University of Idaho

BAE450

Environmental Hydrology

Streamflow

Module 3

To become familiar with methods to measure or estimate streamflow

Start Audio Lecture!

Measurement of Streamflow

Who collects streamflow data?

- USGS
- NRCS
- US Forest Service
- USDA-ARS
- US Corps of Engineers
- USBR
- Tennessee Valley Authority

Measurement of Streamflow

What are some typical units?

- discharge Q: cfs (ft^3/s), cms (m^3/s)
- volume V: ft^3, m^3, gallons, liters, acre-ft
- time t: seconds, minutes, days, years

Continuity

The most important equation in stream or channel measurements is the continuity equation, which is stated as

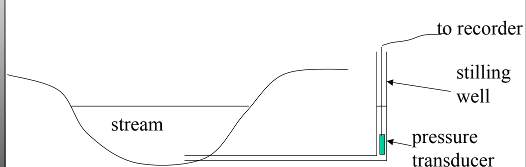
$$Q = v * A$$

where Q is discharge, v is velocity, and A is the cross-sectional area of flow

So, for two cross-sections, 1 and 2, the following should hold: $Q = v_1 * A_1 = v_2 * A_2$

Stage Height & Rating Curve

In many cases, a measurement of stage height is recorded using a staff gauge, pressure transducer or nitrogen bubbler. To convert the stage height to a discharge, frequent measurements of discharge are needed to develop a rating curve



Measurement of Streamflow

Measurement of velocity:
- current meter (cupped vanes)
- electromagnetic device (Marsh McBirney)
- pitot tube

Measurement of discharge:
- salt or dye injection

Estimation of velocity:
- Manning's equation

Methods

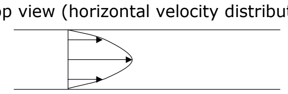
Measurement of velocity/discharge:
- Velocity-area method

Measurement of discharge:
- salt or dye injection

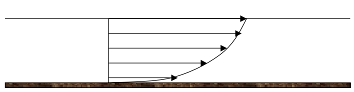
Estimation of velocity:
- Manning's equation

Velocity Distributions

top view (horizontal velocity distribution)

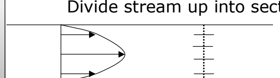


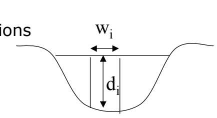
side view (vertical velocity distribution)



Velocity Area Method

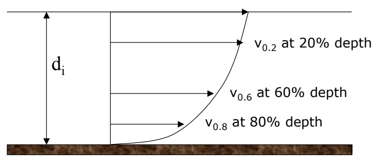
Divide stream up into sections





$$Q = \sum_{i=1}^{n} w_i d_i \overline{v_i}$$

Average Velocity

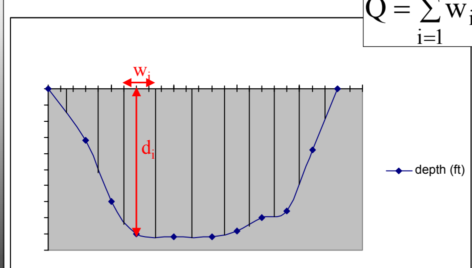


$$\bar{v} \approx \frac{\sum_{1}^{10}}{10} \approx \frac{v_{0.2} + v_{0.8}}{2} \approx v_{0.6} \approx v_0$$

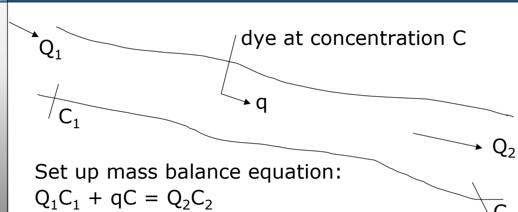
best — good (if d_i>2ft) — fair (if d_i<2ft) — poor

Velocity Area Method

$$Q = \sum_{i=1}^{n} w_i d_i \bar{v}_i$$



Salt or Dye Injection



Set up mass balance equation:
$Q_1C_1 + qC = Q_2C_2$
then assume that $q << Q_1$ and $Q_1 \approx Q_2$

$$Q_1 = \frac{qC}{C_2 - C_1}$$

Manning's Equation

Velocity can be estimated using:

$$v = \frac{1.49}{n} R^{2/3} S^{1/2} \qquad Q = vA$$

Where:
v = velocity (ft/s)
n = roughness coefficient (Table 7.1)
R = hydraulic radius (ft)
S = slope of channel bed or head loss per unit length of channel (ft/ft)

Manning's Equation

The hydraulic radius is defined as:

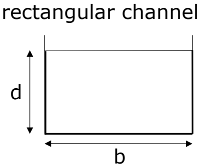
$$R = \frac{A}{P}$$

Where:
A = cross-sectional area (ft^2)
P = wetted perimeter (ft)
R = hydraulic radius (ft)

Hydraulic Radius

The hydraulic radius for rectangular channel:

$$R = \frac{A}{P}$$

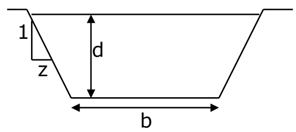


A = b * d
P = b + 2*d
R = (b*d)/(b+2*d)
If b = 3 and d = 2, R = 6/7

Manning's Equation

The hydraulic radius for trapezoidal channel:

$$R = \frac{A}{P}$$



$A = b*d + z*d^2$

$P = b + 2*d(z^2+1)^{1/2}$

If b = 3, d = 2, and z = 2, R = 14/11.94

Manning's n

The roughness coefficient is a critical parameter which must be determined from a table, or by calibration

A smaller roughness will result in a larger Q

n varies between about 0.01 to 0.15

Channel Flow

Typically, for canals and ditches, weirs and flumes are used to determine flow

Usually, a relationship between Q and H (stage height) is established

Figure 8.6A shows an example of a weir

Flume Equation

The general relationship for a flume (or weir) is:

$Q = C A \sqrt{(2gH)}$

where C is a coefficient, A is cross-sectional area (ft^2), g is the gravitational constant, and H is height of water in the flume

Usually, H is measured at critical depth where a unique relationship exists between flow and water level

Weir Equation

The general relationship for a weir is:

$Q = C L H^{3/2}$

where C is a weir coefficient, L is the weir length (ft), and H is height of water above the riser crest

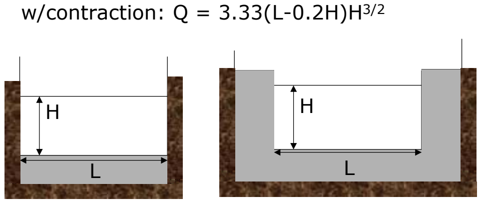
- note that A in flume equation is replaced with L*H

Weir Equations

Rectangular:

w/out contraction: $Q = 3.33 L H^{3/2}$

w/contraction: $Q = 3.33(L-0.2H)H^{3/2}$

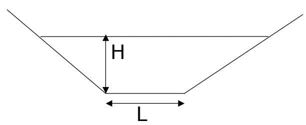


w/out contraction

w/ contraction

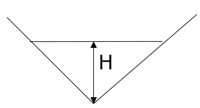
Weir Equations

Cipoletti (trapezoidal) : $Q = 3.37\ L\ H^{3/2}$



Weir Equations

90 degree V-notch: $Q = 2.5\ H^{5/2}$



Notes on Flumes and Weirs

Coefficients should be evaluated in-situ

Rules exist for installation and design of flumes and weirs, including where to measure H

Tables exist for different dimensional shapes