

Entiat Subbasin Hydrograph Separation Analysis
Chelan County Conservation District/Entiat WRIA Planning Unit
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INTRODUCTION

Hydrograph separation is the process of separating a plot of stage or discharge vs. time, known as a stream hydrograph, into baseflow and surface runoff components. Baseflow comprises the groundwater contribution to total stream flow, and a key starting assumption in performing a hydrograph separation is that baseflow is a significant contributor to total streamflow in the selected stream. Clearly, it would be inappropriate to apply such a technique to an ephemeral stream fed only seasonally by meltwater, or a stream that was only actively flowing after major precipitation events.

The hydrograph separation analyses in this study were conducted using the computer program HYSEP (Sloto and Crouse, 1996), which is distributed to the public through the U.S. Geological Survey (USGS). HYSEP is based upon algorithms that duplicate manual hydrograph separation techniques, improving the consistency of the results and the speed at which they can be produced.

Hydrograph separation is an established technique for quantifying groundwater contribution to annual streams. However, streams that are significantly affected by regulation or snowmelt conditions require special treatment. The Entiat River is profoundly affected by snowmelt from late winter to late summer. This will be discussed further in the results section of this report.

Purpose and Scope

This study was conducted in support of the Entiat (WRIA 46) Water Quantity Sub-Committee Draft Plan of Work. Specifically, task II.C.2 of the water quantity plan of work is to estimate groundwater present in the Entiat basin and a subtask of that is the evaluation of groundwater-surface water interaction through hydrograph separation techniques. Under the draft plan of work, the study is limited to the Entiat River basin. Analyses were performed for three stream gaging sites (discussed below) within the basin: 1) the Entiat River near Ardenvoir (USGS gage number 12452800), 2) the Entiat River near Entiat (USGS gage number 12452990), and 3) the Entiat River below Entiat Falls (US Forest Service).

METHODS

Theoretical Basis

HYSEP allows the user to select one of three methods to separate baseflow and surface runoff components of a stream hydrograph. The three methods are: 1) fixed interval, 2) sliding interval, and 3) local minimum. The local minimum consistently yields the most

conservative estimates of baseflow (Sinclair and Pitts, 1999) and was the method chosen for this study.

Surface runoff duration following a precipitation event is calculated from the empirical formula:

$$N=A^{0.2}$$

Where N is the number of days after which runoff ceases, and A is the drainage area in square miles (Linsley et al., 1982). The interval $2N^*$ is the odd integer between 3 and 11 nearest to $2N$ (Pettyjohn and Henning, 1979). As an example, the stream gage on the Entiat River near Ardenvoir, Washington (USGS gage number 12452800) has a drainage area of 203 square miles, yielding a $2N^*$ value of 5, where N is 2.89 and thus $2N$ is 5.78.

The local minimum method checks each day in the daily mean streamflow data for a station, and if it is the lowest discharge in the preceding and following $[0.5(2N^*-1)]$ day periods, it is considered a local minimum and connected by straight lines to adjacent local minimums. The resultant baseflow hydrograph may be visualized by connecting, through linear interpolation, the low points of a stream hydrograph.

Since HYSEP is unable to distinguish the effects of stream regulation or snowmelt from precipitation events, the program will tend to over-estimate the baseflow component of total streamflow for those periods during which those factors are active. Therefore, HYSEP results for streams such as the Entiat that are profoundly affected by spring and early summer snowmelt require special treatment. This will be discussed further in the results section of this report.

Streamflow Data

The U.S. Geological Survey maintains three continuous recording stream gages within the Entiat basin, two of which reside on the mainstem Entiat River. Historical daily mean streamflow data are available to the public via the USGS NWIS (National Water Information System) website. The USGS gage number 12452800 (Entiat River near Ardenvoir) is located at river mile 18, is known locally as the Ardenvoir gage, and has been in operation since 1957. Near the mouth of the Entiat at river mile 1.5 is gage number 12452990 (Entiat River near Entiat), known locally as the Keystone gage. The Keystone gage has been in operation since 1996. An earlier gage, 12453000- Entiat River at Entiat, was located at river mile 0.5 and ceased operation in 1958.

In addition to the USGS gages, the U.S. Forest Service (USFS) maintained two continuous recording gages on the mainstem Entiat from 1966 to 1978 as part of the USFS Entiat Barometer Watershed program. These were known as the Entiat Falls and North Fork gages, and were located at river miles 33.5 and 34, respectively.

Daily mean discharge values for all records had to be converted from text format into a binary Watershed Data Management (WDM) format for entry into HYSEP. This was done using another USGS public domain program known as IOWDM (Flynn et al. 1997).

