SIMULATION METHODS FOR WATERSHED MANAGEMENT

Discharge

Topics

- Discharge measurement
- Unit hydrograph method

Measurement of discharges

- Purposes:
  - Water balance assessment
  - Identification and quantification of hydrological extremes
  - Waterborne transport
  - Hydropower plants
  - Ecological assessment

Measurement of discharges

Instant (occasional) measurement vs. Continuous (regular intervals) measurement

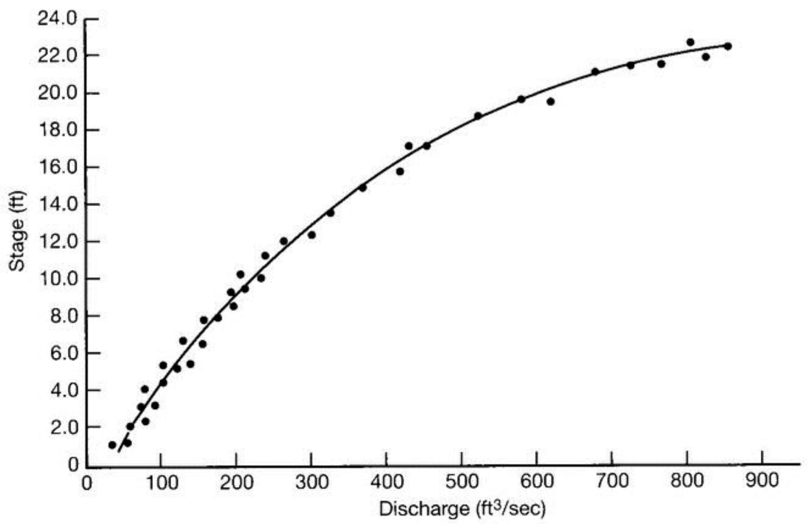
- There are many methods to measure discharge:
  - Measurement of water level (stage) in a stream channel in combination with the rating curve
    - Mechanical recorders
    - Pressure sensors
    - Ultrasonic sensors
  - Flumes (Venturi flume, Parshal flume)
  - Weirs
  - Measurement of velocities
    - Propeller current meter
    - Acoustic Doppler current meter
  - Chemical tracers (salt dilution)

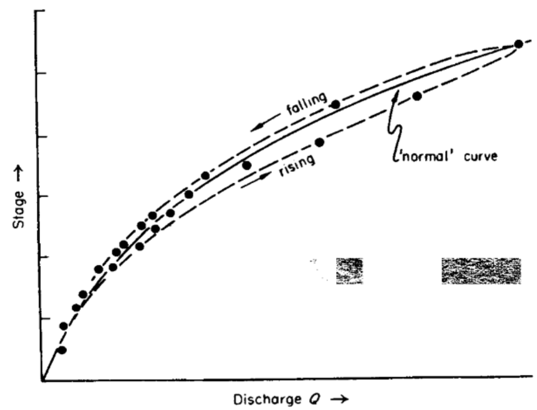
Measurement of discharges

Rating curve

The curve describing stage – discharge relationship. Usually ploted with discharge on the x axis (horizontal) and stage on the y axis (vertical). The curve can be either measured or calculated.

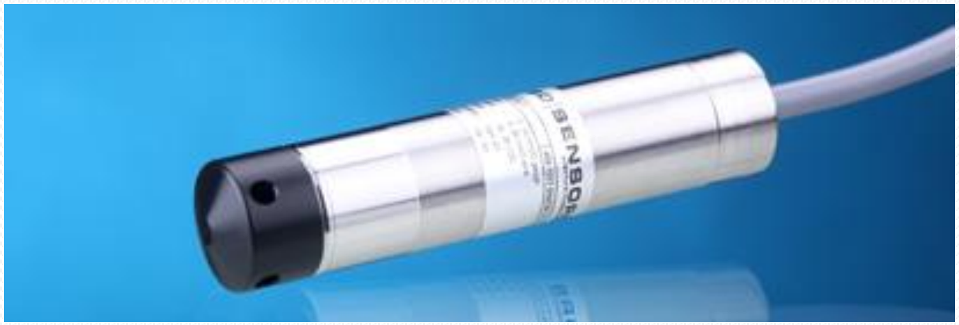
- Calculated curves are usually based on hydraulic methods application. The accuracy mostly depends on a proper selection of Manning roughness coefficient.
- Measured curves need sufficient amount of measured pairs of stages and discharges. The curve should be considered valid only in range of measured data.





