Goals
- Introduce volumetric flow = stream discharge
- Flow/velocity relationship
- Volumetry
- Calibrated Weirs
- Manning's Eqn for calculating flow.

1) Measuring Discharge

What is the volume of water that flows from the watershed per unit time?

A) Can measure stream velocity with a water anemometer (velocity meter) than multiply by cross-sectional area.

\[ Q = VA_{xs} \]

B) Run water thru a device that tells us the flow rate directly (a weir or a flume.)

c) Measure stream level \( h \) and find flow from a "rating curve."

D) Estimate flow using an equation plus some info about the slope of the streambed + bed conditions.
Flow: Mass Flow: \( \dot{m} = \frac{M}{T} \) \( \{\text{g/day}\} \)

Volumetric Flow: \( Q = \frac{V}{T} = \frac{L^3}{T} \) \( \{\text{m}^3/s\} \)

Connection: \( \rho = \frac{m}{V} \)

\[ \therefore \dot{m} = \rho Q \]

Ex: Given \( Q = 1.5 \text{ m}^3/\text{s} \)
\( \rho_w = 1.0 \text{ kg/L} = 10^3 \text{ kg/m}^3 \)

\[ \dot{m} = (1.5 \text{ m}^3/\text{s})(10^3 \text{ kg/m}^3) = 1.5 \times 10^3 \text{ kg/s} \]

Flow and Velocity: Consider rectangular channel:

\[ Q = \frac{V}{A_{xs}} \]

\[ V = \text{mean velocity of water} \]

Ex: Channel is 1.5 m deep, 4 m wide
Velocity is 0.80 m/s

\[ Q = \frac{(0.80 \text{ m/s})(1.5 \text{ m})(4 \text{ m})}{A_{xs}} = 4.8 \text{ m}^3/\text{s} \]

\[ A_{xs} = 6 \text{ m}^2 \]

Ex: Flow is 500 L/s; \( A_{xs} = 2.0 \text{ m}^2 \) Velocity?

\[ V = \frac{(500 \text{ L/s})(1/1000 \text{ m}^3/\text{L})}{2.0 \text{ m}^2} = 0.25 \text{ m/s} \]
5. **Issues for Natural Streams**

A) Velocity varies across stream, and also with depth.

Even for ideal geometry:

\[ U = f(z) \]

\[ U = 0 \text{ at bottom: "No Slip Condition"} \]

B) Cross-sectional area is complex in real stream

\[ Q_t = \sum_{i=1}^{n} U_i A_i \]

**Solution:**
- Divide stream cross-section evenly across
- Find trapezoidal area of each segment
- Find mean velocity \( U \) for each
- Sum up \( U_i A_i \)
**Velocimeters**

- **Rotary Type** (we use)
  - Current proportional to speed of rotor

- **Acoustic Doppler**:
  1. Sends out 10-16 MHz signal (ultrasonic)
  2. Sound bounces off micro particles in water
  3. Reflected sound waves received back at head.

  Fluid velocity proportional to Doppler Shift.
  - NEVER contacts the measured volume (except with soundwaves)
  - 3-D, very accurate, fairly expensive

**ADP**: Acoustic Doppler Profiler

- Can scan up & down & produce 3-D image of whole velocity profile
VELOCIMETRY

Advantages:
- Gives details of flow, distribution, shear
- Portable, no permanent required
- Use in almost any size stream or river (estuaries, open ocean even)

Disadvantages:
- Must know $A_{ss}$ to get $Q$ (shape)
- $A_{ss}$ varies with $Q$. As $Q$ goes up, river rises & $A_{ss}$ gets bigger.
- Hard to automate unless use expensive ADP
- Labor intensive (unless ADP)

Alternatives:

WEIRS

Height $H$ over weir or $Q$

Flat "Broad-Crested" Weirs

"Sharp-Crested" Weirs

Oftentimes "V" or Trapezoid Notch

Read $H$

Or float level gauge
1. Measure lots of Q's (with velocity meter, etc.) and record H
2. Plot Q vs. H
   ⇐ "Rating Curve"
3. Now, can find Q just by knowing H

- Measurement of stream stage and flow
Alternative to Float: Bubbler

Tank of compressed air or N₂

\[ p = \rho g H \]

Hence \( \rho_a \) read here = \( \rho g H \)

TELLS US \( H \)

Pa same thru out tube (very slow flow) \( \sim \) STATIC

\[ p_a = p_w = \rho g H \]

No moving parts.