Data synthesis

Long periods of record are less affected by short-term variations in climate and lend themselves to more representative estimates of average conditions. The 44 years (water years 1958-2001, inclusive) of continuous high-quality data from the Ardenvoir gage, in conjunction with temporally overlapping records from other, shorter-term gage records, presented a method to extend those shorter-term records through correlation with and extrapolation from the Ardenvoir gage record. As a component of task II.B.1.d, Entiat (WRIA 46) Water Quantity Sub-Committee Draft Plan of Work, extended daily mean flow data for both the Keystone and Entiat Falls gages have been synthesized (Rhodus, 2002). For analytic purposes, these synthetic records have been combined with measured records to form “composite” records.

At the Keystone and Entiat Falls gages, composite 45-year records were created using a 5- and 12-year overlap, respectively, with data from the Ardenvoir gage (see Appendix A). The synthesis for Keystone also involved a 1-year overlap (WY 58) with the decommissioned USGS gage number 12453000.

Summary of analyses performed

Using both the historical and extrapolated records available for the Keystone, Ardenvoir and Entiat Falls gage sites, a total of five separate HYSEP analyses were performed. For the Keystone gage, HYSEP was performed using both the water year (WY) 1997-2001 NWIS record and the composite WY 1958-2001 record. Only the NWIS record was used for the Ardenvoir gage, and both the measured and composite records were used for the Entiat Falls gage. The stations, periods of record and source of data for each analysis is summarized in Table 1.

Table 1. Summary of daily mean streamflow records used for HYSEP analysis.

Site name	Agency/Site number	Period of record	Source
Entiat R. near Entiat	USGS/12452990	WY 1997-2001	USGS-NWIS
Entiat R. near Entiat	USGS/12452990	WY 1997-2001 WY 1958-1996	USGS-NWIS G. Rhodus (syn) ¹
Entiat R. near Ardenvoir	USGS/12452800	WY 1958-2001	USGS-NWIS
Entiat R. below Entiat Falls	USFS	WY 1967-1978	USFS
Entiat R. below Entiat Falls	USFS	WY 1958-1966 WY 1967-1978 WY 1979-2001	G. Rhodus (syn) USFS G. Rhodus (syn)

¹ - synthesized data (see text)

RESULTS AND DISCUSSION

The HYSEP output files located in Appendices B-E contain monthly summaries of total streamflow, baseflow and surface runoff for each water year analyzed for each station/record. They also contain annual baseflow summaries, annual baseflow summaries ordered by frequency, seasonal distribution tables for baseflow and surface runoff, and flow duration tables for total flow, baseflow and surface runoff. Figures 1-5 on the following pages summarize the mean monthly values for total streamflow, baseflow and surface runoff for all water years analyzed for each station and record.

Due to the seasonal snowmelt effects mentioned earlier, the summary information for the months March through July may be assumed to greatly overestimate the baseflow component of total streamflow. The months of March through July have been omitted from the baseflow and surface runoff plots on Figures 1-5.

The use of both historically measured and composite records for hydrograph separation presents an opportunity for comparison of results. While the use of the composite records at the Keystone and Entiat Falls gages does seem to reduce some of the short-term climatic variability (compared to the shorter measured records), thus producing a “smoothing” effect on the graphs in Figures 1-5, the range of values for monthly mean streamflow, baseflow and surface runoff are not greatly affected.

This report is chiefly concerned with producing estimates of baseflow contributions to total streamflow for the Entiat River, so that these data are available to the Water Quantity Technical Sub-Committee of the Entiat Watershed Planning Unit (and other concerned entities). However, it also addresses, in part, the utility of using synthetic streamflow records created through correlation analysis and extrapolation from overlapping gage records.

Figure 1.
 Comparison of monthly mean streamflow,
 mean baseflow and mean surface runoff
 for USGS gaging station 12452990,
 Entiat River near Entiat, Washington

