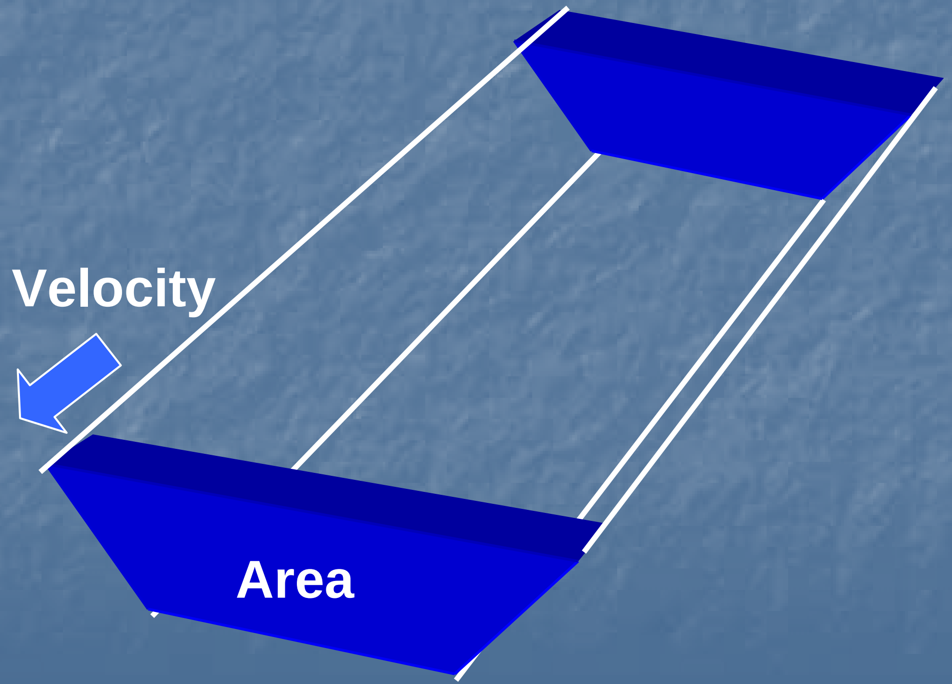
Discharge

Discharge (Streamflow) is:

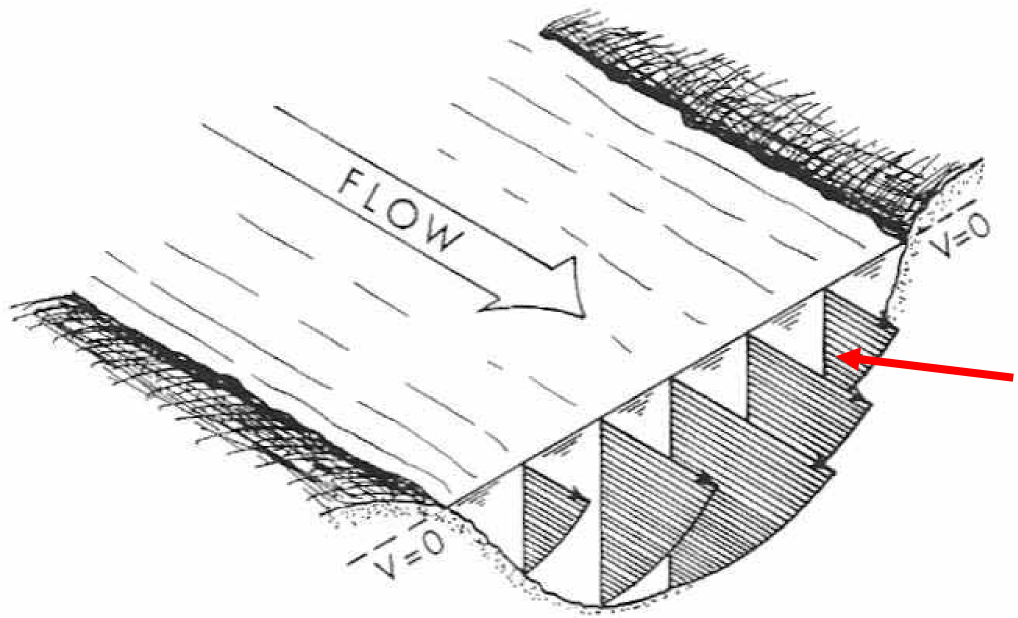
Q = Velocity (L T^{-1}) x Area (L^2)

Units: L^3 T^{-1}

e.g., m^3 s^{-1}



Where is the average velocity ??



PERSPECTIVE VIEW

FIGURE 4.11. Measurements of channel cross section and velocity needed to determine streamflow discharge.

Source: Brooks et al., *Hydrology and the Management of Watersheds*

Real data: deepest part does not have the most flow!

