

ASSIGNMENT 4 - STREAM DISCHARGE

Due: Wednesday, 27 February 2019 — Total Marks: 20

Objectives

This assignment introduces you to principles of stream discharge measurement using (1) velocity-area measurements and (2) the stage-discharge relation. You will be working with datasets collected previously for these analyses. Note that an R script ('lab4.R') is available on the course website to assist you with this assignment.

Background

Discharge (Q) is the volume of water per unit time ($\text{m}^3 \text{s}^{-1}$) passing through a channel. Accurate measurements of Q are necessary for many research problems in earth and environmental sciences. There are several methods available for estimating discharge, including the area-velocity method and salt dilution gauging.

Part 1: Velocity-Area Method (10 marks)

Using a current meter, discharge volume can be determined using the discharge-area method. The basis of this technique involves summing the discharges estimated through segments of the cross-sectional flow area.

Total discharge Q is the product of cross-sectional area (A) and average velocity (V):

$$Q = V \cdot A \quad (1)$$

In natural channels, it is necessary to measure the velocity and area components of discharge at successive locations (or verticals), and to integrate over the entire channel. For the example shown below, the estimated discharge between verticals 1 and 2 can be calculated as

$$Q_{12} = \left(\frac{\bar{v}_1 + \bar{v}_2}{2} \right) \left(\frac{d_1 + d_2}{2} \right) \cdot (x_2 - x_1) \quad (2)$$

where \bar{v}_i is the average velocity measured at point i , d_i is the water depth at point i , and x_i is, by convention, the distance from the left bank at point i .

Procedure

1. Estimates of surface velocity (V , in cm s^{-1}) and channel depth (d , in cm) along its cross-section x (in cm), obtained for a creek near Valemount, BC, are given in the data file 'velocity-area.csv'. Import the data to R.

```
> dat = read.csv('velocity-area.csv', head=T)
> attach(dat) # allows use of variable names (column headers) in R commands
```

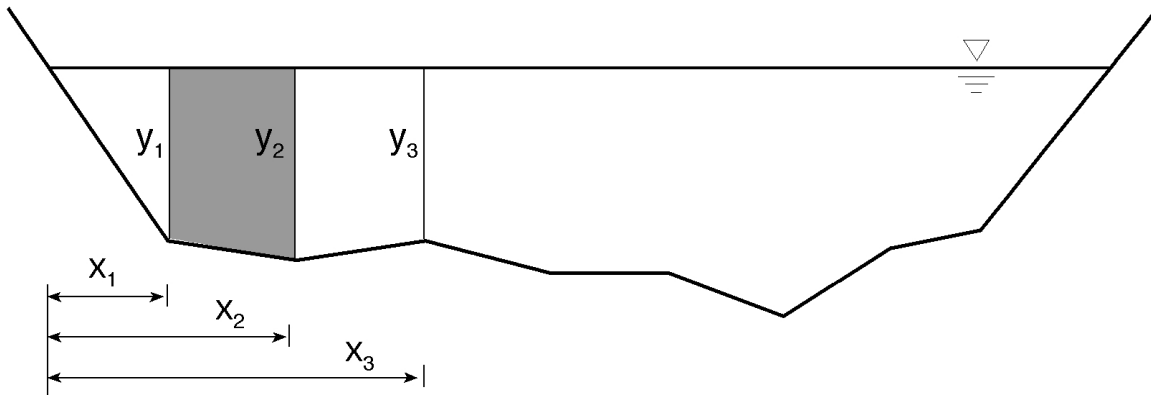


Figure 1: Example of the velocity-area method.

- Estimates of discharge for the area between successive verticals will be calculated from Eq. [2]. First create two new empty variables of size $(n - 1)$ to store your discharge estimates and distance midpoints:

```
> Q = rep(0, (length(X)-1) )
> Xmid = rep(0, (length(X)-1) )
```

- Convert the observed depths and cross section distances to metres, the surface velocities to m s^{-1} , and then loop through the measurements to estimate discharge and distance mid-points for each subsection:

```
> for (i in 2:length(X)){
  Q[i-1] = ((V[i]+V[i-1])/2) * ((D[i]+D[i-1])/2) * (X[i] - X[i-1])
}
> for (i in 2:length(X)){
  Xmid[i-1] = X[i-1]+(X[i] - X[i-1])/2
}
```

Questions

- Create an annotated plot showing distance from left-bank (Xmid) versus sectional discharge (Q). [5 marks]
- Using Equation [2], calculate *by hand* the discharge for the cross sectional area between 100 and 110 cm. Compare with your R calculation of discharge for the same section. [2 marks]
- Using the results you obtained from step 3 above, what is the total discharge of the creek (in $\text{m}^3 \text{s}^{-1}$)? [3 marks]

Part 2: Stage-Discharge Relations (10 marks)

Observations of stream height (or stage) can be collected continuously using stage-height recorders or pressure transducers (more common). To convert stage observations to discharge, discharge (Q) must be measured at different stages (H), and a stage-discharge relation can then be calibrated. The stage-discharge relation takes the form

$$Q = a \cdot H^b \quad (3)$$

where a and b are fitted coefficients.

Stream discharge (Q , in $L s^{-1}$) and stage height (H , in cm) measurements for a small stream were recorded in 2007 and 2008. The data are available in the file 'stage-height.csv', which can be found on the course website.

Procedure

1. open the data file in R, and using the `subset(...)` command, split the dataframe into two separate dataframes:

```
> dat = read.csv( 'stage-height.csv', head=T )
> sh07 = subset( dat, dat$year == 2007 )
> sh08 = subset( dat, dat$year == 2008 )
```

2. Using stage as the independent variable and discharge as the dependent, fit stage-discharge relations to the 2007 and 2008 data following Equation [3]. You will first need to set up a list of initial values for the non-linear model to begin with, and the 2007 model is done here for you:

```
> init = list(a = 0.01, b = 3)
> nlm07 = nls(Q~a*(H^b), data = sh07, start = init)
```

3. Using the 2007 and 2008 stage-discharge models, generate curves of predicted values for a range of possible stage heights. The 2007 example is given here for you:

```
> newdata = data.frame ( H = seq (0, 50, 1) )
> Qpred07 = predict(nlm07, newdata)
```

Questions

1. Produce an annotated plot comparing the 2007 and 2008 stage-discharge relations, with stage on the x-axis, and discharge on the y-axis. Using different colors/symbols, plot the observations and predicted curves for each year, and provide a legend. [5 marks]
2. Describe the differences between the 2007 and 2008 rating curves, and speculate about why they might be different. [5 marks]