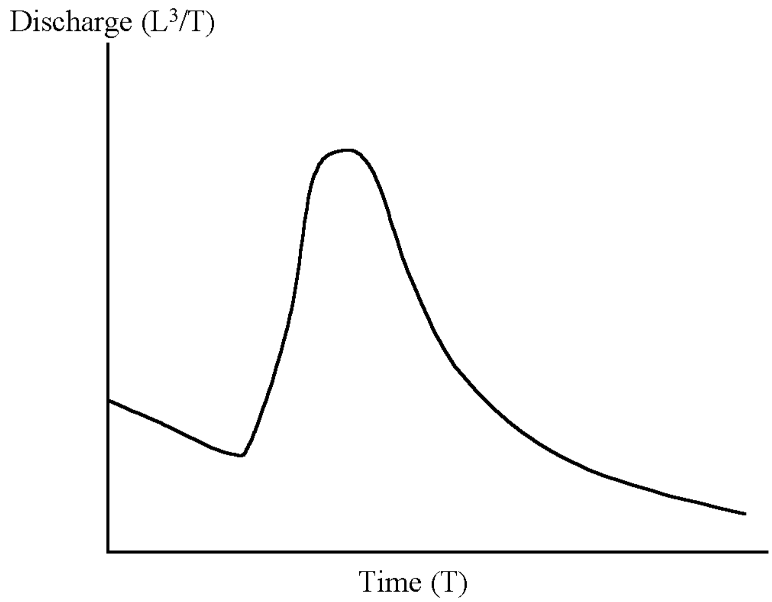

Figure 1: Idealized hydrograph

2 Base Flow Separation (Single Event Time Scale)

To actually analyze hydrographs or prepare for rainfall-runoff modeling the DRH (storm) flow has to be extracted (separated) from the observed hydrograph. This analytical process is called base flow separation. Several methods are cited for separation of the base flow component from the observed hydrograph, the more frequently cited methods are: constant discharge, constant slope, concave method, and the master depletion curve method. The part of the hydrograph remaining after separation is called the direct runoff hydrograph (DRH) and it is the subject of the remainder of the section. On small watersheds often the base flow is negligible and any hydrograph derived during/after a storm is a DRH.

2.1 Constant-discharge method

The base flow is assumed to be constant regardless of stream height (discharge). Typically, the minimum value immediately prior to beginning of the storm is projected horizontally. All discharge prior to the identified minimum, as well as all discharge beneath this horizontal projection is labeled as baseflow and removed from further analysis. Figure 2 is a sketch of the constant discharge method applied to the representative hydrograph. The cross-hatched area in the sketch represents the discharge that would be removed (subtracted) from the observed runoff hydrograph to produce a direct-runoff hydrograph.

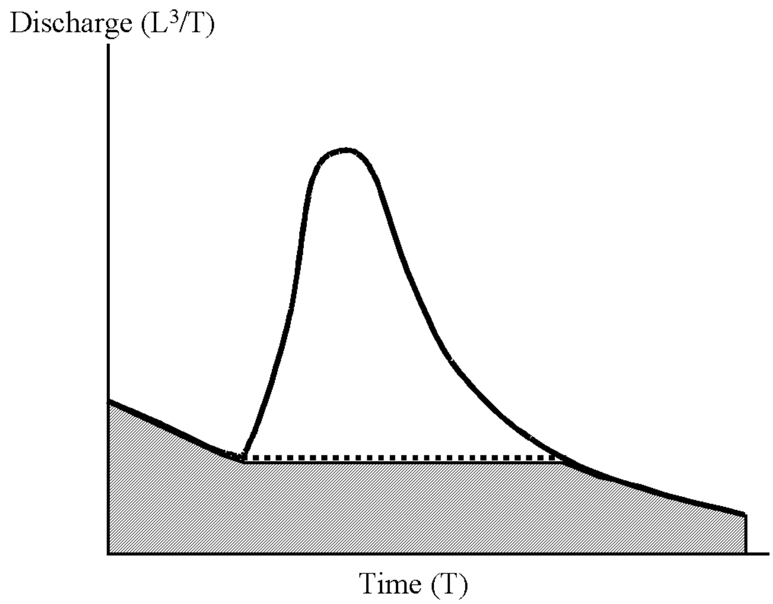

Figure 2: Baseflow Separation - Constant Discharge

The principal disadvantage is that the method is thought to yield an extremely long time base for the direct runoff hydrograph, and this time base varies from storm to storm, depending on the magnitude of the discharge at the beginning of the storm (Linsley et, al, 1949). The method is easy to automate, especially for multiple peak hydrographs.

