Methods of Hydrologic Data Analysis

The first step in any hydrologic data analysis project is to gather the data and relevant background information on your study watershed. The USGS NWIS website (http://waterdata.usgs.gov/nwis) contains all of the data and information you need for this assignment. If you click the site information button, enter your gage name or number, and browse the available datasets for your river. For this analysis, you will need daily discharge data, peak streamflow, and the annual water data report. Other datasets may also be helpful for understanding the hydrologic behavior of your river.

Hydrologic analyses are almost always conducted for "water years" not calendar years. A water year begins on October 1st and ends September 30th. For example, water year 2009 began on October 1st, 2008. This convention was adopted because September-October are not typical periods of major floods in most parts of the U.S., alleviating problems of annual peak flows being counted twice because they began at the end of one year and were still high at the beginning of the next year.

Daily Unit Discharge Hydrograph

Unit discharge is the total discharge of the river divided by the watershed area. Thus, it has units of $ft^3/s/mi^2$ or $m^3/s/km^2$. Unit discharge is very useful for comparing the hydrologic behavior of watersheds of different size (since discharge scales with area). The USGS website reports discharge in ft^3/s and not as unit discharge or in metric units. Thus, you will need to download data from the web and then do appropriate conversions in a spreadsheet.

From the data summary page for your gage, select the daily data → discharge link. On the resulting page, uncheck the boxes for other available parameters (e.g., temperature, gage height), and set the period of record of interest. First take a look at the various graphs, then select the box for tab-separated data. Save the resulting file and then open it up in Excel or another spreadsheet program to complete the graphing in *metric units of unit discharge*. If you have a choice of more than one daily discharge value, select the mean daily discharge.

A properly formatted unit discharge hydrograph (Figure 1) has a descriptive title, labeled axes, and a logarithmic y-axis. If you need help with formatting the graph in Excel, please don't hesitate to ask for help!

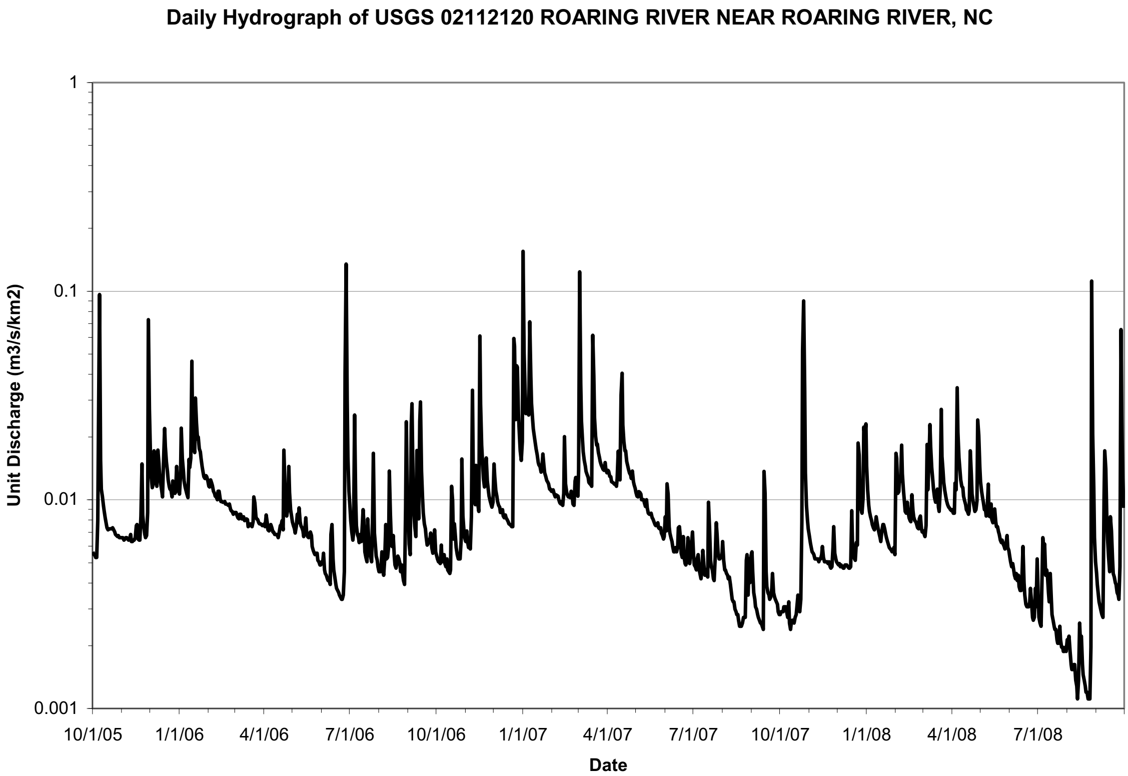

Figure 1. Hydrograph of unit daily mean discharge for Roaring River near Roaring River, North Carolina for water years 2006 through 2008.