http://www.utdallas.edu/~brikowi/Teaching/Field_Methods/How_Real_Time_Stream.html
http://my-fyp.site44.com/surface%20runoff.html

Measurement of discharges

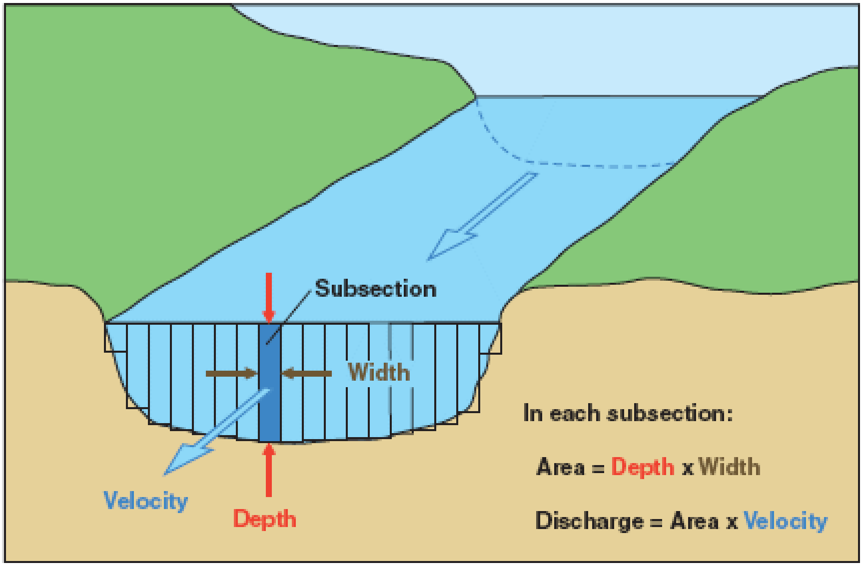


http://www.bdsensors.cz/
http://www.bannerengineering.com/en-US/products/sub/498

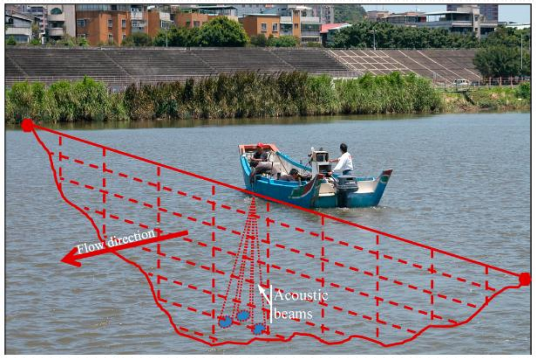
Measurement of discharges

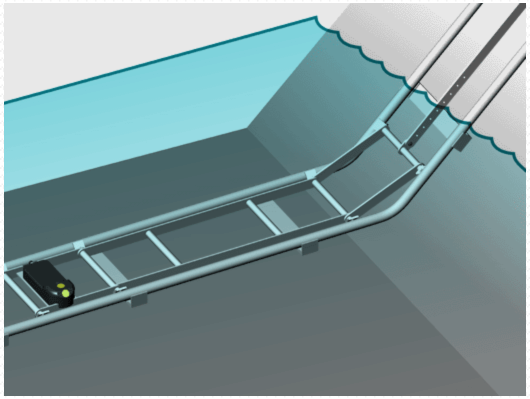
(Photograph courtesy of Michael Nolan, U.S. Geological Survey)

The current-meter method uses equipment such as (A) the Price AA current meter; (B) the Price AA current meter attached to a wading rod; and (C) the Price AA meter suspended above a heavy weight.



