Fluvial Geomorphology
Geosciences 560 – Spring 2008
University of Montana
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Homework 3: Analysis of USGS gage data

Due Wednesday, April 2, 2008

Analysis of Clark Fork above Missoula gage data

In this exercise you will analyze discharge data from the USGS Clark Fork above Missoula MT gage (# 12340500). Daily discharge data are available from 1929-present, and peak flow data are available for 78 years (1908,1930–2006). The url for the Clark Fork above Missoula MT gage data is: http://waterdata.usgs.gov/mt/nwis/uv/?site_no=12340500&agency_cd=USGS
From the main page for the Missoula gage site, you can access a variety of data by scrolling through the "Available data for this site" window. If you're not familiar with gaging station data, take a look at the various types of data.

Data for all USGS gages in Montana can be found, organized by river basin, at:
http://waterdata.usgs.gov/mt/nwis/current/?type=dailydischarge&group_key=basin_cd
Some of you may need to refer to other gage data for your independent projects.

Flood frequency analysis

Flood frequency analysis entails using measured annual peak discharge data to quantify the recurrence interval or probability of occurrence of discharges of various magnitudes. This technique is used to analyze a variety of river processes and to determine the magnitude of floods with various recurrence interval (e.g., the so-called "100-year flood" and other design floods for a given stretch of river). Recurrence interval is the length of time (in years) between occurrences of a specified flood flow, on average. For example, a flood magnitude with a 100-year recurrence interval can be expected to occur once every 100 years, on average – when averaged over a very long time. A better way to think about the '100 year flood' is that it has a 1 in 100 chance of occurring in any given year. As you will calculate below, the probability of occurrence of a given discharge is simply the reciprocal of the recurrence interval.

From the "Available data for this site" window on the main page for the Missoula gage, go to "Surface water: peak streamflow", which include the highest flow for each calendar year. Download the peak flow data to Excel or another program of your choice. There are several ways of doing this, but my method is to open a tab-separated file (from output formats), then save that (from whatever browser you're using) as a txt file, then import into Excel using Excel's Text Import Wizard, delimited file format. You're now ready for some data analysis.

Flood frequency analysis using simple recurrence interval calculation

In a new column in your spreadsheet, convert peak flow data to metric units (cfs to m^3/s). Copy these annual daily maximum flows into another column and sort these in descending order. It can also be useful to sort the years in an adjacent column. In another column, assign a rank to each peak flow, such that the largest recorded flow is 1, the next largest is 2, etc. Next, calculate the recurrence interval of each flow:

RI = (n + 1)/m

where n is the total number of years in the discharge record and m is the rank of an individual flow. Note that RI is sometimes referred to as return period (Tr). Next, calculate the probability of a given flow occurring, in percent:

P=(1/RI)*100

The columns in your spreadsheet should look something like the following (there are a number of other columns that will be included in the USGS format that are not shown here):

Year	Peak Daily Q (cfs)	Peak Daily Q (m^3/s)	Sorted year	Sorted peak daily Q (m^3/s)	Rank	Recurrence interval (yrs)	Probability (P)
1908	48000	1359	1908	1359	1	=(n+1)/m	=(1/RI)*100

Plot the recurrence interval (x-axis, logarithmic scale) versus discharge (y-axis, normal scale). Be sure to have the graph show minor gridlines for the x-axis (using Chart Options in Excel). Fit a line (would be a curve if log scale not used) to this plot. This is a simple approach to flood frequency analysis- your fitted curve allows you to use your analysis to determine discharge magnitudes associated with various recurrence intervals and vice versa. You can fit a line using Excel's trendline function. Although this will give you the best-fit line, the line may be excessively influenced by your largest magnitude flood, depending on the data set you're working with. Alternatively, you can fit a straight line by eye to the data set as a whole, where you focus on fitting the central tendency of the majority of the points in the middle range without letting the highest discharges influence the position of your line much.