Flow duration curves

[The following text is excerpted from the OSU Streamflow Tutorial (http://water.oregonstate.edu/streamflow/analysis/flow/index.htm).]

What is it?

The flow duration curve is a plot that shows the percentage of time that flow in a stream is likely to equal or exceed some specified value of interest. For example, it can be used to show the percentage of time river flow can be expected to exceed a design flow of some specified value (e.g., 20 cfs), or to show the discharge of the stream that occurs or is exceeded some percent of the time (e.g., 80% of the time).

How is it calculated?

The basic time unit used in preparing a flow-duration curve will greatly affect its appearance. For most studies, mean daily discharges are used. These will give a steep curve. When the mean flow over a long period is used (such as mean monthly flow), the resulting curve will be flatter due to averaging of short-term peaks with intervening smaller flows during a month. Extreme values are averaged out more and more, as the time period gets larger (e.g., for a flow duration curve based on annual flows at a long-record station).

Step 1: Sort (rank) average daily discharges for period of record from the largest value to the smallest value, involving a total of n values.

Step 2: Assign each discharge value a rank (M), starting with 1 for the largest daily discharge value.

Step 3: Calculate exceedence probability (P) as follows:

$P = 100 * [M / (n + 1)]$

P = the probability that a given flow will be equaled or exceeded (% of time)
M = the ranked position on the listing (dimensionless)
n = the number of events for period of record (dimensionless)

<u>What does this particular information tell you about your stream?</u>
A flow duration curve characterizes the ability of the basin to provide flows of various magnitudes. Information concerning the relative amount of time that flows past a site are likely to equal or exceed a specified value of interest is extremely useful for the design of structures on a stream. For example, a structure can be designed to perform well within some range of flows, such as flows that occur between 20 and 80% of the time (or some other selected interval).

The shape of a flow-duration curve in its upper and lower regions is particularly significant in evaluating the stream and basin characteristics. The shape of the curve in the high-flow region indicates the type of flood regime the basin is likely to have, whereas, the shape of the low-flow region characterizes the ability of the basin to sustain low flows during dry seasons. A very steep curve (high flows for short periods) would be expected for rain-caused floods on small watersheds. Snowmelt floods, which last for several days, or regulation of floods with reservoir storage, will generally result in a much flatter curve near the upper limit. In the low-flow region, an intermittent stream would exhibit periods of no flow, whereas, a very flat curve indicates that moderate flows are sustained throughout the year due to natural or artificial streamflow regulation, or due to a large groundwater capacity which sustains the base flow to the stream.

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An example, properly formatted flow duration curve is shown below (Figure 2).