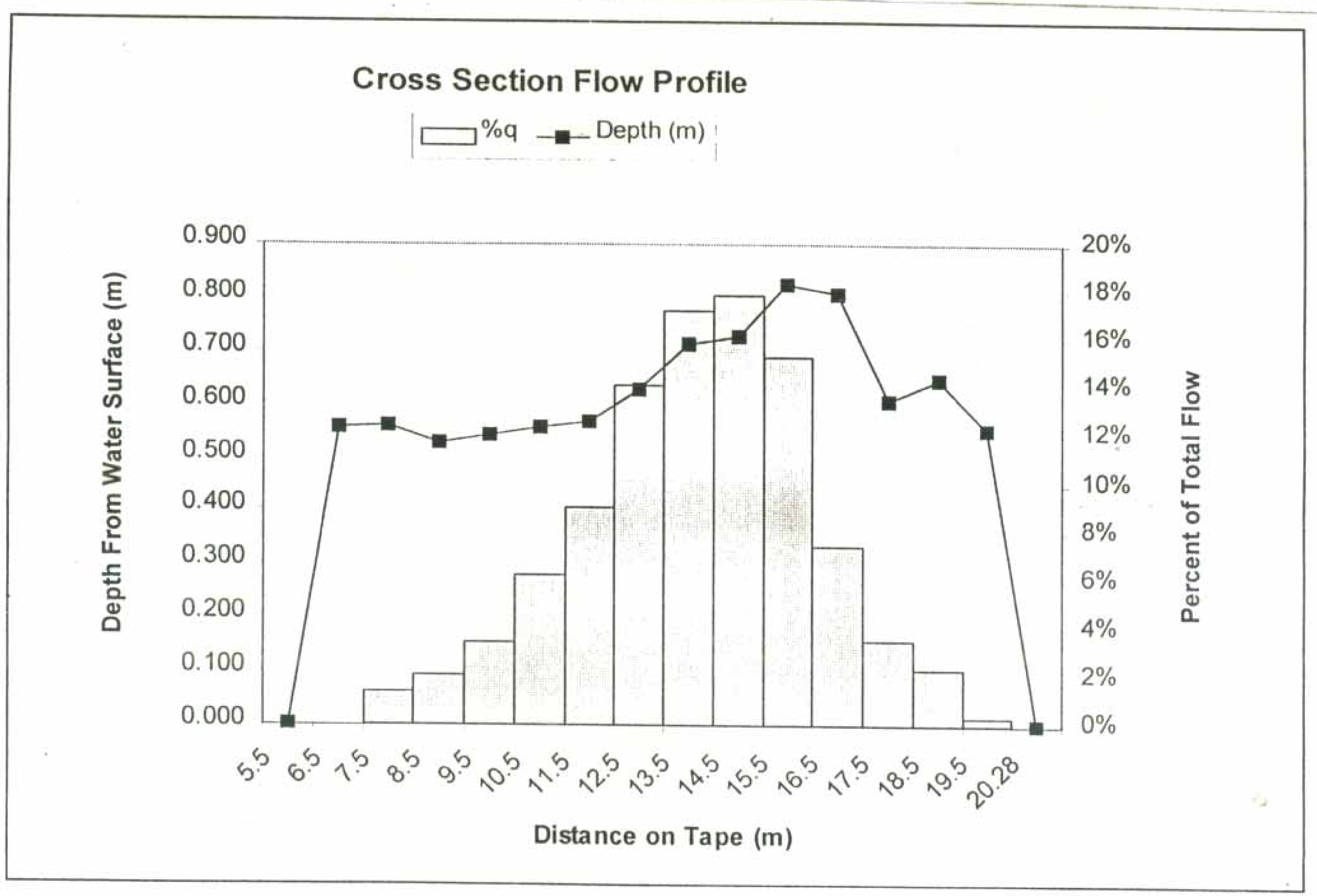
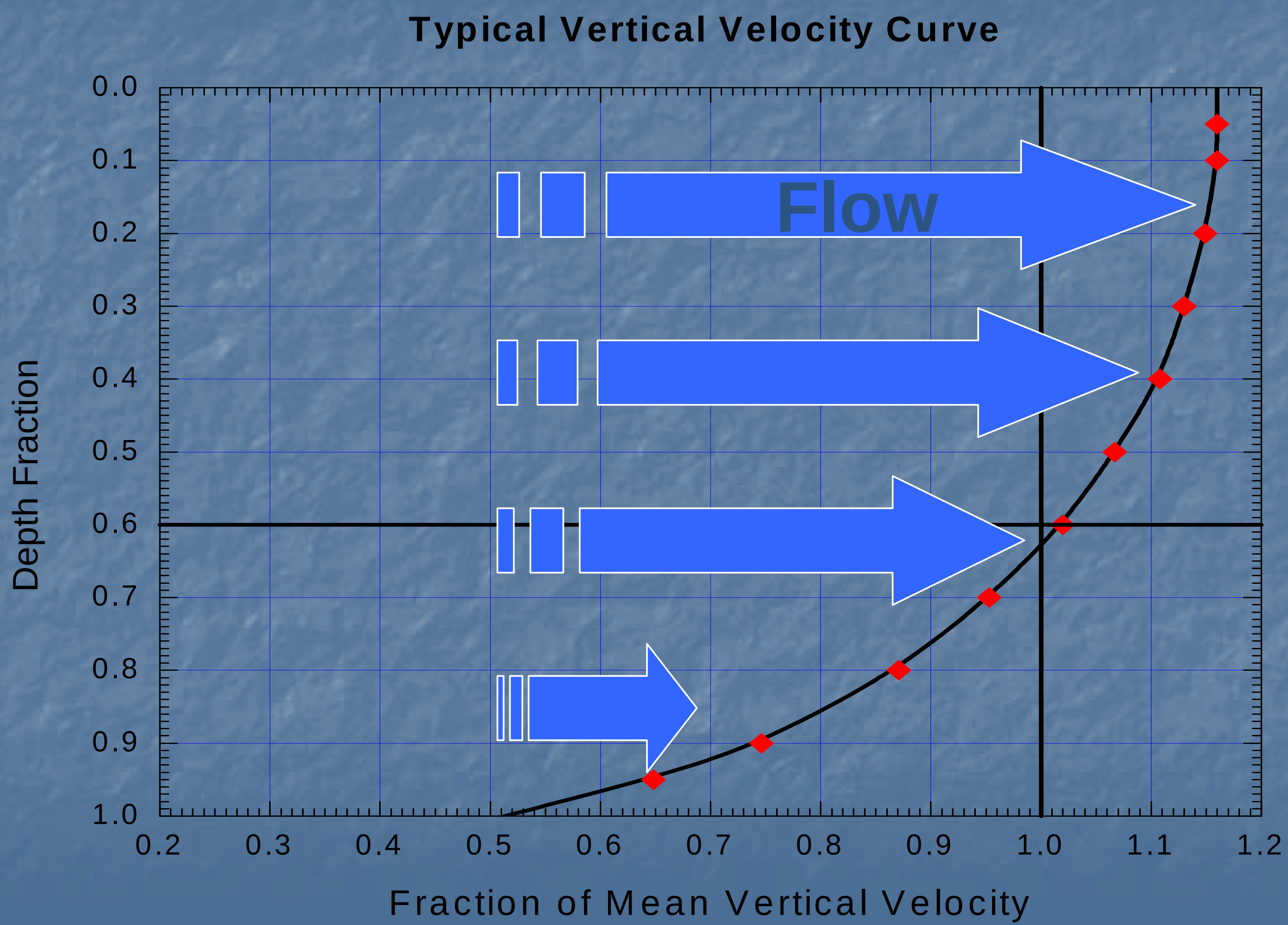
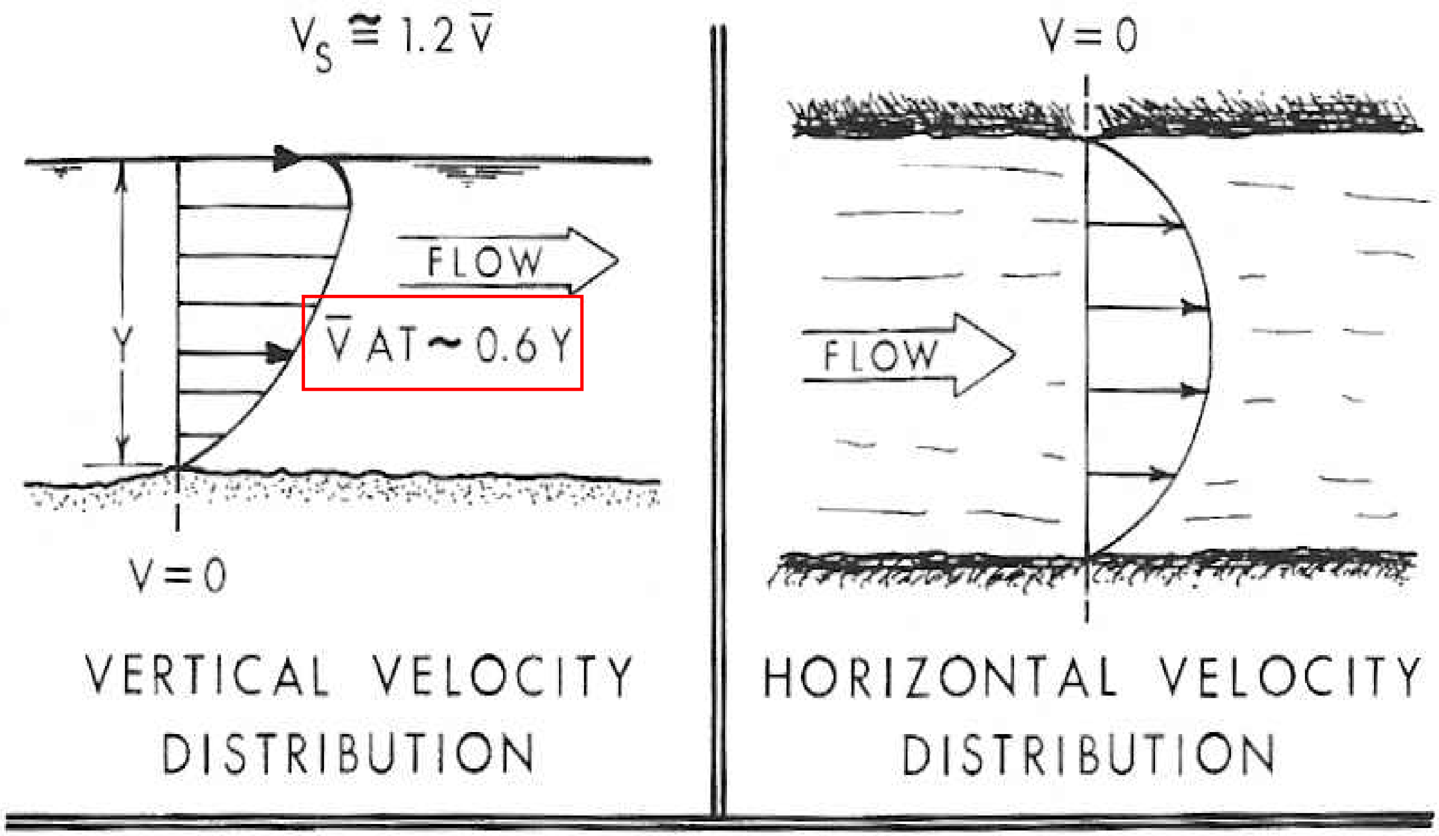


Figure 2: Velocity Head Flow Profile.

Where is the mean velocity?



Where is the average velocity?



Measuring discharge

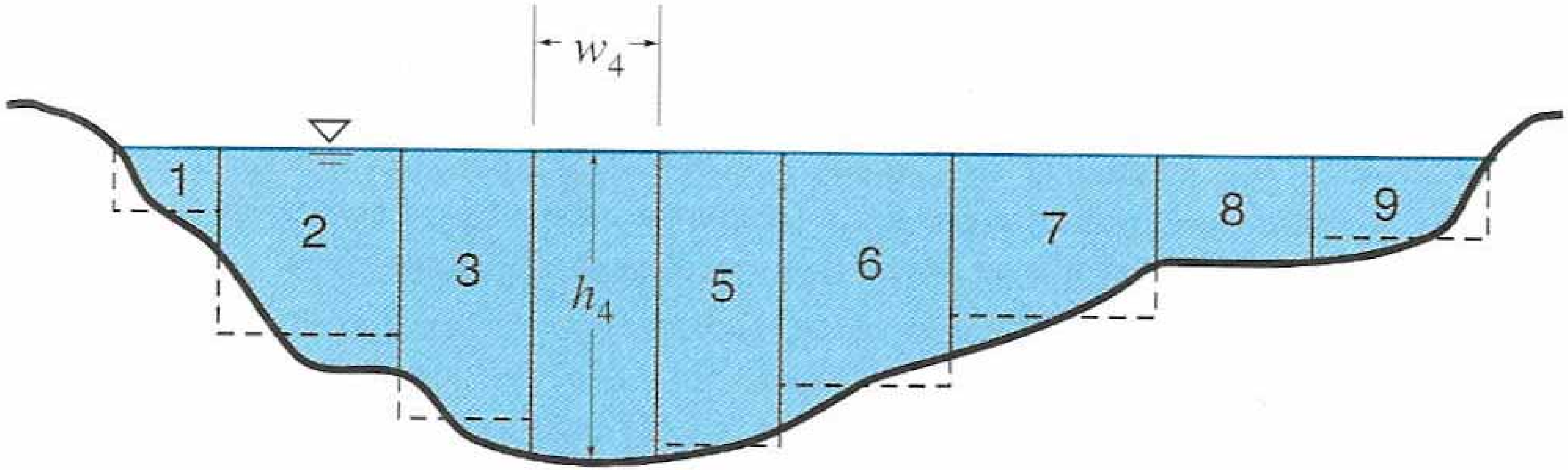


Figure 4.11 Method for determining discharge in a stream. The stream is subdivided into a number of rectangular elements. A current meter is used to measure the speed of the flow at a distance $0.4h$ from the stream bottom in each rectangle. The water velocity at this depth is approximately the average velocity for that segment, assuming that the logarithmic velocity profile for turbulent flow is valid. Discharge is calculated by multiplying the average velocity for each rectangle by the area of that rectangle and summing across the stream.

