# Hydrometric Practical Training SuSe 2011

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**(Material provided by Bernd Riemeier, senior eng. )**

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# Hydrometric Practical Training SuSe 2011: Dates

**2 lessons for introduction:**

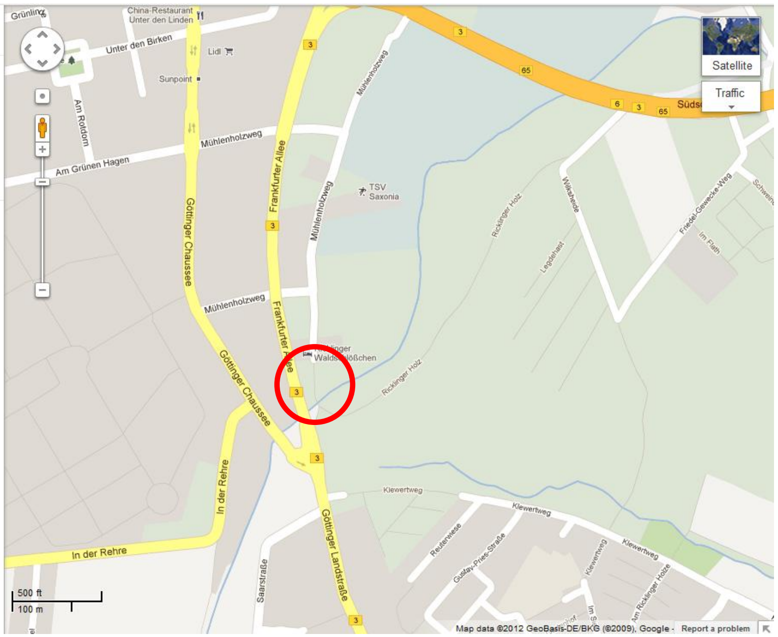
**Fri, 18.05., 09:45 – 11:15,**
**Fri, 18.05., 11:30 – 13:00,**

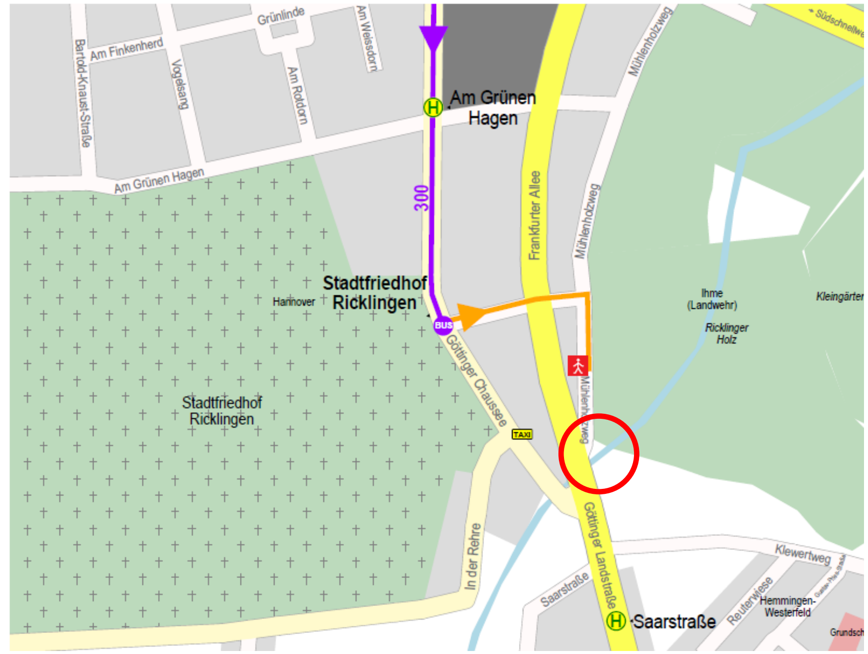
**Room: 3408 - 719, Appelstr. 9A**

- **Practical training at the Ihme river in Oberricklingen:**
  **Date: Fr, 25.05., 8:30 to 12:30 (duration about 4 hours)**

