STREAM HYDROLOGY - DISCHARGE MEASUREMENTS & PROFILE

Purpose

    I.   To determine the total discharge volume in cubic feet per second (cfs) of a stream.

    II.   To develop a map of the cross sectional profile of a stream in terms of its depth and discharge.

Materials & Equipment

- Yard Stick or ½ inch PVC pipe marked off in inches segments to 6 feet (1 for each team)
- measuring tape (1 for each team)
- Flow meter (or alternative) (1 for each team)
- Field Notebook

Procedure

There are three steps that you will need to accomplish in order to develop a hydrologic picture of the stream. They are:

    1)   Define the research area.

    2)   Establish a stream profile and determine the water's depth and velocity.

    3)   Calculate the discharge rate.

    4)

1) Define the research area.

Your study area (or reach) should be long enough to include all the physical features of the stream such as riffles and pools. A general guide is to have the reach at least 12 to 15 times as long as the bank is wide. After choosing the reach, you will need to establish two or three transects or cross-sections. These transects should be located so that the flow of water is uniform (or as close as possible) across the whole transect; in other words the flow should be parallel to the bank. If the stream has low discharge, you may need to use rocks to build a small straight channel through which the majority of the water can pass.

2) Establish a stream profile and determine the water's depth and velocity

This paper will present two methods to determine discharge amounts. One method uses a flowmeter to directly measure the discharge in several sections of the stream. The other method uses a floating object to calculate an average discharge rate.

Flowometer Method

The transect of the stream is made of an incremental number of sections or cells. We will measure depth and water velocity in each cell. After calculating the discharge in each cell, sum the values to calculate the total for that transect.

After choosing the transect site, use a measuring tape to define the transect line by anchoring the tape on both banks. Anchor the free-end of the measuring tape on the left bank as looking upstream. The cells should be generally equal in length. (If there are any irregularities in the bead, such as a large rock, you can start a new cell at one edge and the next when the bottom becomes regular again). There should be a minimum of five cells in each transect, but you can use more if it is convenient.

Measurements of depth and velocity are made at the middle of each cell. Typically the flowometer is placed at 0.4 times the depth of that cell. Be sure that the students stand downstream of the flow device and that their legs do not create eddies. Also be sure the check that the flow meter is facing into the current. Students can measure the depth in inches then divide by 12 to convert to feet (e.g. 1.7 ft).

Float Method
       If a flow measuring device is not available you can use a float to calculate the surface velocity of the stream. An orange, a block of ice, a zip-lock bag filled ¾ full with water, or water-logged stick will all float just below the surface and minimize the effects of air currents. You will need to mark off a known length of the reach of at least 60 feet. Introduce the float just up stream of the first marker so the float has time to reach the stream's velocity. Measure the time it takes to pass between the two markers. Ideally, you should time three passages of the float and average the three times.
       The students need to also measure the average width and depth of the stream. Once you have all the data, the discharge calculation is very easy.

Data Table
The table below is used to collect stream profile data. Please feel free to copy this or have the students transcribe it into their field notebooks.

Table 1 - Hydrology Data Sheets
Use this data sheet if you are using a flowometer.

	Distance from bank (ft)	Depth (ft)	Velocity (ft /sec)
Increment #1	_____	_____	_____
Increment #2	_____	_____	_____
Increment #3	_____	_____	_____
Increment #4	_____	_____	_____
Increment #5	_____	_____	_____

Add as many observation sites as you need by modifying the table.

Use these tables if you used the float method to determine the average velocity of the stream.

Average Width
Cross section #1   _____ inches

Cross Section #2   _____ inches

Cross Section #3   _____ inches

Average Depth
Increment #1   _____ inches

Increment #2   _____ inches

Increment #3   _____ inches

Increment #4   _____ inches

Increment #5   _____ inches

Average Float Time
Trial #1   _____ seconds

Trial #2   _____ seconds

Trial #3   _____ seconds

3. Discharge Calculations
I.   Calculations Using Flowometer

After you have gathered the data for each cell in the study transect, you need to calculate the discharge volume for each cell. Those volumes are added together to calculate the total discharge for that transect. The discharge volume for any cell is calculated using the formula

$$Q = wDv \qquad (1)$$

Where Q is the discharge (cfs) for the cell; w is the width in feet, D is the depth in feet and v is the velocity in feet/sec.

The total discharge from a transect is calculated by adding all the individual cell discharges. Using formula (1)

$$Q_{total} = w_1D_1v_1 + w_2D_2v_2 + ... w_nD_nv_n \qquad (2)$$

Where Q_{total} is the total discharge from the transect, $w_1D_1v_1$ is the discharge from the first cell, $w_2D_2v_2$ is the discharge from the second cell, and $w_nD_nv_n$ the discharge from the nth cell.

The illustration below is an Excel spreadsheet that is set up to calculate width interval, cell area, cell discharge, and total discharge.