Choosing a cross-section for measuring discharge

- Straight;
- Free from obstructions (logs, rocks, algae, etc.);
- Smooth bottom and banks;
- Minimal turbulence;

Surveying a cross-section: Methods

- String and line level
- Stadia rod
- Measure key points, not systematic spacing!
- Extend to above bankfull;

Measuring velocity

- Simplest is ?

Measuring velocity

- Floats
  - Usually an orange for 5 or so meters;
  - Measure distance and time;
  - Multiply velocity by 0.85;

Measuring velocity

- Most common are current meters:
  - Vertical axis
    - Price AA;
    - Pygmy;
  - Horizontal axis (propeller type)
    - Ott (originally German);
    - Chinese imitation used in Vietnam;

Current meters

- Hand-held using a wading rod;
- Suspended from a boat or a bridge;
  - Need heavy weight (“fish”) of 20-70 kg;
  - Challenge to keep a boat on a straight line in a fast-moving river!


HÀ TÂY 06

Depth of velocity measurements

- Very shallow streams (<0.4 m) measure at 0.6 of the depth;

- Deeper streams measure at 0.2 and 0.8 times the depth;

Depth of velocity measurements

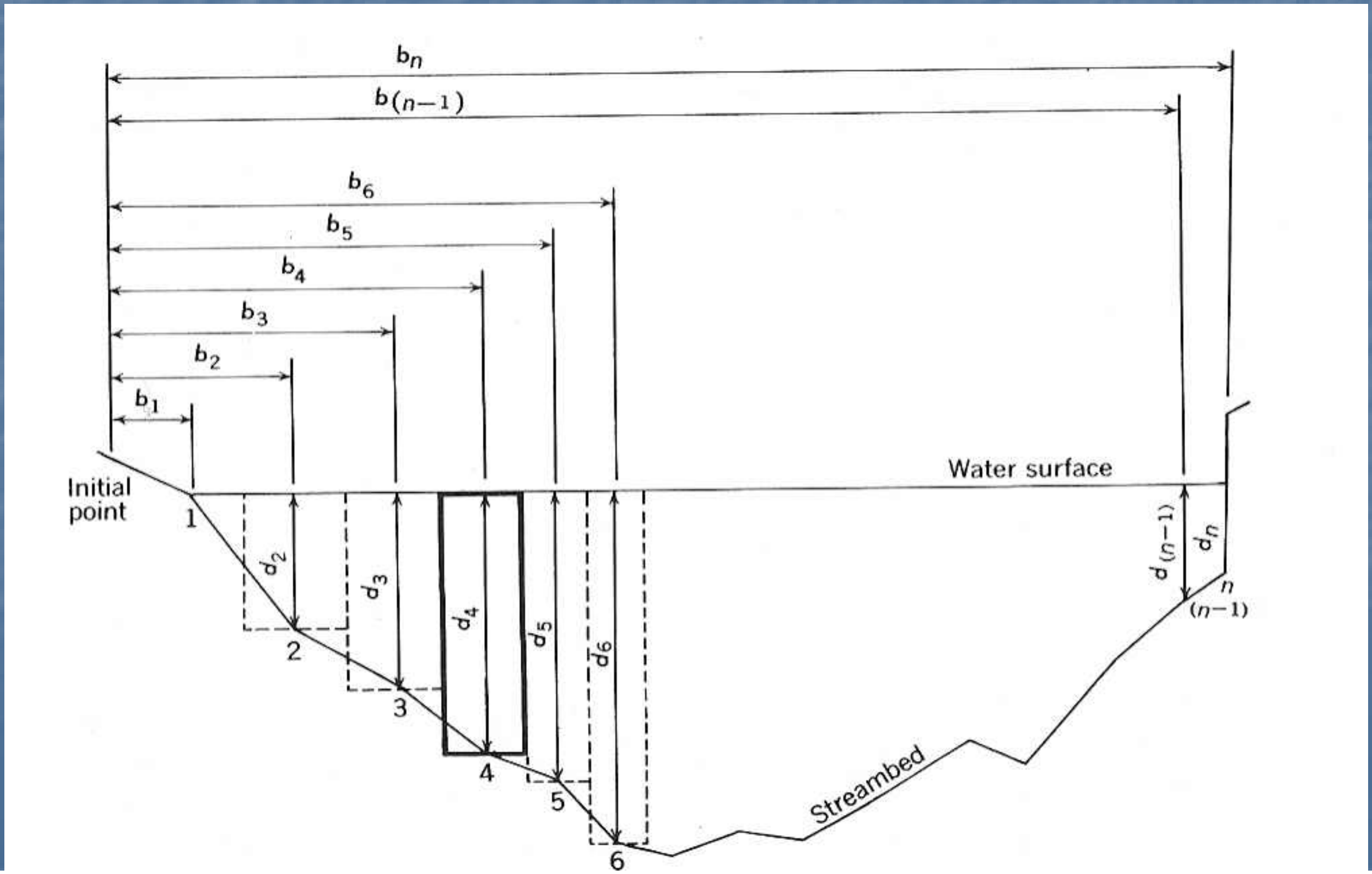
- Very shallow streams (<0.4 m) measure at 0.6 of the depth;

- Deeper streams measure at 0.2 and 0.8 times the depth;

Streamflow Computation

$Q = \Sigma(q_x)$
$Q = \Sigma(a_x v_x)$
a = Area
v = Velocity

$$q_x = v_x \left[\frac{b_{(x+1)} - b_{(x-1)}}{2} \right] d_x$$



Current meters are very accurate!

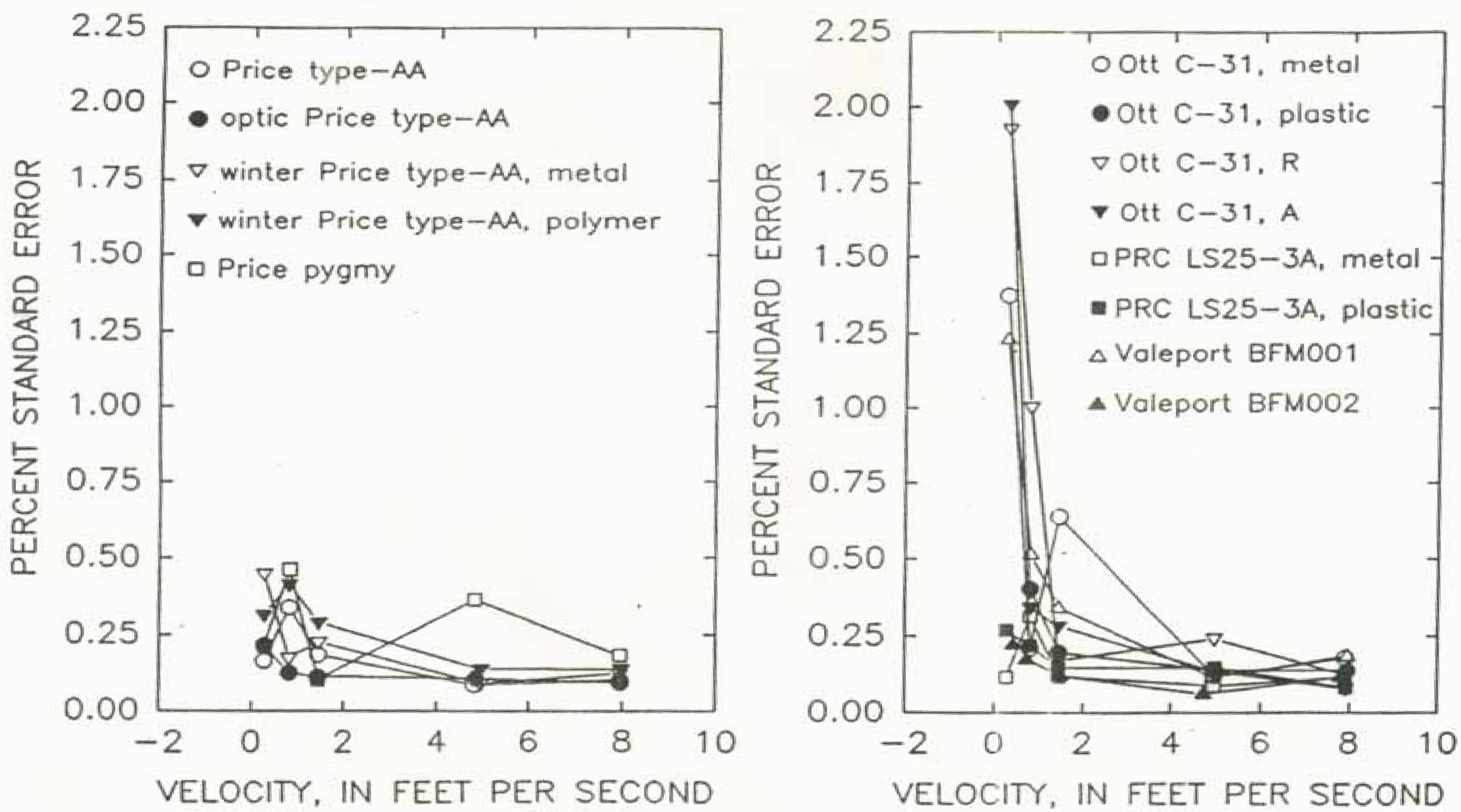


Figure 2. Precision tests. Percent standard error computed by velocity for (A) vertical-axis meters and for (B) horizontal axis meters (PRC, People's Republic of China).

