AN ANALYSIS OF RECESSION FLOWS FROM DIFFERENT VEGETATION TYPES

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Introduction

The magnitude and variability of recession flows from a watershed depend upon many factors (generally, it is not feasible to quantify each of them separately because these factors are closely related). However, it has been commonly assumed that recession flows are less dependent upon precipitation and intensity distribution than upon physical storage capacity of a watershed (Linsley et al., 1975). Since, characteristically, these flows are more-or-less steady, it has been a common practice to represent them by general mathematical models.

To evaluate recession flow characteristics from different watersheds in Arizona and to facilitate comparisons, a general mathematical model with one constant was chosen. Assuming that variability due to evapotranspiration, soil moisture conditions, and land use patterns can be "lumped" into the constant, differences attributed to vegetative cover types and season of occurrence can be analyzed.

Objectives

The objectives of this study can be outlined as follows: (1) to develop a general mathematical model suitable for the recession flows analyzed, and to use the constant in the model to characterize differences; and (2) to statistically compare the constant values to infer significant differences.

Study Areas

The study areas, Sycamore Creek, Cherry Creek, East Fork and West Fork of the White River, and Pacheta Creek, are catchments in the Salt-Verde River Basin of north-central Arizona. These watersheds vary climatically from cold and humid to dry and arid, depending upon their elevations and the season of the year. In general, two seasons of precipitation are recognized on the watersheds, one in the summer and the other in the winter. Summer storms, (high intensity and short duration) derive their moisture from the Gulf of Mexico. Winter storms, which derive most of their moisture from the Pacific Ocean, bring rainfall events of lower intensity and longer duration, and snow.

Sycamore Creek, located near Sunflower, has elevations ranging from 3,310 to 7,130 feet. Vegetation is mostly chaparral, with scattered oaks and other species of desert plants. The watershed receives 20 inches of precipitation annually. Soils are derived from granite and schist.

Cherry Creek, near Young, has elevations ranging from 4,950 to 6,450 feet. For the most part, vegetation is mesquite and grasses, with scattered shrubs. Pinyon and juniper prevail at higher elevations. Annually, the watershed receives approximately 20 inches of precipitation. Soils are derived from sandstone parent materials.

East Fork of the White River, near Fort Apache, has elevations exceeding 6,000 feet. Vegetation is mostly pinyon and various species of juniper. The watershed receives about 18 inches of precipitation annually. Soils are mostly basalt and sandstones. North Fork of the White River, located near Greer, ranges in elevation from 8,000 to 11,590 feet. Vegetation is predominantly mixed conifer forests. Annually, the watershed receives 24 inches of precipitation. Soils consist of basalt.

Pacheta Creek, near Maverick, has elevations ranging from 7,850 to 8,520 feet. Vegetation is mostly ponderosa pine, with scattered Douglas-fir. It receives more than 25 inches of precipitation annually. Soils are formed on basalt and cinders.

Methods

Average daily streamflow for the water years of 1967 to 1976 was summarized from the U.S. Geological Survey water data reports for Arizona. Individual recession hydrographs were selected for analysis according to the following criteria: (1) A set of data points that exhibited a more-or-less steady recession was considered a recession event. Complex recessions were separated into individual recessions depending upon the number of surges. Recessions that demonstrated extensive fluctuations were eliminated; (2) Recessions that occurred between July 1 and October 30 were considered summer recessions, while those between January 1 and April 30 were winter recessions. Recessions recorded outside these periods were omitted; (3) It was decided that four data points, or a three-day interval, was a minimum duration of a recession event retained for analysis; and (4) Unusually high and low flows were eliminated. A minimum flow was set at 0.25 cfs. The upper limit was not singled out, since these flows varied greatly among the watersheds.

The form of streamflow drainage from a watershed, characterized by recession flows, has been documented (Barnes, 1939; Hursh and Brater, 1941; Knisel, 1963; Brown, 1965; and Howe, 1966), according to the form:

$$Qt = Qo\ K^t \qquad (1)$$

where Qt = the discharge after a time period, t

Qo = the initial discharge

K = the recession constant per unit of time

t = the time interval between Qt and Qo in hours or days

In this study, the above-defined mathematical model was used. Each recession hydrograph was displayed on semi-log paper. The slope of each plotted line was determined in terms of a log form, as follows:

$$\text{Log } K = \frac{\text{Log } Qo - \text{Log } Qt}{t} \qquad (2)$$

From previous studies, it has been shown that more than one straight line with divergent slopes often occurs with semi-log plots of recession flows. A study by Brown (1965) on recession flows in Arizona demonstrated that, typically, recessions are two limb types. To reduce the complexity of interpreting various limbs in the study described herein, it was decided that those exhibiting two recession limbs on semi-log paper would be used for final differentiation.