**Lecture Notes will be available on STUD-IP:**
**Notes, exercises, manuals for the instruments**

# Hydrometric Practical Training: Meeting Place River Ihme




**Approach:** **by bicycle or car** e.g. via Göttinger Chaussee in southern direction, left hand into the road Mühlenholzweg, crossing below Frankfurter Allee, then right hand further on into the Mühlenholzweg until meeting place near the bridge
By **tram (Line 3, 7 or 17)** until station Wallensteinstraße, then by bus no. 300, 360, 363 or 365 until station Ricklinger Friedhof, crossing Göttinger Chaussee, into the road Mühlenholzweg, crossing below Frankfurter Allee, then right hand further on into the Mühlenholzweg until meeting place near the bridge.

# Hydrometric Practical Training: Clothing

## Measurements are carried out in all weathers

**Clothing:**
Rubber boots are suitable, because measurements are carried out in water too.
A few pairs are provided by our institute.

Clothing has to be suited to the weather:

- Rainy weather requires rainproof and warm clothing, because all measurements will last a few hours.
- In summer there are often midges (mosquitoes) at the measuring points on warm days. It is suitable to wear clothing covering completely arms and legs.

# Hydrometric Practical Training: Table of Contents

# Hydrometric Practical Training: Discharge Measurements - Introduction

**Discharge:** Flow rate at a measuring point

**Runoff:** Flow rate referring to the catchment

Units of measurement:
Discharge, runoff ($m^3 \cdot s^{-1}$, $l \cdot s^{-1}$)
Specific discharge ($l \cdot s^{-1} \cdot km^{-2}$)
Height of discharge (mm) within a time step (e.g. hour, day, month, year)

## Why measurements of discharge?

Aim: acquire data for hydrology and water resources management

- provide time series of discharge for balancing, modeling, forecast etc., often focus on extremes (high, low water);
- measurements of discharges to determine the stage-discharge-curve (W-Q-relationship).

By means of the stage-discharge-curve hydrographs of discharge can be determined from hydrographs of stage to specify

- peaks of discharge
- flow volumes above a certain threshold value.

# Hydrometric Practical Training: Measurement Methods

| Direct measurement methods | Indirect measurement methods | Other methods |
|---|---|---|
| ➢ Vessel measurement methods (volume per second)<br>➢ Hydraulic methods Measuring weirs, Venturi flume, Parshall flume (steady relation W to Q); Slope-area-method (hydraulic calculation); Turbine flow (pressure difference h to Q or kW to Q); Volume of water of a watergate (number of charges x volume)<br>➢ Tracer-Dilution methods (dilution method, colourants, salts, radioactive matter, change of concentration) | ➢ Propeller current meter methods (Woltmann current meter, rotations per second) on a rod, cable suspended, heavy weight current meter (on a gibbet, cable way systems)<br>➢ Acoustic methods (runtime of acoustic pulses in horizontal planes)<br>➢ Electro-magnetic methods (Faraday-principle, induced electrical voltage)<br>➢ Float methods (way of float per time) surface floats, double floats, rod floats | ➢ Acoustic Doppler Current Profiler (ADCP-method)<br>➢ Dipping bar according to JENS<br>➢ Pitot tube (pressure measurement)<br>➢ Hot-wire probes (cooling down is dependent on velocity) |

# Hydrometric Practical Training: Vessel Measuring Method

Also called Bucket and stopwatch method

Precise and simple discharge measurement method

- Suitable only for small discharges,
- Feasible, if water can be collected, e. g. at an overflow weir