Number of measurements across the stream is most important factor for a good measurement of streamflow

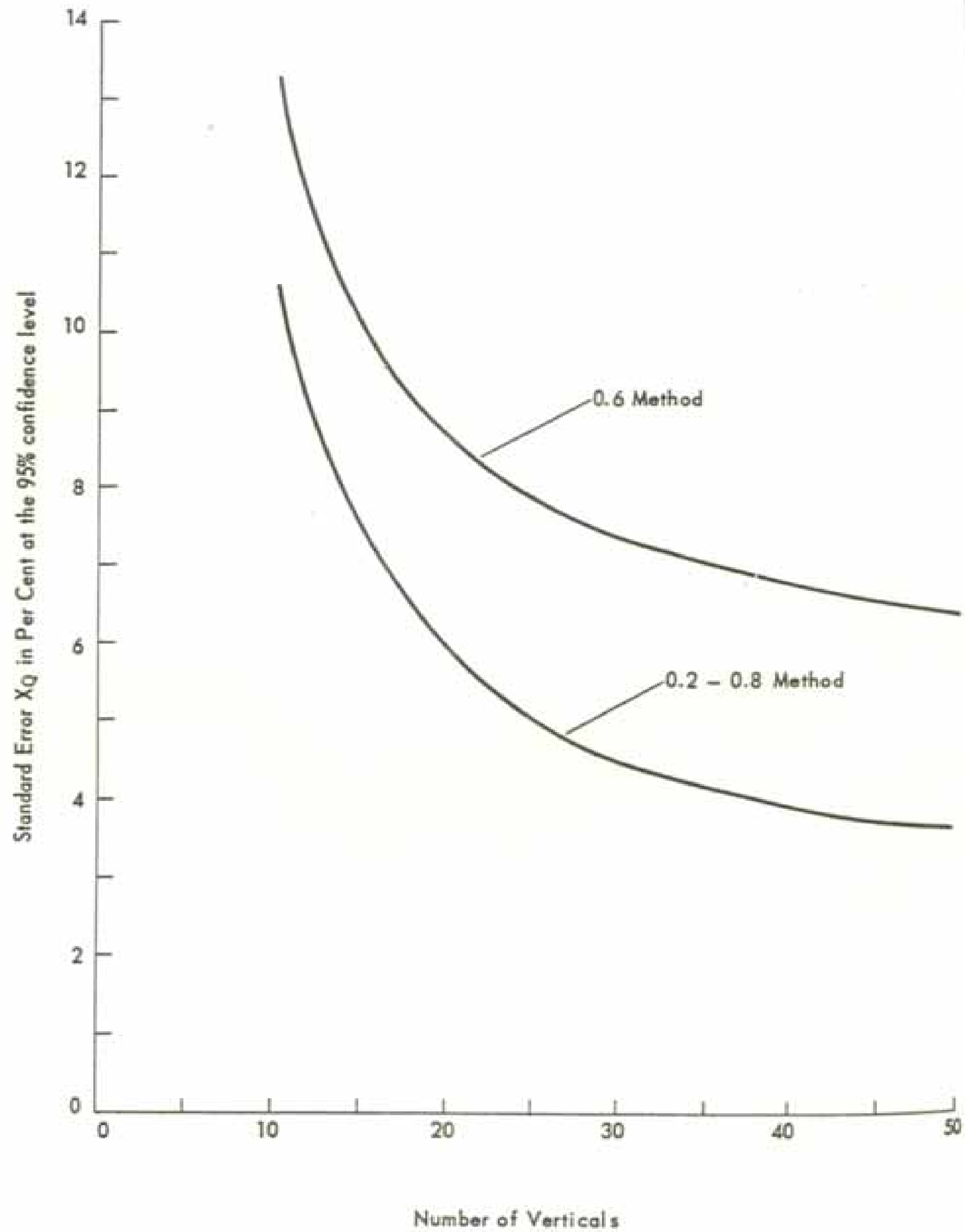


Figure 3. *Standard error of individual measurement of discharge performed by current meter*

Duration of velocity measurements

- Minimum of 40 seconds;
- Maximum of 70 seconds (otherwise takes too long!);

Velocity also varies over time, even at constant flow!

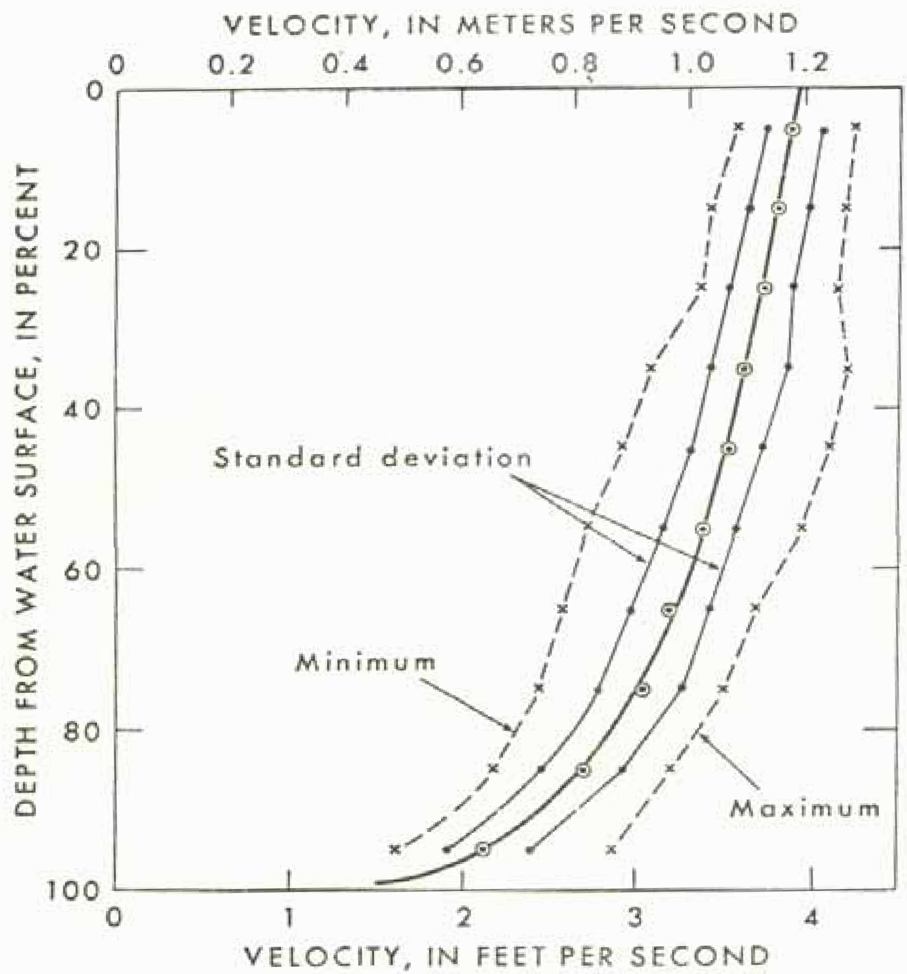


Figure 1. *The 66-minute vertical-velocity curve, vertical 280 in the measuring section of the gauging station, Columbia River below Priest Rapids Dam, 14 August 1963*

Velocity head

- Higher velocity streams have more momentum;
- Momentum causes water to pile up against an obstruction;
- Height of water (H) is proportional to velocity;
- $V = (2gH)^{0.5}$

  where g is gravity (980 cm s^{-2})