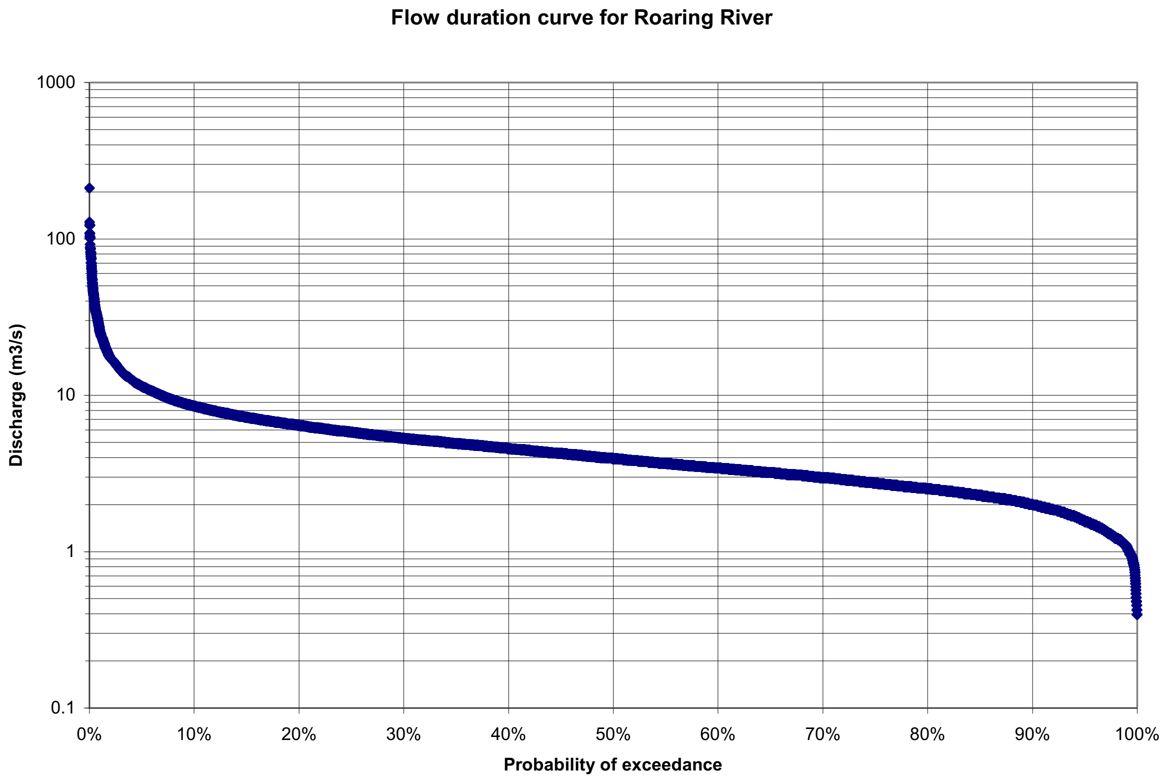


Figure 2. Flow duration curve for water years 1964-2007 for Roaring River near Roaring River, NC based on mean daily discharge data from the USGS.

Flood Frequency Analysis

[The following text is excerpted from the OSU Streamflow Tutorial (http://water.oregonstate.edu/streamflow/analysis/floodfreq/index.htm).]

What is it?

Flood frequency analyses are used to predict design floods for sites along a river. The technique involves using observed annual peak flow discharge data to calculate statistical information such as mean values, standard deviations, skewness, and recurrence intervals. These statistical data are then used to construct frequency distributions, which are graphs and tables that tell the likelihood of various discharges as a function of recurrence interval or exceedence probability.

Flood frequency distributions can take on many forms according to the equations used to carry out the statistical analyses. Four of the common forms are: Normal Distribution; Log-Normal Distribution; Gumbel Distribution; and Log-Pearson Type III Distribution.

Each distribution can be used to predict design floods; however, there are advantages and disadvantages of each technique. Click on the above links to learn more about each technique. According to the U.S. Water Advisory Committee on Water Data (1982), the Log-Pearson Type III Distribution is the recommended technique for flood frequency analysis.

[This is the end of the excerpt.]

While the log Pearson Type III distribution is the recommended technique, its application is a bit more complex than we are going to undertake for this class. A tutorial on the log Pearson method is available on the OSU Streamflow Tutorial website linked above.

Instead, we will use the older Weibull plotting position method. Download the annual peak flow time series for your river from the USGS website, and assign probabilities to each event as you did for the flow duration curve. Use the provided plotting paper to graph probability (x-axis) versus discharge (y-axis). Note that this is special paper; Excel will not be able to generate this sort of graph. A pdf version of the graph paper is available on Blackboard if you need an extra copy. It will be handy if you label your x-axis with both the probability and the recurrence interval (1/probability). Draw a straight-line visual best-fit line through the data points, and use your best-fit line to determine the flood magnitude for a given recurrence interval. An example graph created by the USGS is shown below.