Current-meter discharge measurements are made by determining the discharge in each subsection of a channel cross section and summing the subsection discharges to obtain a total discharge.





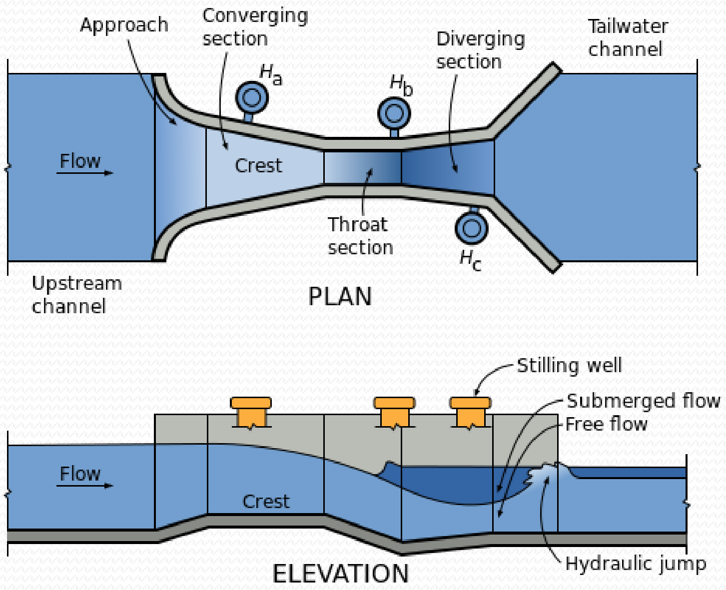
http://water.usgs.gov/edu/streamflow2.html

Yen-Chang Chen et al. Pollutant Flux Estimation in an Estuary Comparison between Model and Field Measurements. Environments, 2014, 1(1), 107-123.

http://www.approtekmooring.com/fixed_mounting/sidewall_mounting/SWM/SWM-anim.gif

Measurement of discharges

Dr. Ralph Parshall began the development in 1915 by altering Venturi flume



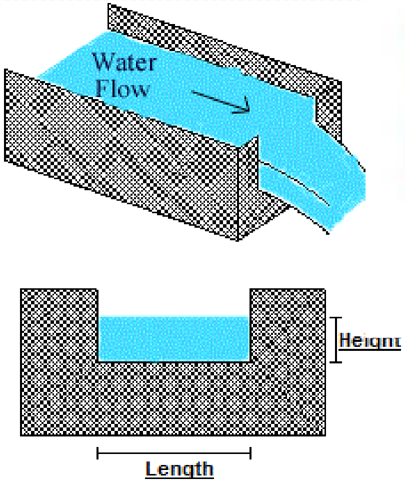
$$Q = C \cdot H_a^n$$

http://lib.colostate.edu/archives/water/parshall/flume.html
https://en.wikipedia.org/wiki/Parshall_flume#/media/File:Parshall_Flume.svg

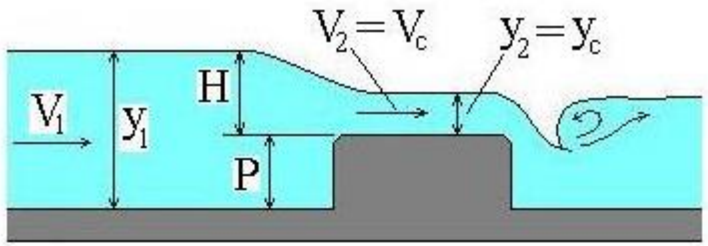
Measurement of discharges

Weirs

- Crest shape: broad crested x sharp crested
- Cross-section shape: triangular (V-notch), rectangular, trapezoidal etc.