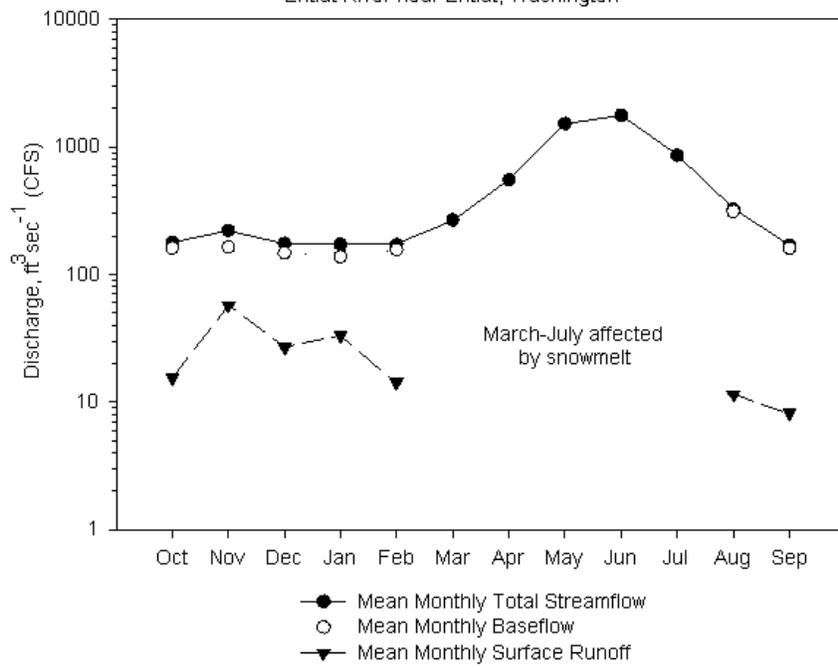


Figure 2.
 Monthly mean streamflow, baseflow
 and surface runoff (synthesized record)
 for USGS gaging station 12452990,
 Entiat River near Entiat, Washington

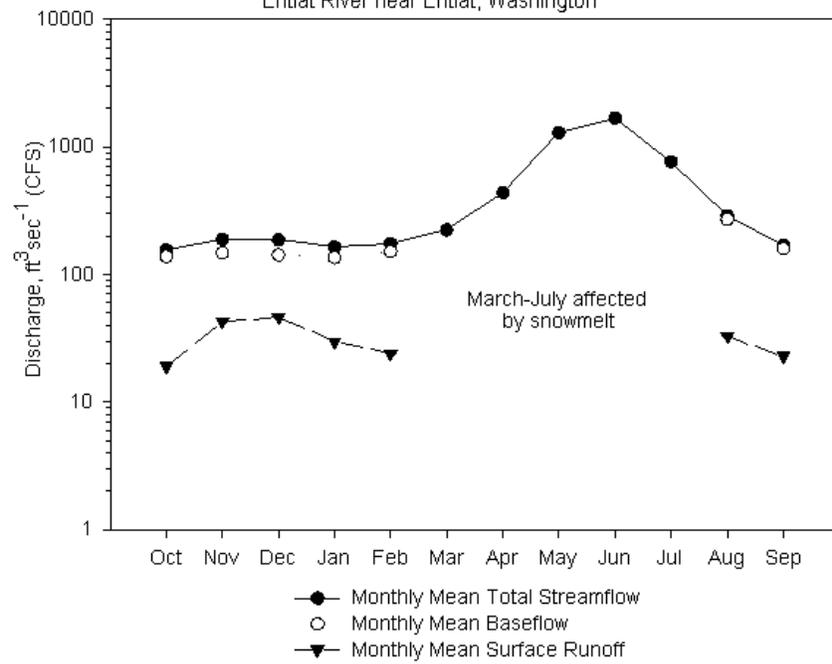


Figure 3.
 Comparison of monthly mean streamflow,
 mean baseflow and mean surface runoff
 for USGS gaging station 12452800,
 Entiat River near Ardenvoir, Washington

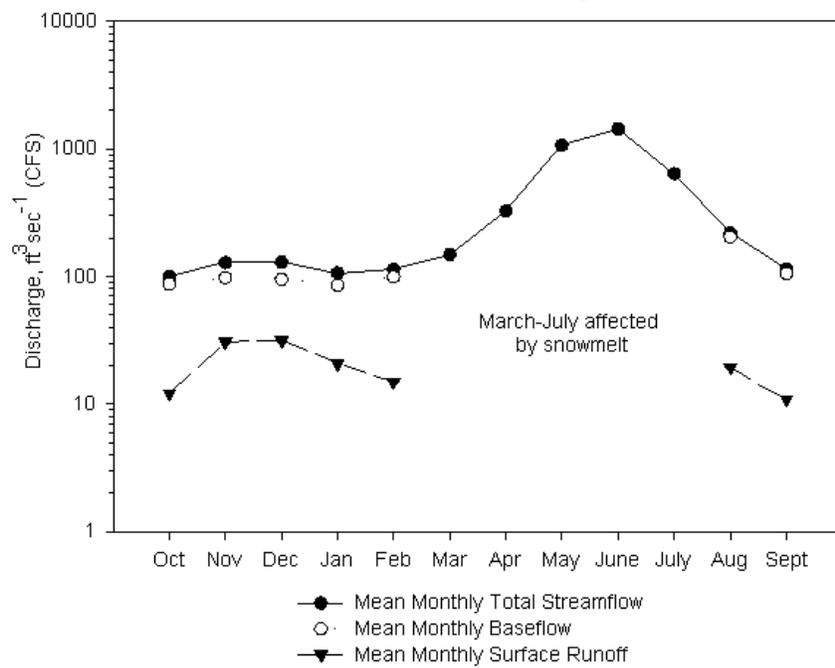


Figure 4.
 Monthly mean streamflow, baseflow
 and surface runoff for USFS Barometer Watershed
 gaging station, Entiat River below Entiat Falls