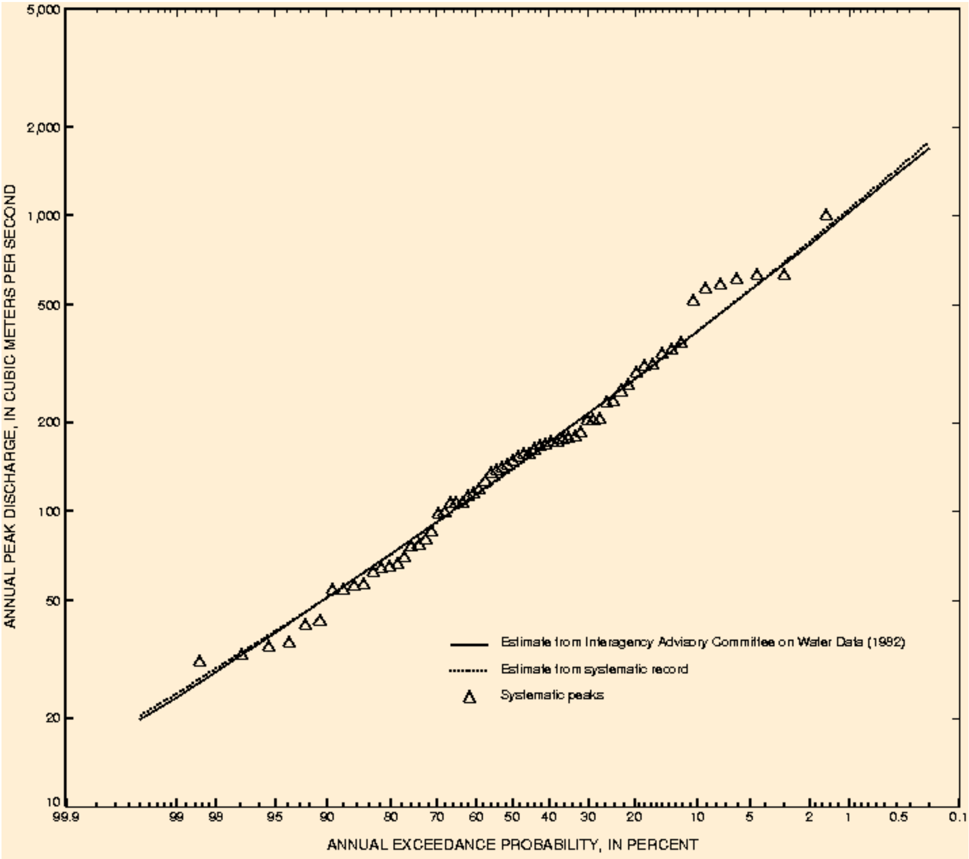
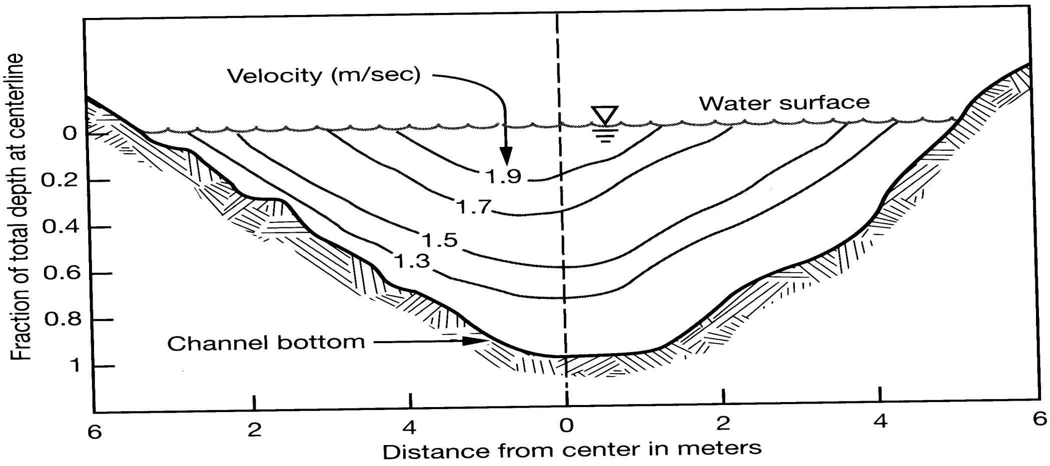


Figure 3. Flood-frequency curve for Virgin River at Littlefield, Ariz. (gaging station 09415000).

Measuring Stream Discharge
(http://snobear.colorado.edu/Markw/IntroHydro/05/lab09/lab09.htm)

The process of measuring stream flow (volume rate of flow), or discharge, is called stream gauging. There are numerous methods of stream gauging, including direct methods, such as volumetric gauging, and dilution methods, as well as indirect methods involving stage-discharge relations, or rating curves. Since the velocity of a stream varies with depth and width across a stream, it is important to understand what it is you want to measure when choosing a stream gauging method. If you are interested in stream surface velocity, the float method would work well. This method involves throwing some buoyant, highly visible object into the stream and measuring the time it takes to float a known distance. If you are interested in obtaining a more accurate stream discharge measurement, the velocity-area method might be your method of choice.



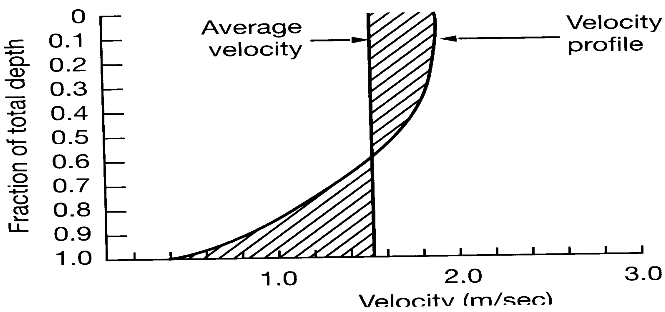


Figure 1a and 1b showing stream velocity distribution. Figure 1a is a cross -sectional view with contours indicating how velocity varies from top to bottom and across the stream channel. Figure 1b is an example of a velocity profile. Notice how how velocity changes with increasing depth, reaching the average velocity at approximately 0.6 of the total depth (or 0.4 of the depth from the bottom).