To characterize recession flows from watersheds of different vegetative cover types, slopes of each recession limb was determined from equation (2), and their averages were grouped according to the season of occurrence. The following null hypotheses were tested (at a significance level of 0.05) to evaluate differences among averages grouped by vegetative cover types and season of occurrence.

In particular, null hypotheses that involved testing variations within a watershed were:

Ho_1 = there were no significant differences among averages of upper and lower slopes analyzed for vegetative cover types and season

Ho_2 = there were no significant differences among averages of upper recession slopes grouped under summer and winter periods

Ho_3 = there were no significant differences among averages of lower recession slopes grouped under summer and winter periods

Null hypothesis that involved testing variations among watersheds included:

Ho_4 = there were no significant differences among averages of upper recession slopes grouped under vegetative cover types and winter periods

Ho_5 = there were no significant differences among averages of upper recession slopes grouped under vegetative cover types and summer periods

Ho_6 = there were no significant differences among averages of lower recession slopes grouped under vegetative cover types and summer periods

Ho_7 = there were no significant differences among averages of lower recession slopes grouped under vegetative cover types and winter periods

To test the above-mentioned null hypotheses, three statistical methods were employed as required: t-tests, analyses of variance, and multiple comparison procedures (Steel and Torrie, 1960).

Results and Discussion

Generally, the recession flows demonstrated straight-line plots, with some exhibiting more than two slopes separated by distinct break points. Some break points occurred at high flows, others at low flows.

Summer recession flows were mostly of the two limb type, while winter recession flows were of both the one and two limb types. Most summer recessions were of shorter duration than were winter recessions. The longest single event in the summer was 9 days; 21 days characterized the longest single event in the winter.

Representing recessions of the two limb type, 66 and 45 individual events of summer and winter grouped recessions, respectively, were identified for analyses. The averages of summer upper limb slopes grouped by vegetative cover type ranged from 0.10 to 0.54 day^{-1}, and lower limbs ranged from 0.03 to 0.10 day^{-1}. Averages of winter upper limb slopes grouped by vegetative cover types ranged from 0.09 to 0.16 day^{-1}, and the lower limbs ranged from 0.02 to 0.04 day^{-1}.

With respect to the above-mentioned hypotheses, the following results were obtained:

Ho_1 = rejected for all vegetative cover types and seasons

Ho_2 = accepted for East Fork and North Fork of the White River and Pacheta Creek, rejected for other watersheds

Ho_3 = accepted for East Fork and North Fork of the White River and Pacheta Creek, rejected for other watersheds

Ho_4 = accepted for all watersheds

Ho_5 = rejected for all watersheds, with multiple comparison procedures employed to determine which averages were different

Ho_6 = rejected for all watersheds, with multiple comparison procedures employed to determine which averages were different

Ho_7 = accepted for all watersheds

It is, generally, beyond the intent of this paper to detail all of the individual differences and interactions among vegetative cover types and seasons of occurrence. These results can be found elsewhere (Sulaiman, 1981). However, the more important conclusions reached as a result of this study are presented, as outlined below:

1. Pinyon-juniper, chaparral, and grassland vegetative cover types can be considered the same, in terms of delayed recession flows.

2. With respect to time, delayed recession flows were more sustained for mixed conifer and ponderosa pine forests compared to grassland vegetative cover types.

3. During the summer, fast or delayed recession flows were generally steeper in slope averages than they were in the winter. Differences were observed in fast recession flows in mixed conifer and ponderosa pine forests, pinyon-juniper, and grassland vegetative cover types. Differences were noted in delayed recession flows in mixed conifer and ponderosa pine forests, and in grassland vegetative cover types.

4. There were no differences in winter recession flows among the vegetative cover types analyzed.

5. Unfortunately, small differences in recession flows could not be statistically detected. Quite possibly, a larger number of observations would be required to increase the precision required in evaluations of small differences.

In conclusion, it is proposed that recession flow analyses (such as presented herein) could be helpful in the assessment of the affects of land use on streamflows of low quantities. However, this exploratory study must be expanded to other sites before specific outcomes can be predicted.

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