Rating curve

DISCHARGE RATINGS AT GAGING STATIONS 11

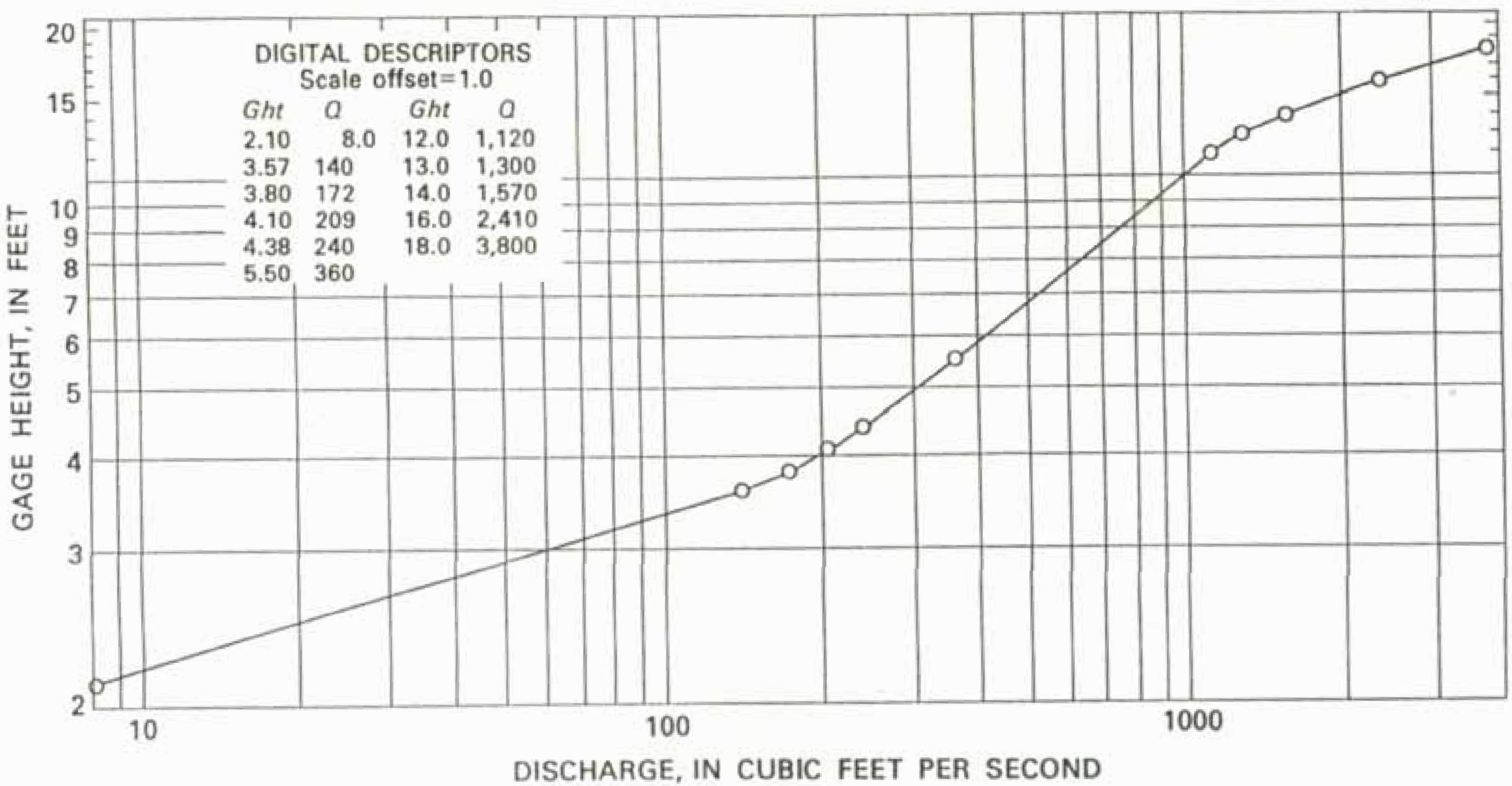


FIGURE 7.—Typical logarithmic rating curve with corresponding digital descriptors.

Stage and Discharge

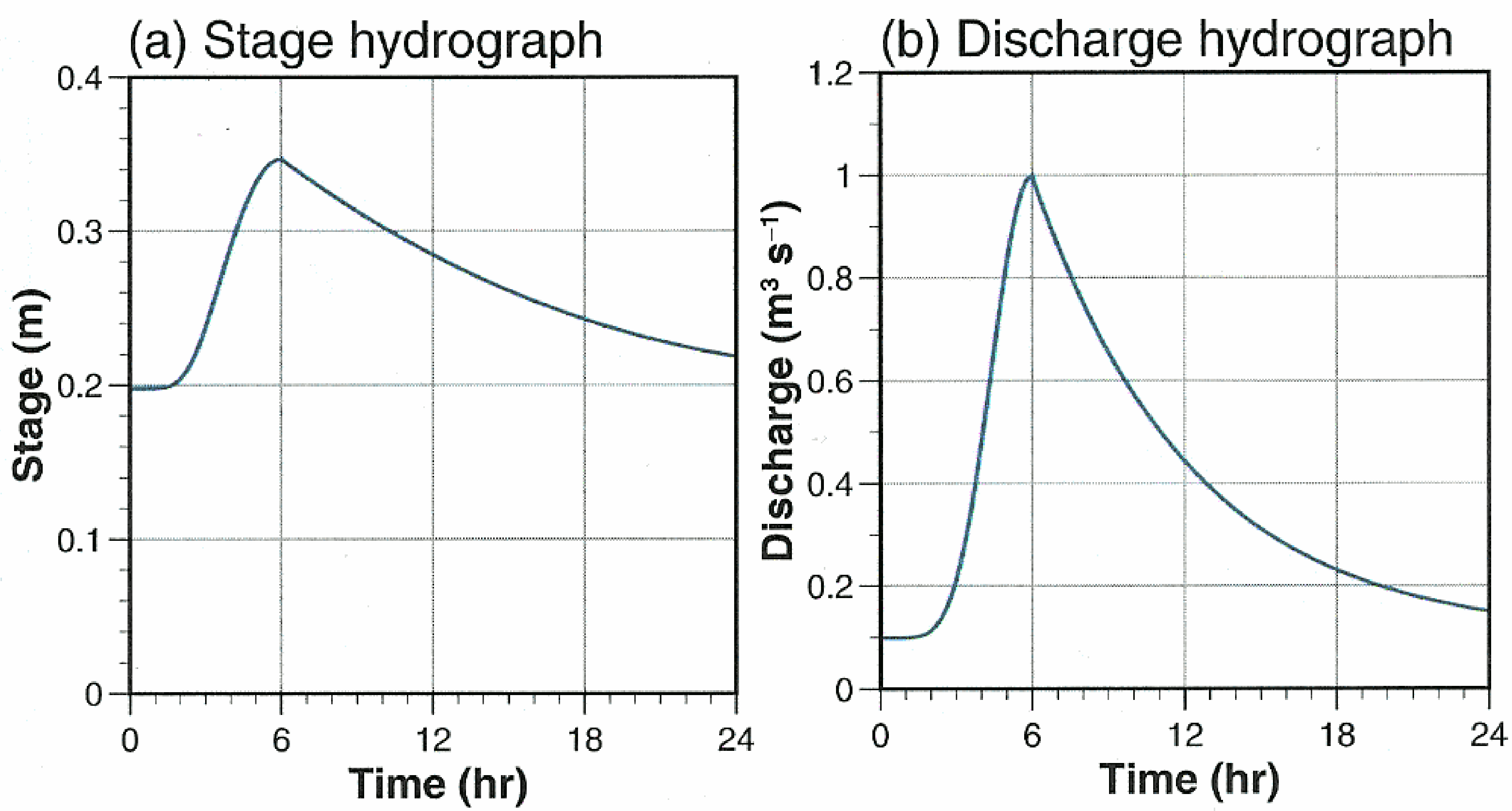


Figure 5.1 The hydrograph. River stage (a) and discharge (b) as functions of time.

Why is the change in discharge than the change in stage?

Back-calculating discharge: Manning's equation

$$Q = (A\ R^{0.67}\ S^{0.5})/n$$

Q = Discharge ($L^3\ T^{-1}$);

A = Cross-sectional area of the stream (L^2)

R = Hydraulic radius, which is the area divided by wetted perimeter; usually substitute mean depth;

S = Slope (m/m);

n = Manning's roughness coefficient;

Back-calculating discharge: Manning's equation

$$Q = (A\ R^{0.67}\ S^{0.5})/n$$

- Most commonly used to back-calculate flow after large floods, as high water mark is usually visible, so we can measure A, R, S, and estimate n after the fact;

Manning's n

- Roughness refers to the loss of energy by friction, form shape, sinuosity, obstructions, etc.;
- Usually assumed to be about 0.03-0.05, but can vary from 0.01 for a concrete channel to 0.15 for a densely vegetated floodplain;
- Decreases as flow depth increases!
- Estimating n is an art!

Palouse River at Colfax: $n \cong 0.01$

Columbia River at Vernita: n = 0.024

Clearwater at Kamiah: n = 0.033

Spokane River at Spokane: n = 0.038

Grande Ronde at LaGrande: n = 0.043

SF Clearwater at Grangeville: n = 0.05

Boundary Creek at Porthill: n = 0.073

Ötz near Ötz Village : n = 0.15?

Second field site

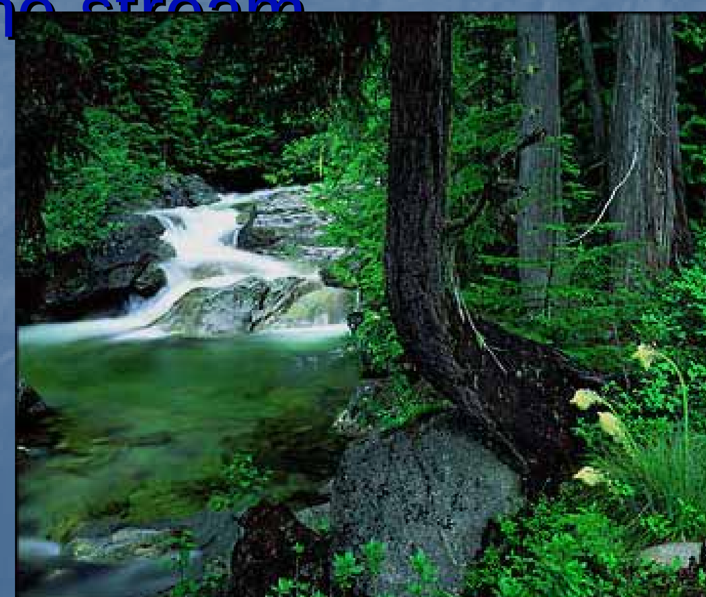
- Identify bankfull
- Identify location for x-section
- Estimate Manning's n

Significant figures

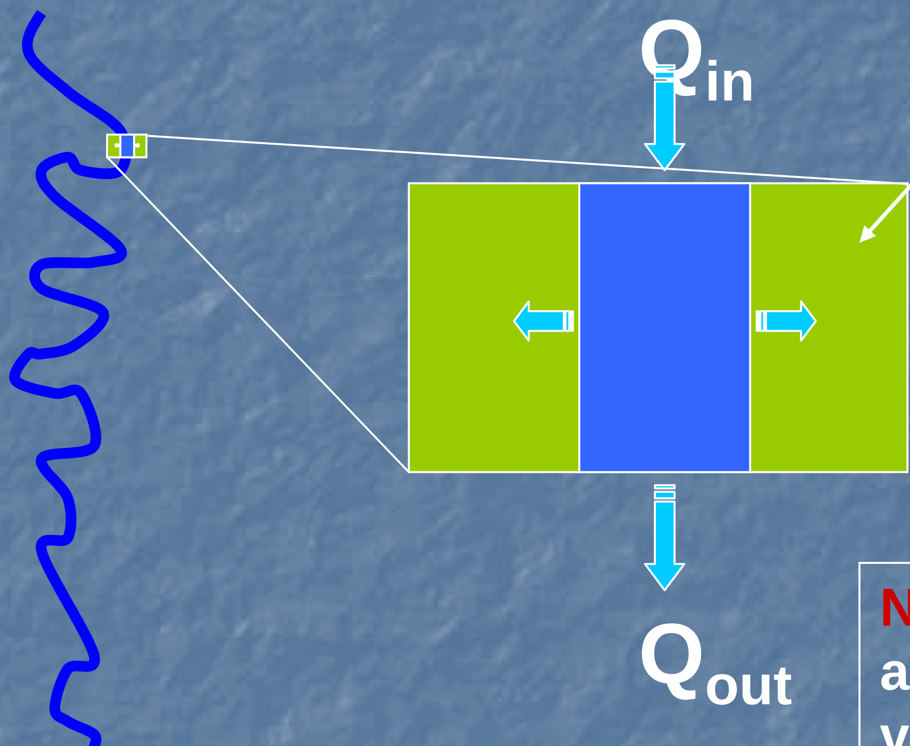
Controls of Channel Morphology

What determines channel morphology?