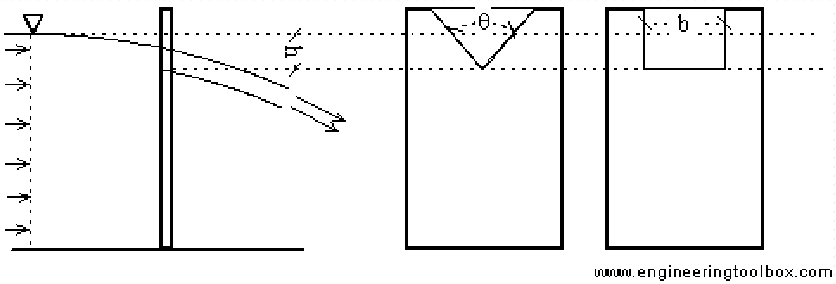
http://irrigation.wsu.edu/Content/Calculators/Water-Measurements/Rectangular-Contracted-Weir.php



Broad Crested Weir

http://img.bhs4.com/74/e/74e90e405e86deefb51c67cf425789ee84bfadb8_large.jpg

http://www.engineeringtoolbox.com/weirs-flow-rate-d_592.html

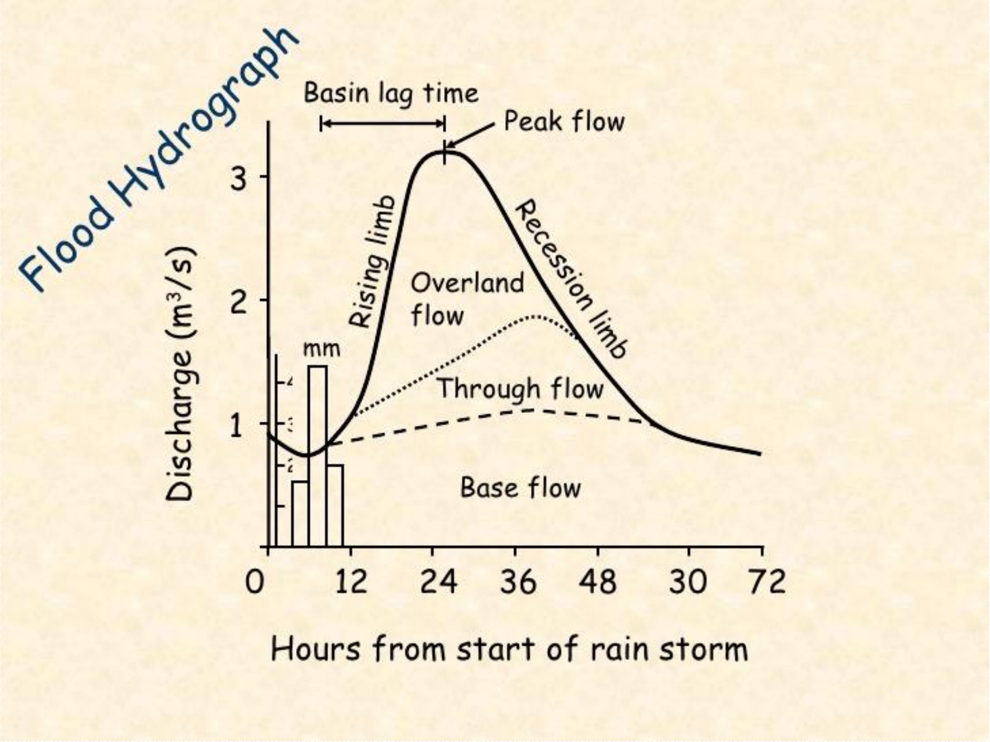


Flood hydrographs

- Stage hydrograph
- Discharge hydrograph

Main characteristics of hydrographs

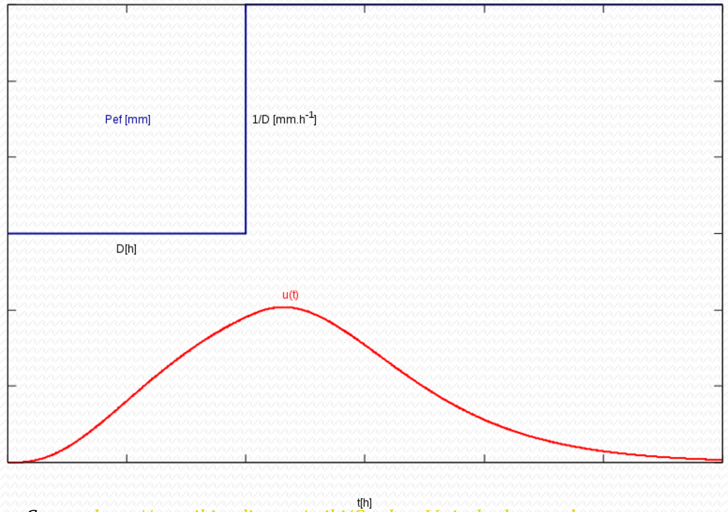
- Peak flow/peak discharge
- Lag time
- Time to peak
- Hydrograph volume
- Hydrograph duration



