Measuring stream flow

Discharge - flow through a stream has units of volume (L³) per unit time typically in cfs, mgd, acre-feet/day and is considerably more difficult to measure than flow through a pipe or open channel. In both of those cases the constant geometry of the system allows assumptions regarding average velocity as a function of distance form the wetted perimeter. In a stream channel geometry is highly variable, precluding such assumptions. Looking at a cross-section perpendicular to flow, we expect velocity at any given time to vary with both vertical (depth) and horizontal location, thus making it difficult to assess an average value. We can also expect the distribution of velocities to change with depth (stage) as the stream will change in width and some obstructions will be covered/uncovered. As a final problem, the stream channel is not fixed in time, even at constant stage due to scour and deposition.

wetted perimeter - Assuming a cross-section perpendicular to the flow, the wetted perimeter is the length along that cross-section that represents contact between the stream channel and water. For a rectangular cross-section, wetted perimeter is equal to width plus 2 times the depth.

hydraulic radius – Derived quantity equal to cross-sectional area divided by wetted perimeter; has units of L. For a given cross-sectional area, hydraulic radius will be at a minimum for a circular pipe, which is the most efficient method of conveying fluid. Effectively, the wetted perimeter describes the area which resists flow through friction.

Manning equation - this gets used when other methods are impossible, such as during transients, flow above the rating curve, no gauging station, etc., relates average velocity to hydraulic radius, slope of the water table and an empirical measure the 'Manning Coefficient' which is supposed to represent frictional losses, an estimate of the cross-section can then be used to estimate flow, the USGS publishes photographs to estimate the Manning coefficient. This is an empirical relationship and hence can not be used in the derivation of other parameters

\[ V = \frac{1.49R^{\frac{2}{3}}S^{\frac{1}{2}}}{n} \]

- \( V \) = average velocity (ft/s)
- \( R \) = hydraulic radius (ft)
- \( S \) = slope of stream surface (ft/ft)
- \( n \) = Manning coefficient

mountain streams (high resistance to flow) \( n \sim 0.05 \), real empirical
concrete ditches (low resistance to flow \( n = 0.12 \), much less empirical

floats – For a really rough estimate of discharge, one can estimate cross-sectional area and average velocity. Pick two cross-sections on the calmest stretch possible, estimate the area of each and average. toss something that floats in and time how long it takes to go
from one cross-section to the other. Do this several times and take an average. This is not very accurate, but may be the best that you can do in some situations, or at least a start before choosing another method. Even if you know the cross-sectional areas precisely, the float method is biased. Water along the top surface of the stream is moving faster than average, plus it is difficult to get the float into all possible stream lines, and ones that involve eddies may not be representative. May want to break the stream up into several flow channels, get an average velocity for each. Water at the top of the stream is faster than the average. The surface velocity multiplied by 0.85 is a reasonable estimate of average velocity. Lightweight items that float high in the water are affected by wind. Something that floats a little bit deeper like an orange is more representative.

**gauging** - the measurement device has a bullet shaped housing with a what looks like a wind speed indicator attached, the housing is placed at 0.6 times stream depth and the velocity measured, this is done across the stream at regular intervals and all the data summed to find cross-sectional area and flow rate, describe winch mounted and pygmy meters

**stage heights** - if the river has a stable cross section, meaning it isn't changing it's channel, flow rate will be directly correlated to river stage, the USGS measures the stage at numerous locations, quite often at highway bridges (stable x-section, easy access), describe a gauging station (stilling well), the stage height is converted to flow using a calibration curve based on gauged data, this has to be checked frequently and doesn't work for floods above the calibration curve. Note that once the river exceeds its banks, small increases in stage will result in large increases in flow.

**weirs** - basically these means placing a dam across the river and forcing it to flow across a notch such that the water falls freely after passing the notch which in theory should have a knife edge. Empirical equations have been developed that relate weir dimensions, including depth of water to the flow rate. This technique is also used to measure flow during pump tests.

V-notch weir (90° notch)

\[ Q = 2.5H^{5/2} \]

*Q* – discharge (ft³/s)

\( H \) – backwater depth (ft)

rectangular weir with edge contractions

\[ Q = 10/3(L - 0.2H)H^{1/2} \]

*Q* – discharge (ft³/s)

\( H \) – backwater depth (ft)

\( L \) – length of weir crest (ft)
Portable weirs may be used for small streams, ditches and outflow from aquifer tests. Permanent weirs are essentially a dam in the stream and may be subject to regulations. These are very commonly used in irrigation canals. Note that the notch must be sufficient to measure flows. It does you no good to have water flowing over the top of the weir. The weir equations are sensitive to $H$, so small errors in $H$ can lead to big errors in $Q$. Thus using too big of a weir will lead to substantial error, because $H$ is a pain to measure accurately. For low flows, a v-notch weir is most accurate. You need to consider the range of flows to be measured. Do you care about maximum/minimum flows, or normal flow? You can put a v-notch in the base of a rectangular weir to cover a large range of flows.

Installing a weir, fixing it in place, minimizing leakage.

**Flume** – Essentially this means forcing flow through a rectangular open channel that has a constant cross-sectional area and slope. Flow is then estimated though use of the Manning equation, which is well understood for flumes. In order for this to work the flume has to be long enough so that end effects dissipate before the measurement section.

**Estimating stream loss/gain**

- seepage meter
- in-stream piezometers
- sequential gauging stations
- wells perpendicular to the stream
- hydrograph separation
- tracer applications
- geochemistry