- Width, depth, slope, roughness, discharge, velocity, sediment load, sediment size
  - Change 1 variable, and the stream … ge



The Floodplain



Floodplain

High Roughness =

Lower Velocity =

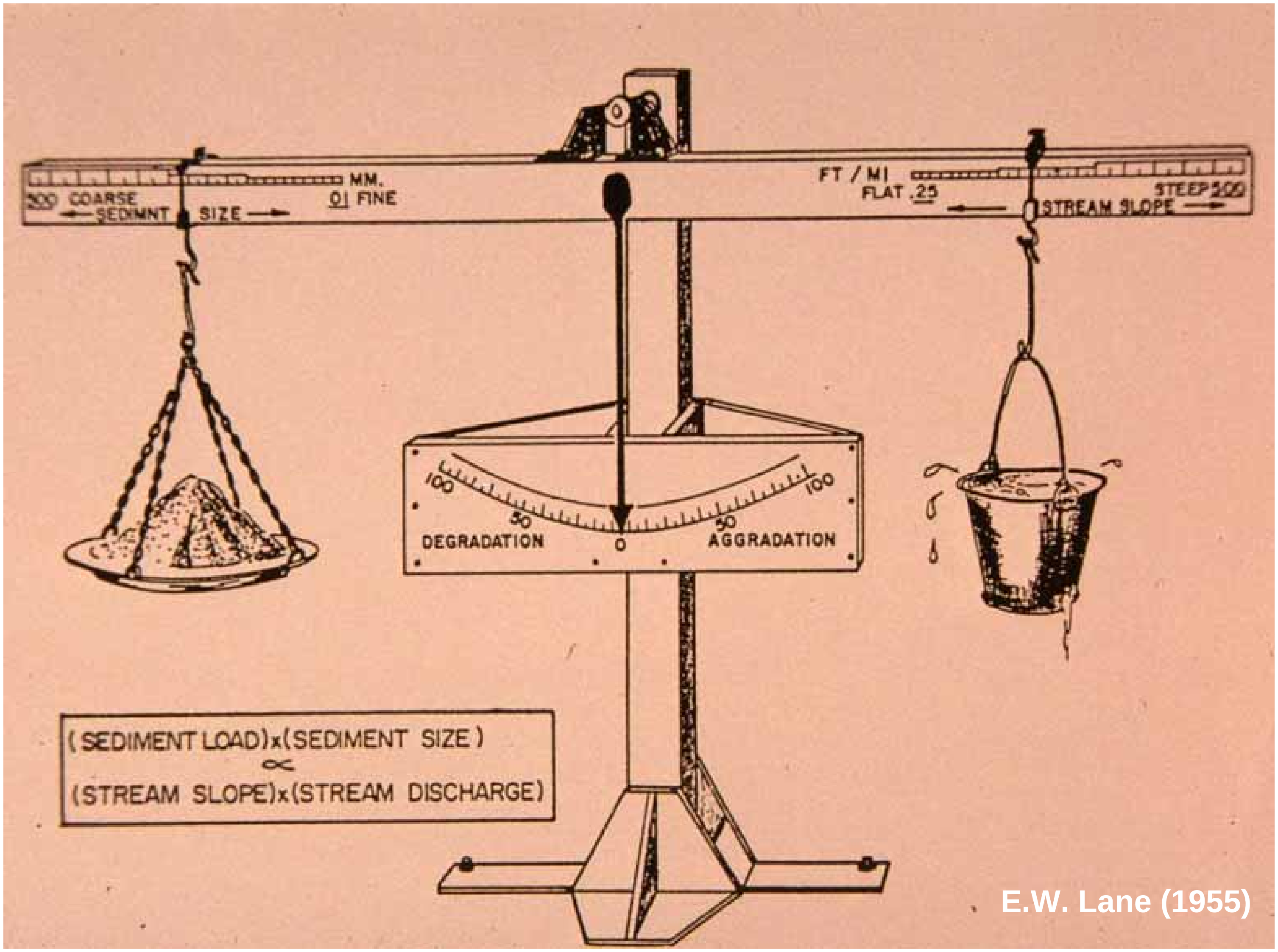
Lower Competence =

Sediment Deposition

Note: Floodplains also affect other water quality variables.
Ex: nutrient reduction, biodegradation of organics

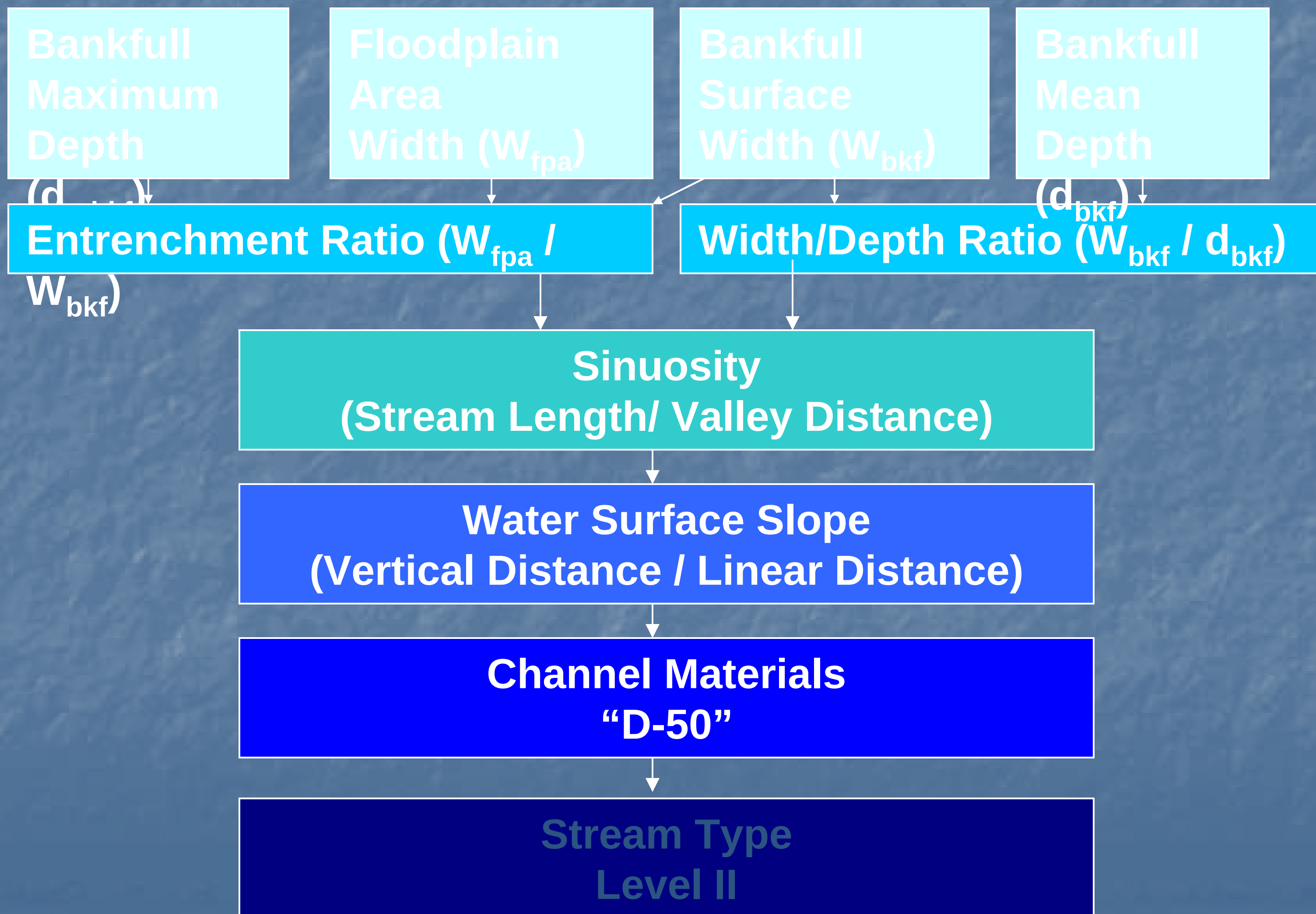
Note: Floodplains may also be a source of contaminants

Channel Balance of Forces



E.W. Lane (1955)