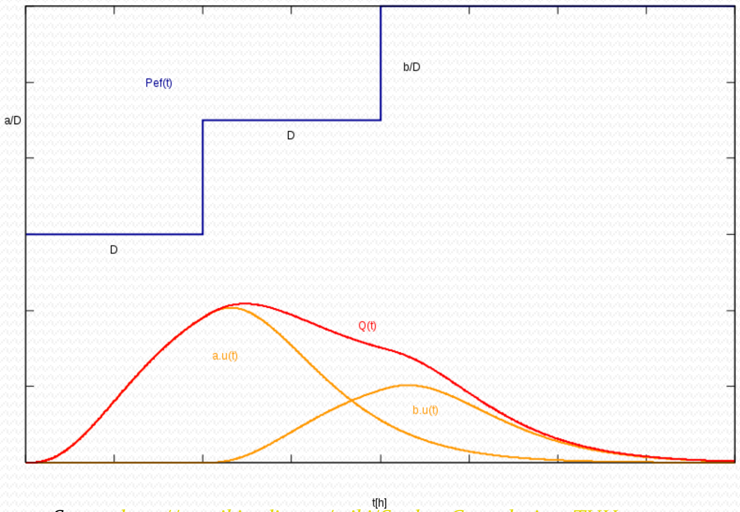
http://www.slideshare.net/DuncanAshton/hydrograph-explanation-and-animation

UH mtehod

- First concept by **Leroy Sherman** (1932)
- UH is considered as hypothetic response of the catchment to **effective** rainfall with unit total
- Assumes **time-invariancy** of transformation process and principle of superposition
- Method is used to transform effective precipitation into runoff hydrograph



Source http://cs.wikipedia.org/wiki/Soubor:Unit_hydrograph.svg
Author: Stanislav Horacek