Flood frequency analysis using Log-Pearson Type III distribution
A more rigorous flood frequency analysis technique, which you'll perform next, is to use statistical calculations and fit one of several common distributions to the data. Among the common distributions are the Normal, Log-Normal, Gumbel, and Log-Pearson Type III Distributions. The last of these, the Log-Pearson Type III distribution, is the recommended technique for flood frequency analysis. Rather than listing each of the steps involved in constructing a flood frequency analysis using a Log-Pearson Type III distribution here, you should instead refer to the following url for instructions:

http://water.oregonstate.edu/streamflow/analysis/floodfreq/index.htm

This site has both detailed instructions for flood frequency analysis and useful links to other types of streamflow data analysis. Using your data from the CFR above Missoula gage, complete the flood frequency analysis based on a Log-Pearson Type III distribution. There is a nice tutorial on the website that you can use as your guide. You will need to go back and forth between the main page of the above website (analysis techniques) and the tutorial page (excel methods). Note that you should use C_w in the K value table (as indicated in the text of the analysis methods section), not C_s (as indicated in the the text of the table).

When completing a more rigorous flood frequency analysis such as this, results may differ depending on whether the peak flow data represent mean daily peaks (i.e., the average flow over a 24-hour period for the highest day of the year) versus instantaneous peaks (this is the largest flow recorded at whatever the gage's measurement interval is; gages currently record at 15-minute intervals). As you might imagine, the instantaneous peaks can be a lot higher than the daily peak, depending on the shape of the peak flow hydrograph. Note that on the Oregon State website, you have a choice of tutorials; use the methods for instantaneous data.

You should produce 2 summary results from this analysis (while showing all work): a table showing the discharges with recurrence intervals of 2, 5, 10, 25, 50, 100, and 200 years, and a plot of those data, on the same graph as the flood frequency curve produced using the simple RI calculation above.

Describe the differences between the two curves and discuss the potential errors in estimates of flood frequency produced by using the simple RI calculation.

The 1908 flood is often referred to as a 500 year event. Discuss the accuracy of this estimate, based on your flood frequency analysis.

In addition, your analysis should include the following:
1. Plot of peak Q vs year. The USGS site shows such a scatter plot of this, but bar charts are a more effective way of conveying this info. Make sure your plot illustrates the data gap in the peak flow record. Do you see any trends or periodicity? If so, discuss. What was the lowest peak flow year on record? Discuss possible reasons for such low flows.
2. Evaluation of peak flow timing. At what time of the year do peak flows typically occur here? What does this imply about the hydrologic regime and the runoff that generates peak flows?
3. Your spreadsheet showing all calculations.

If you are unsure about how to perform some of the Excel functions suggested here, a good resource that provides some detail on these Excel functions is a writeup of a flood frequency exercise by Steve Sheriff: http://www.umt.edu/geosciences/faculty/sheriff/350-Computation_Computer_Techniques/floodfrequency.htm

Analysis of USGS Field Measurements

From the "Available data for this site" window on the main page for the Missoula gage, go to "Field measurements." Download "field measurements" to a tab separated file, open in Excel. These are data collected over the years at this gaging station by USGS personnel. These data provide a nice record of channel changes at this site over time. Spend some time looking at the data and understanding what each column represents. All of the analyses below should be done in metric, so you'll need to create some new columns with the appropriate unit conversions.

1. Plot inside gage height versus *Q*, first for the data set as a whole, then for the most recent rating set (9). What you've plotted here is a stage-discharge rating curve, which describes the relationship between flow depth (stage) and discharge, for a specific cross-section. The

discharges used to develop rating curves are developed from field measurements of cross-sectional flow area and velocity ($Q=UA$); then, once a rating curve has been established at a site, discharge can be determined based on measurements of depth only. So when you see daily/hourly USGS discharge data, these data are based on continuous automated measurements of depth (stage). Changes in cross-sectional morphology produce changes in stage-discharge relationships, which is why stable reaches are desirable as gage locations.

Your rating curve probably isn't a straight line. Would you expect it to be linear or not? Explain your reasoning.

2. Plot the at-a-station hydraulic geometry; i.e., plot Q vs width, depth, and velocity, all on the same plot and using log scales on both axes. Fit power functions to each relationship. Report the coefficient and exponent for each relationship. What is the product of the coefficients? What is the sum of the exponents?

3. Plot channel width vs time. Is any trend in channel width (i.e., narrowing or widening) evident? Is this plot an accurate way of assessing changes in width? How would you explain the obvious outliers?

4. Calculate the width-depth ratio for each measurement. Plot Q vs w:h. What can you infer about cross-section shape and confinement from this curve?