Level II Flowchart



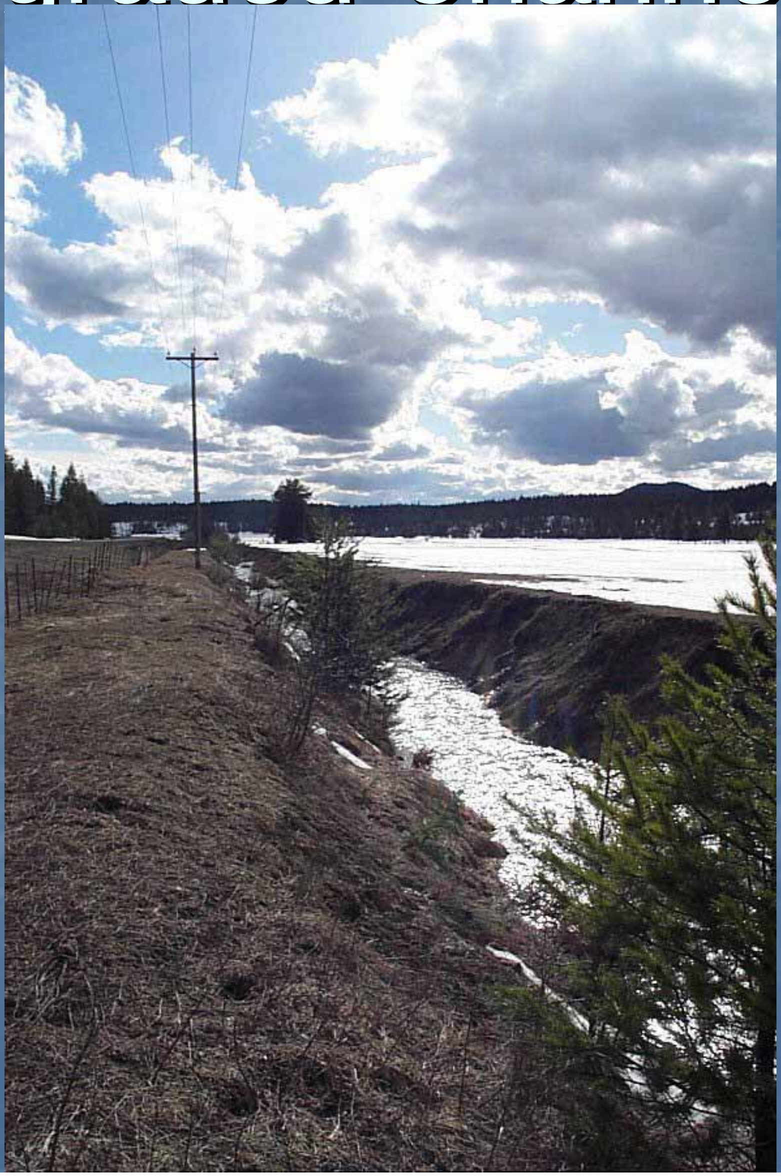
4 Levels of Classification

1. Broad morphological classification
   - General description
2. Morphological description of stream types
   - Delineation and interpretation of reaches
   - **Rosgen stream classification: A, B, C, etc.**
3. Stream state or condition
   - Determination of existing condition
   - Estimation of departure from potential

- **Aggradation:** The process by which sediments collect in streambeds and floodplains, thereby raising their elevation
- **Degradation:** The process by which streambeds and floodplains are lowered by erosion and sediment transport
- **Dynamic Equilibrium:** Streams are in a state of dynamic equilibrium – resilience to rapid change
- !! Rapid aggradation or degradation can occur if dynamic equilibrium is upset

Example: Degraded Channel

Consequences of Slope Increase and Roughness Reduction

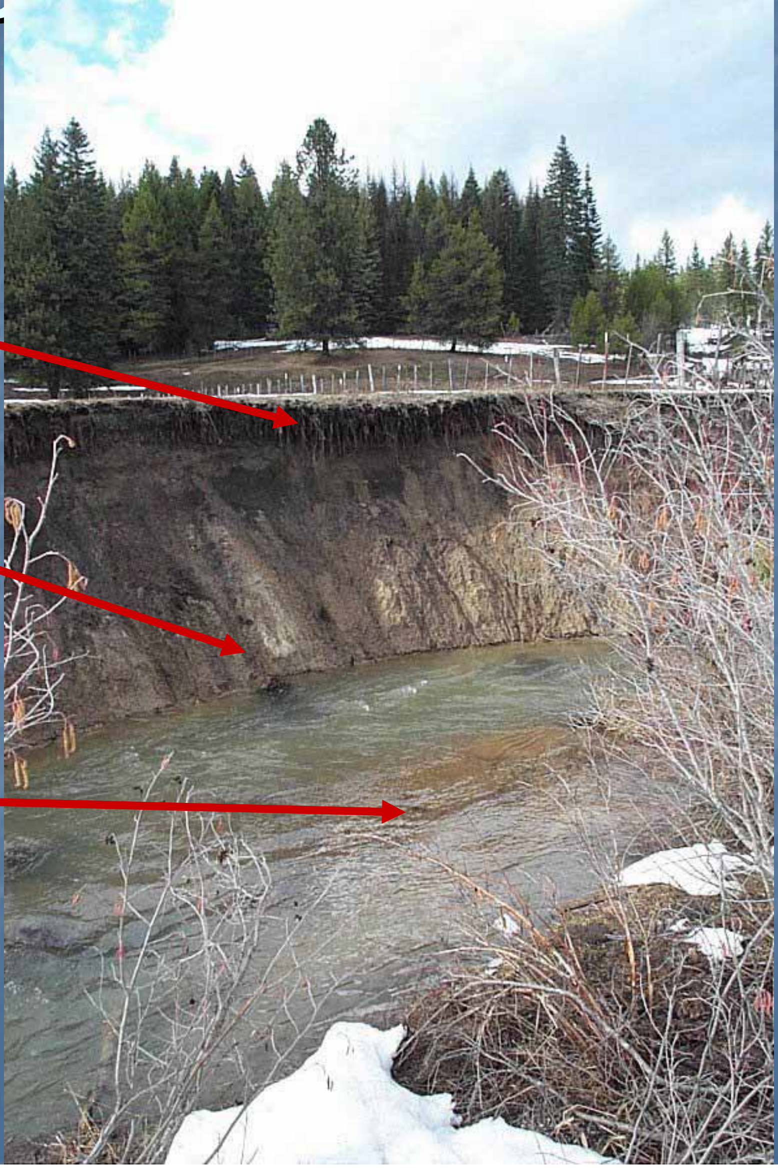


Example: Degraded Channel

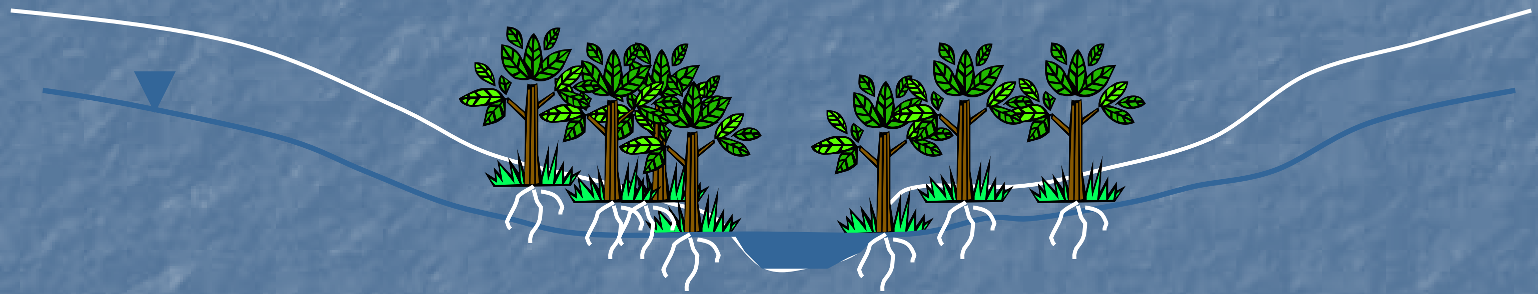
Riparian Vegetation "Disconnected"

Deep Channel Incision

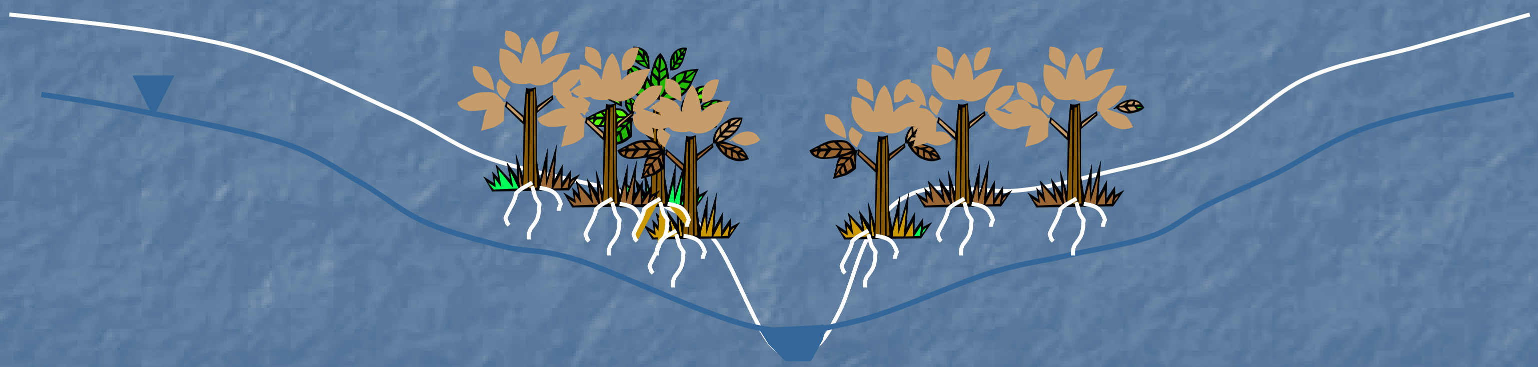
New Floodplain Starting to Form



Channel Degradation



Roots access capillary fringe and shallow groundwater



In incised channel, vegetation connection to shallow groundwater is lost, hence channel stability is further reduced