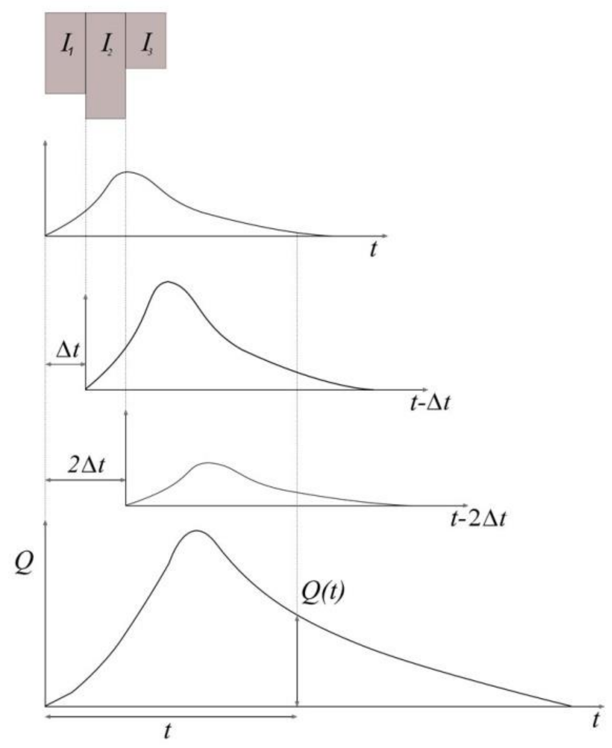


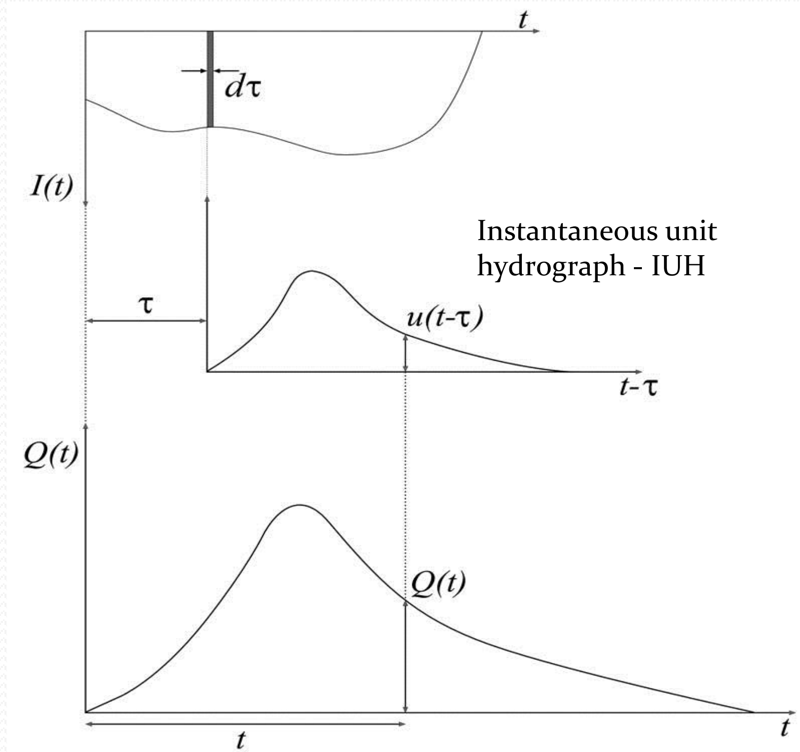
Source http://cs.wikipedia.org/wiki/Soubor:Convolution_TUH.svg
Author: Stanislav Horacek

UH method

The method is based on the superposition of response hydrographs corresponding to each effective precipitation pulse.

$$Q(t) = \sum_{1}^{n} u(t-(i-1)\cdot\Delta t)\cdot I_i \cdot \Delta t \qquad\qquad Q(t) = \int_{0}^{t} u(t-\tau)\cdot I(\tau)\cdot d\tau$$





UH method

M = number of precipitation pulses (5)
X = number of unit hydrograph ordinates (7)
n = time step

$$Q_n = \sum_{m=1}^{n \le M} P_m \cdot U_{n-m+1}$$

$$Q_1 = \sum_{m=1}^{1} P_m \cdot U_{2-m} = P_1 \cdot U_1$$

$$Q_2 = \sum_{m=1}^{2} P_m \cdot U_{3-m} = P_1 \cdot U_2 + P_2 \cdot U_1$$

$$Q_3 = \sum_{m=1}^{3} P_m \cdot U_{4-m} = P_1 \cdot U_3 + P_2 \cdot U_2 + P_3 \cdot U_1$$

$$Q_4 = \sum_{m=1}^{4} P_m \cdot U_{5-m} = P_1 \cdot U_4 + P_2 \cdot U_3 + P_3 \cdot U_2 + P_4 \cdot U_1$$

$$Q_{10} = \sum_{m=1}^{5} P_m \cdot U_{11-m} = P_1 \cdot U_{10} + P_2 \cdot U_9 + P_3 \cdot U_8 + P_4 \cdot U_7 + P_5 \cdot U_6 = P_4 \cdot U_7 + P_5 \cdot U_6 + P_6 \cdot U_5$$

$$U_{10}, U_9, U_8 = 0$$

UH method - overview

- Representation of natural catchment by linear system is only approximative and relevance of used principles is limited
- Method doesn‘t consider flow transformation in the stream channel which can vary
- Method assumes spatialy homogeneous rainfall
- Ordinates of unit hydrograph can be calculated from measured rainfall-runoff data
- Parameters of unit hydrograph are estimated or calculated using catchment properties for ungauged catchments (SCS method, Clark‘s method, Snyders method etc.)