2.2 Constant-slope method

In the constant slope method, a line is drawn from the inflection point on the receding limb of the storm hydrograph to beginning of storm hydrograph. This method assumes that the base flow began prior to the start of the current storm, and arbitrarily sets to the inflection point.

The inflection point is located either as the location where the second derivative passes through zero (curvature changes) or is empirically related to watershed area. This method is also relatively easy to automate, except multiple peaked storms will have multiple inflection points.

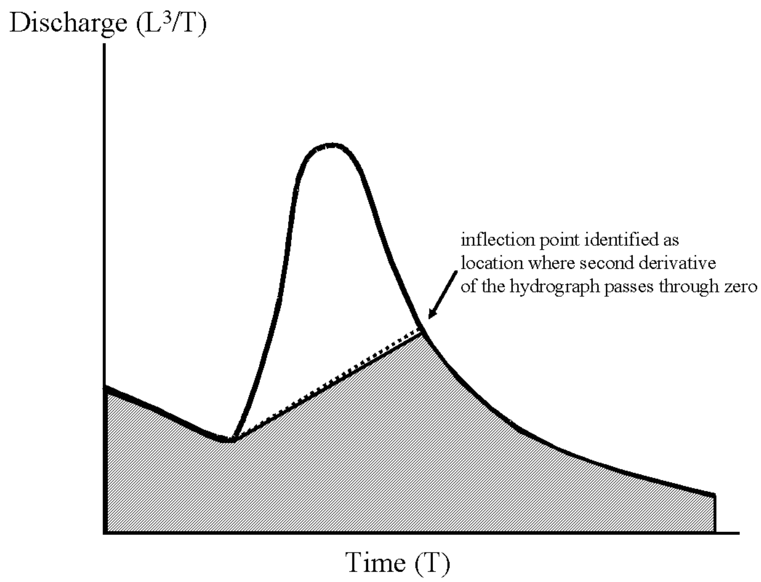

Figure 3: Baseflow Separation - Constant Slope

2.3 Concave method

The concave method assumes that baseflow continues to decrease while streamflow increases to the peak of the storm hydrograph. Then at the peak of the hydrograph, the baseflow is then assumed to increase linearly until it meets the inflection point on the recession limb. Figure 4 is a sketch illustrating the method applied to the representative hydrograph. This method is also relatively easy to automate except for multiple peak hydrographs which, like the constant slope method will have multiple inflection points.

3 Baseflow Separation (Multiple Event Time Scale)

At larger time scales, say on the order of weeks, baseflow separation will play a different role and the methods above are probably inadequate or ill-posed for automated analysis. In continuous simulation, where baseflow is computed as part of the signal, some kind of seed value needs to be supplied to start the model[1].

[1] "Spin-up" the model is a common jargon for this activity.

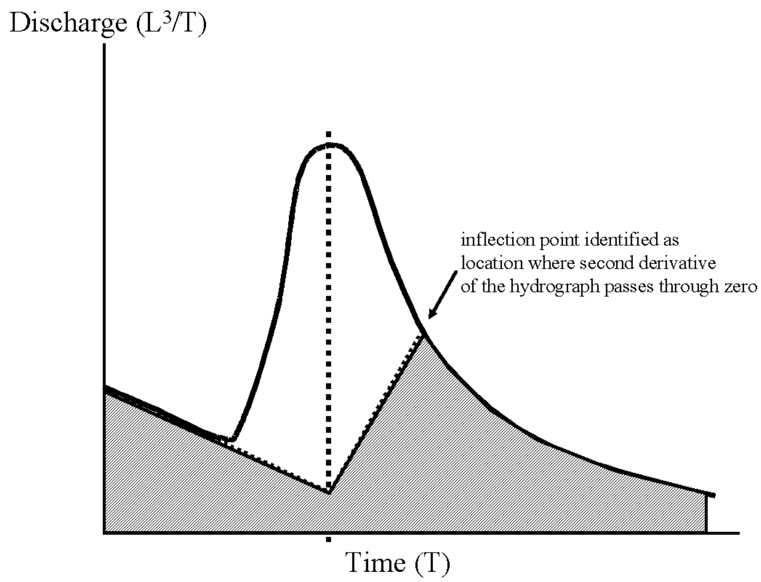

Figure 4: Baseflow Separation - Concave

3.1 Depletion Curve Method

This method models baseflow as discharge from accumulated groundwater storage. Data from several recessions are analyzed to determine the basin recession constant. The base flow is modeled as an exponential decay term . The time constant, k, is the basin recession coefficient that is inferred from the recession portion of several storms.