Figure 1a is an example of how the velocity of a stream can vary in the cross-stream direction and with depth. Stream velocity is typically faster at the surface and toward the middle of the channel, and slower along the sides and bottom of the channel due to differences in friction. The velocity profile in Figure 1b shows how the average velocity is usually at 0.6 times the total depth from the water surface, or 0.4 times the total depth from the bottom of the channel. This is why, in shallow channels (< 2.5 ft or < 0.75 m), current meter measurements are made at four tenths of total depth (from the bottom). In larger streams two velocity measurements are made at each vertical and averaged; one at two tenths of the total depth and one at eight tenths of the total depth. From these diagrams you can see why the float method could give velocities that are higher than the average stream velocity. You can also see how the volume-area method, which involves more detailed measurements of the velocity distribution, could give a more accurate representation of the discharge.

… For the velocity-area method you will establish a cross section … and measure velocity at points along this cross section at known intervals. Functionally, you will do this by dividing your stream into discrete sections where you can calculate the cross-sectional area and measure an average velocity (area x velocity = discharge) (Figure 2). Then you will sum the discharges, Q, of each section to determine the total Q of the stream at that cross-section. Obviously, the more sections you include, the more accurate your determination of discharge is, but there must be a balance between accuracy and efficiency.

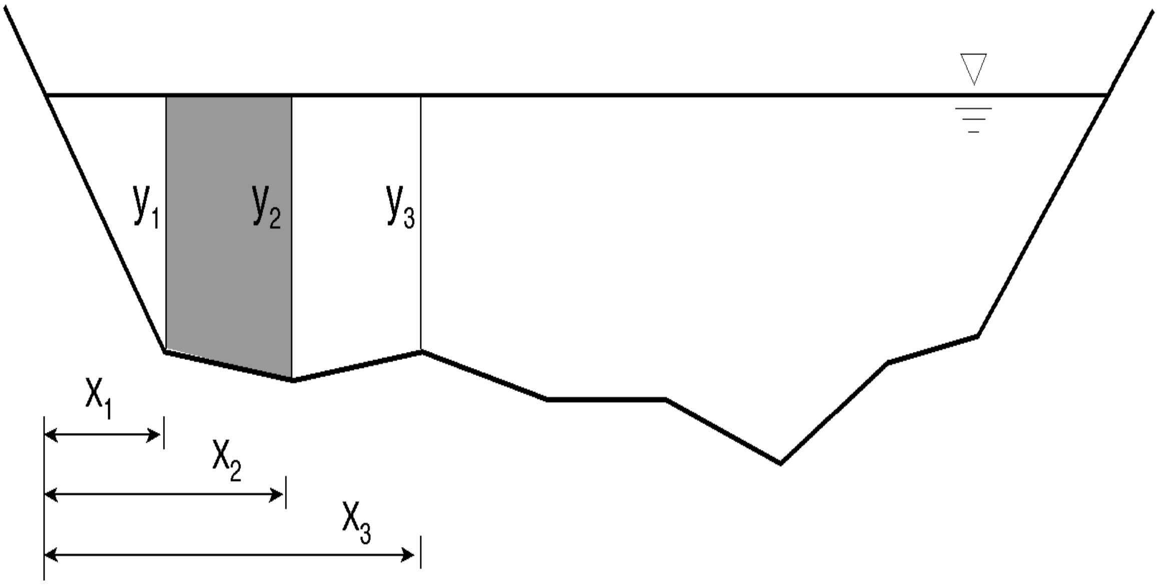


Figure 2 An example of the velocity-area stream gauging cross-sectional set up, where x is the distance from the initial point to a vertical, and y is the depth of a vertical.

$$q = w\left(\frac{y_1 + y_2}{2}\right)\left(\frac{v_1 + v_2}{2}\right)$$

Equation1 To calculate the discharge of each section, where q is the discharge of each section, w is the width of the section, y is the depth of each vertical, and v is the velocity at each vertical.

$$Q = \sum_{i=1}^{n} q_i$$

Equation 2 To calculate the stream discharge (Q) of Boulder Creek you need to sum all the section discharge (q).