Unstable Channels - Examples

Channel Recovery

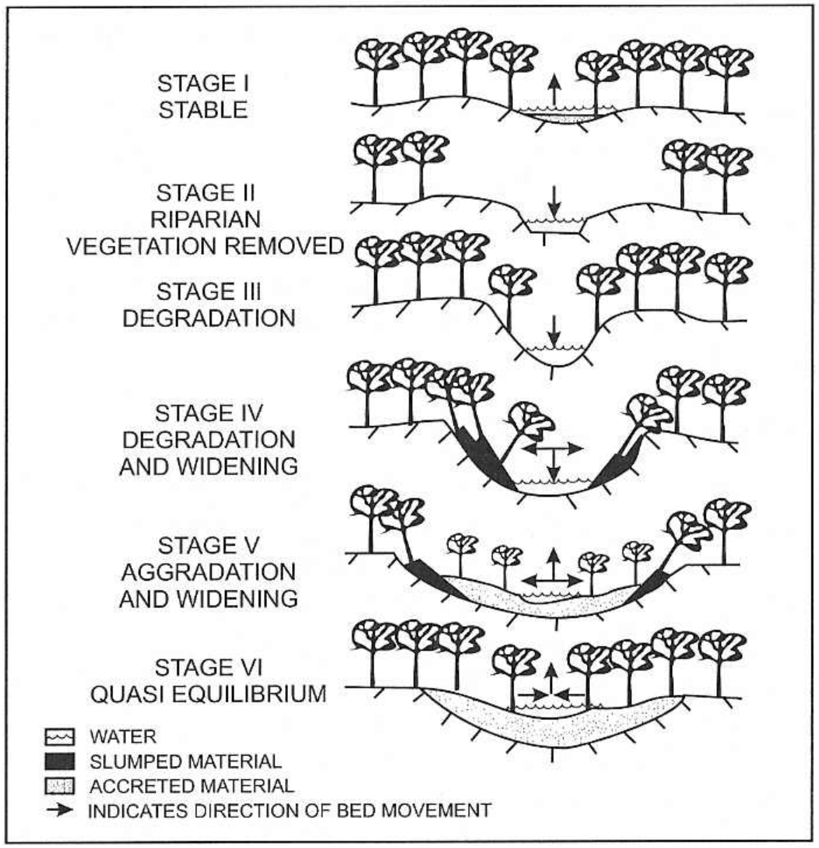
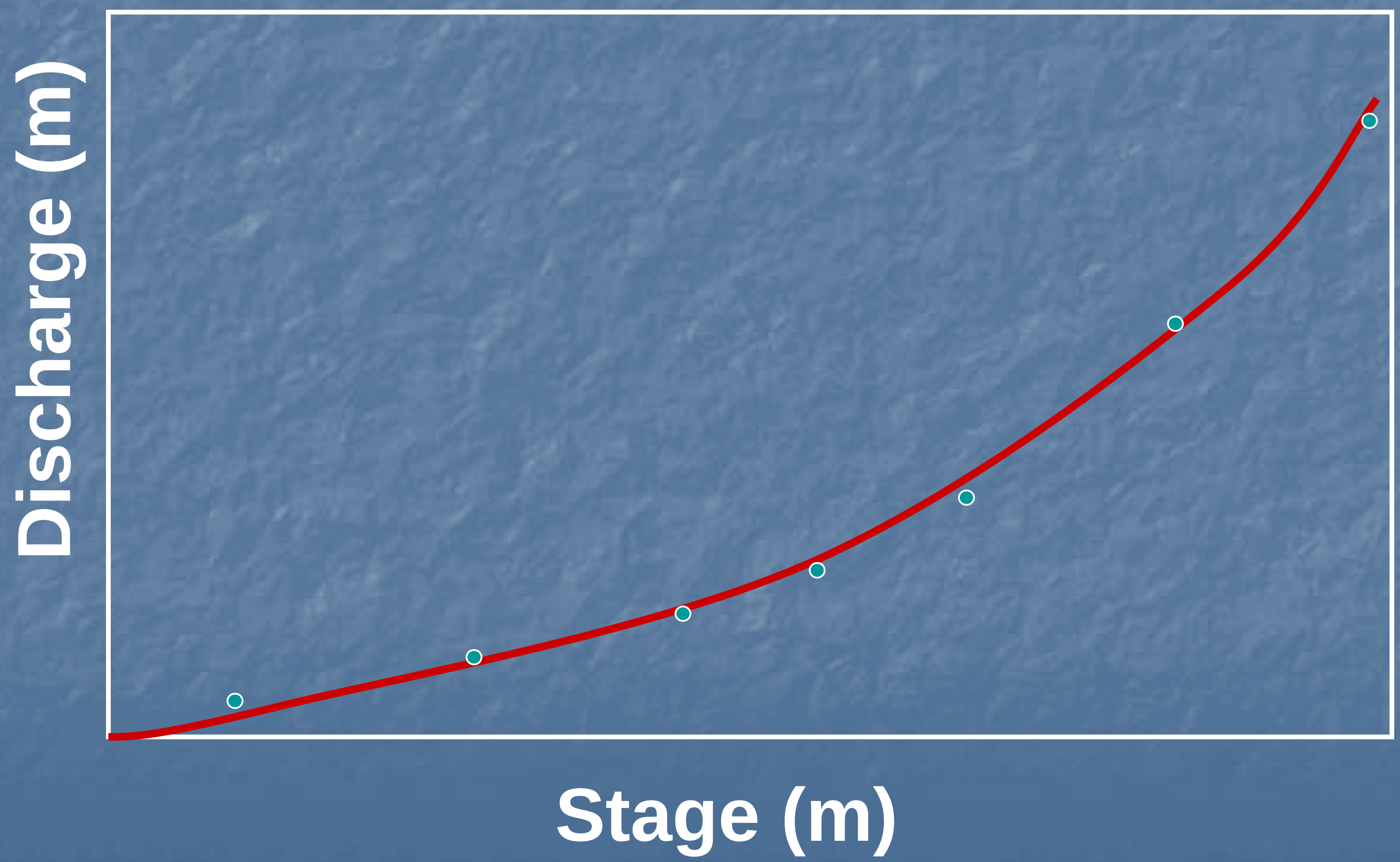


FIGURE 10.3. Channel evolution model developed in west Tennessee (modified from Simon and Hupp 1986 as presented by Simon and Rinaldi 2000).

Convert water level (stage) to discharge with a rating curve




3
120
100
90
80
70
60
50
120
110
100
90
70


5
6
7
8
9
6
10

Streamflow Measurement

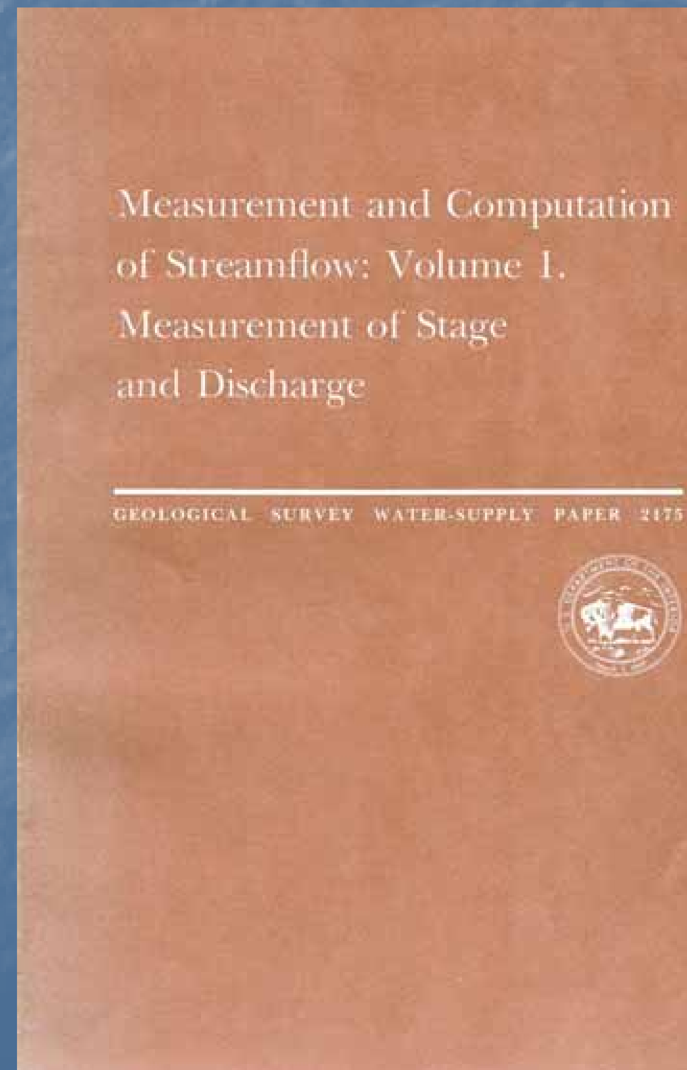
The essential reference:

USGS Water-supply paper 2175: Measurement and computation of streamflow:
Volume 1. Measurement of stage and discharge
Volume 2. Computation of discharge

http://water.usgs.gov/pubs/wsp/wsp2175/

Covers:

Velocity x Area
Weirs: v-notch, rectangular…
Flumes: trapezoidal, H, Parshall…
Dye Tracers…


Measurement and Computation of Streamflow: Volume 1. Measurement of Stage and Discharge

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 2175