Individual storms are plotted with the logarithm of discharge versus time. The storms are time shifted by trial-and-error until the recession portions all fall along a straight line. The slope of this line is proportional to the basin recession coefficient and the intercept with the discharge axis at zero time is the value for .

Figure 5 illustrates five storms plotted along with a test storm where the base flow separation is being determined. The storm with the largest flow at the end of the recession is plotted without any time shifting. The recession is extrapolated from this storm as if there were no further input to the groundwater store. The remaining storms are time shifted so that the straight line portion of their recession limbs come tangent to this curve. By trial-and-error the master depletion curve can be adjusted and the storms time shifted until a reasonable agreement of all storms recessions with the master curve is achieved.

Once the master curve is determined, then the test storm is plotted on the curve and shifted until its straight-line portion comes tangent to the master curve, and the point of intersection is taken as the baseflow value for that storm. In the example in Figure 5, the baseflow for the test event is approximately 9.1 cfs, the basin recession constant is $0.0045/hr$, and the

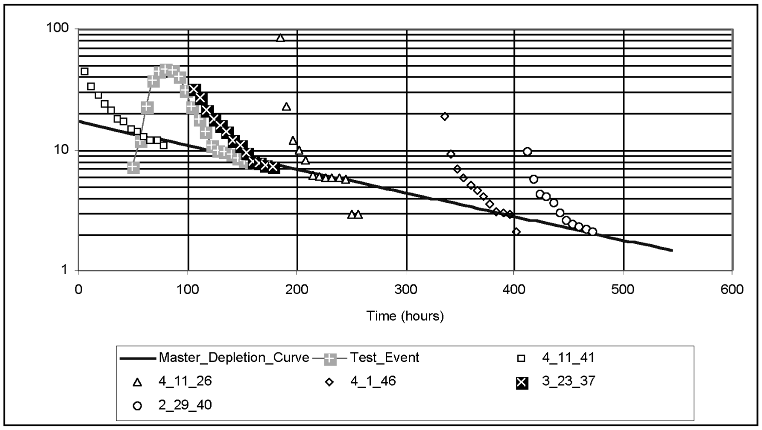

Figure 5: Depletion Curve Method (Data from McCuen, 1998, Table 9-2, pp 486)

baseflow at the beginning of the recession is 17 cfs. Once the baseflow value is determined for a particular test event, then baseflow separation proceeds using the constant discharge method.

The depletion curve method is attractive as it determines the basin recession constant, but it is not at all easy to automate. Furthermore, in basins where the stream goes dry (such as much of Texas) the recession method is difficult to apply as the first storm after the dry period starts a new master recession curve. Observe in Figure 5 the storms used for the recession analysis span a period of nearly 40 years, and implicit in the analysis is that the basin recession constant is time invariant and the storms are independent.

4 Bibliography

Appleby, V.C., 1970. Recession and the baseflow problem, Water Resources Research, Vol. 6., No. 5, pp 1398-1403.

Bates, B., and Davies, P.K., 1988. Effect of baseflow separation on surface runoff models. J. of. Hydrology, 103, pp 309-322.

Chow, V. T., 1964. Handbook of Applied Hydrology. McGraw Hill, New York. Sec. 14., 2pp.

Linsley, R. K., Jr., Kohler, M. A., and Paulhus, J. L. H., 1949. Applied Hydrology, McGraw-Hill, pp 399-400.

McCuen, R.H., 1998. Hydrologic Analysis and Design, 2nd ed., Prentice Hall, Saddle River, N.J.

Nathan, R.J., and T.A. McMahon, 1990. Evaluation of Automated Base Flow and Recession Analyses. Water Resources Research, Vol. 26., No. 7, pp 1465-1473.

Press 1989 Numerical Recipes, Cambridge Press,

Tallaksen, L.M., 1995. A review of baseflow recession analysis. J. of. Hydrology, Vol 165, pp 349-370.

USDA National Engineering Handbook, Chapters 4,5, and 10.

Wurbs and James, 2002. Water Resources Engineering. Prentice-Hall, New Jersey. Pp 462-483.

Chow, V. T., Maidment, D. R., and Mays, L. W., 1988. Applied Hydrology, McGraw-Hill, 572pp.

Chow, V.T., 1964. in Handbook of Applied Hydrology. Sec 14., pp 14-24 to 14-27. McGraw Hill, New York.

Holtan, H. N. and Overton, D. E., 1963. Analyses and application of simple hydrographs, Journal of Hydrology, 1(3), pp 250-264.

Linsley, R. K., Jr., Kohler, M. A., and Paulhus, J. L. H., 1958. Hydrology for Engineers, McGraw-Hill, 340pp.