	A	B	C	D	E	F	G	H	I
1			Site		Water Temp.				
2			Date		Width	9 ft			
3			Method						
4									
5	=(C9-C8)/2				=(C12-C10)/2				
6			Edge Distance (ft)	Width Interval (ft)	Depth (ft)	Area (ft²)	Velocity (ft/sec)	Cell Flow (cf/s)	Percent of Total Flow
7	Left Bank								
8		1	1.3	0.65	0.2	0.13	0.01	0.0013	0%
9		2	2.6	1.15	0.25	0.2875	0.12	0.0345	4%
10		3	3.6	0.95	0.29	0.2755	0.31	0.085405	9%
11		4	4.5	0.8	0.33	0.264	0.4	0.1056	11%
12		5	5.2	0.75	0.38	0.285	0.45	0.12825	14%
13		6	6	0.8	0.42	0.336	0.56	0.18816	20%
14		7	6.8	0.7	0.62	0.434	0.78	0.33852	36%
15		8	7.4	0.65	0.33	0.2145	0.25	0.053625	6%
16		9	8.1	0.35	0.17	0.0595	0.11	0.006545	1%
17	Right Bank								
18									
19							Q Total (cf/s)	0.941905	
20		=(C16-C15)/2							
21								Add down	
22									
23									
24									
25									
26									
27									

The students will measure Edge Distance (Column C), Depth (Column F) and velocity (Column G). The Width Interval (Column D) is calculated by subtracting the distance to the previous cell from the distance to the next cell then dividing by 2. (see notes on the illustration). The Area is calculated by multiplying Width times Depth. The cell discharge is calculated from equation (1) from above. The total discharge is calculated by summing the discharges from each cell.

II. Velocity Calculations for the Float

If you do not have access to a flowometer, you can calculate the total discharge by calculating the mean velocity of the stream and the average depth of the transect. Using equation (1) from above you can then calculate the total discharge.

The surface velocity is the length divided by the average time or

$$V_s = L/t \tag{3}$$

Where V_s is surface velocity, L is the length of the reach and t is the average time.

In order to correct for the effects of the stream's bottom there is a correction factor "k". Generally, the value k=0.85 is used in the following equation. If the bed is very smooth k=0.80 and if it is very rocky k=0.90.

$$V = k\,V_s \tag{4}$$

The discharge can then be calculated by using the equation (1).

$$Q = wDV$$

Where w is the width of the stream, D is the average depth of the transect, and V is the mean velocity from equation (4).


II. To develop a map of the cross sectional profile of a stream in terms of its depth and discharge.

From the discharge and depth data you gathered at the transect, students can easily graph the flow and depth data. The depth data will give an approximate "map" of the cross-section of the stream.

Graphing the stream depth.

Using the depth and distance from shore data from the illustration above, a quick and easy way to make the cross-section graph look correct in Excel is to use the format axis window. If you select "values in reverse order" then the "X" axis and depth will be properly orientated.

Stream Bottom Profile

Distance from Left Bank (ft)
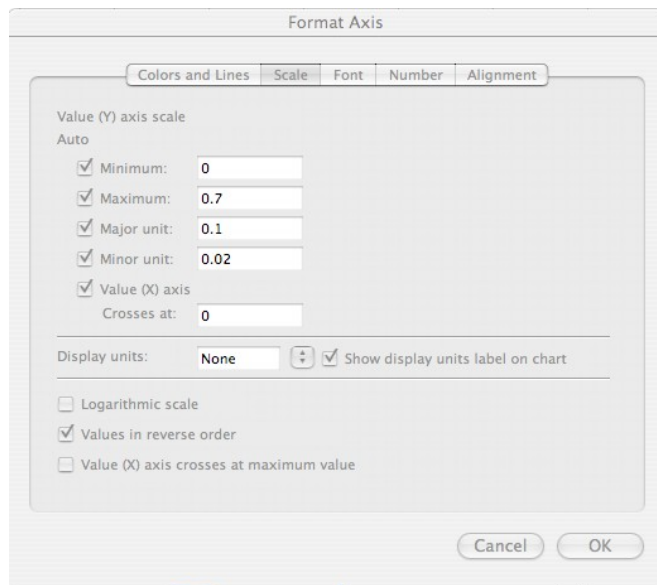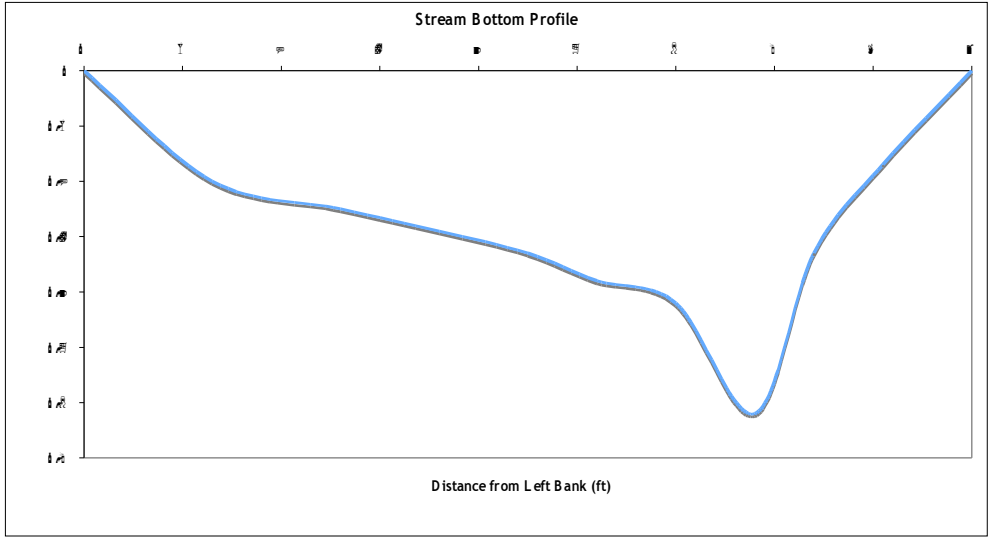
You may also want the students to construct a scatter plot of Depth vs. Velocity to help them visualize the positive relationship between depth and velocity for this stream. Using the XY scatter plot in Excel the hypothetical data from above produces the following scatter plot:

Depth vs. Velocity

Velocity (ft/sec)