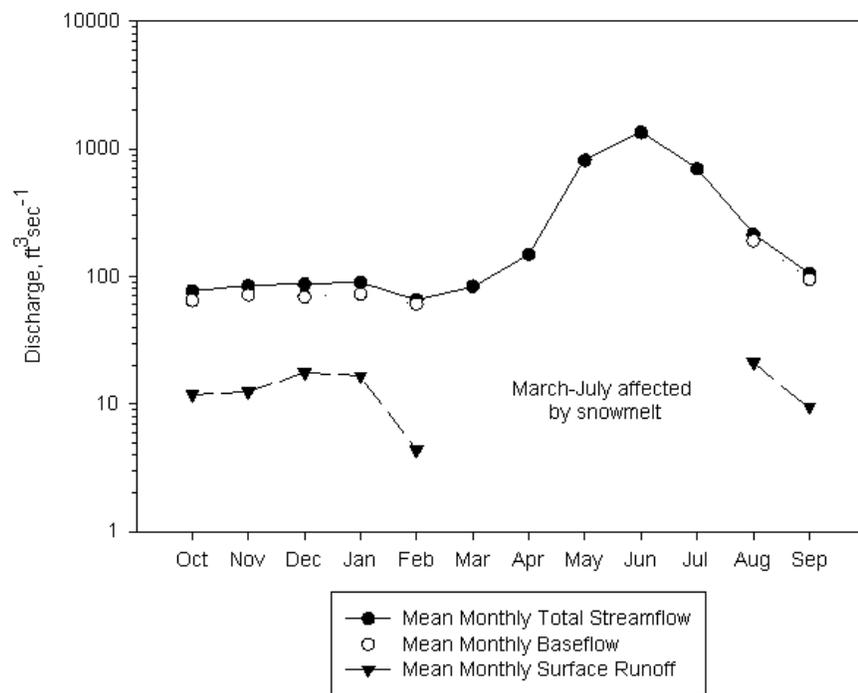
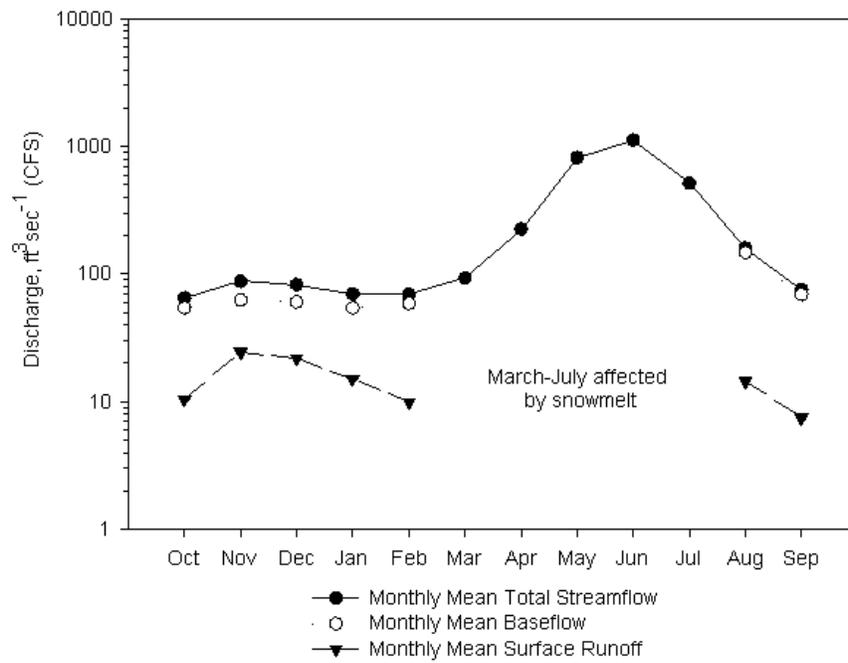


Figure 5.
 Monthly mean streamflow, baseflow
 and surface runoff (synthesized record)
 for USFS Barometer Watershed gaging station,
 Entiat River below Entiat Falls



References

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