$$Q = \frac{V}{t}$$

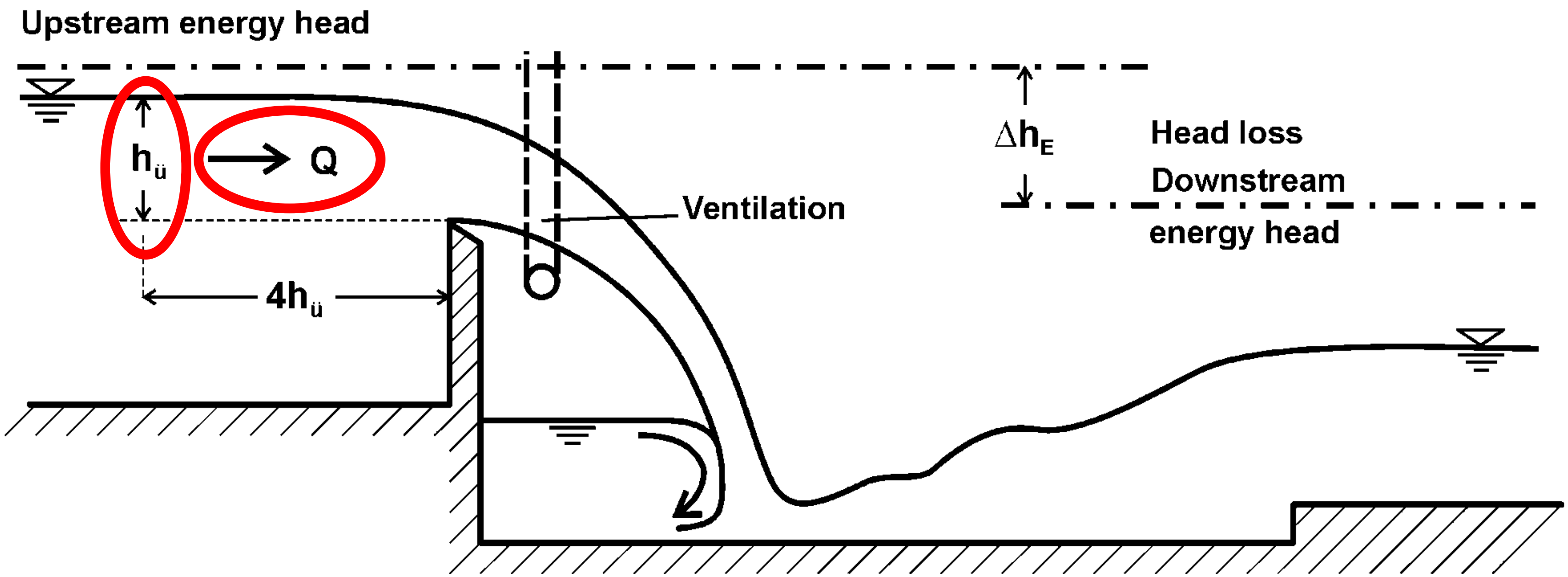
Q Discharge

V Volume of a vessel (pot, bucket, ton) must be known

t Time of filling of the vessel measured by a stopwatch

Several measurements have to be averaged

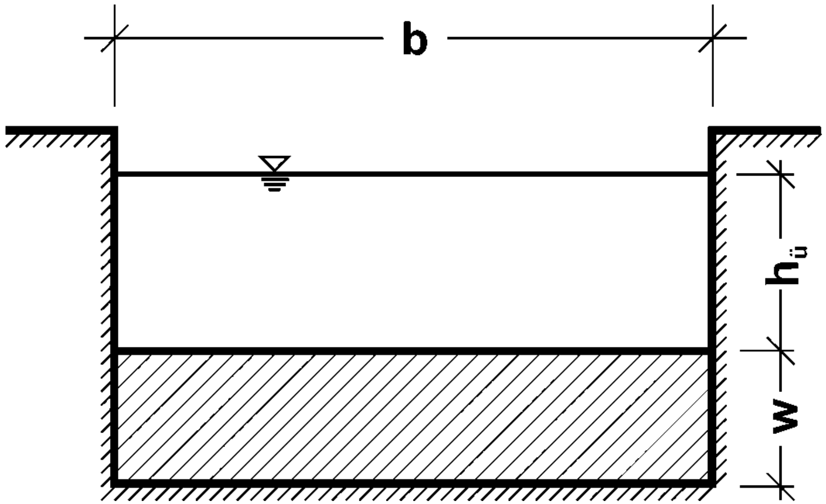
# Hydrometric Practical Training: Measuring Weirs




**Longitudinal section of a weir**

Sharp edged overfall with overflow coefficient μ = 0.64

# Hydrometric Practical Training: Measuring Weirs



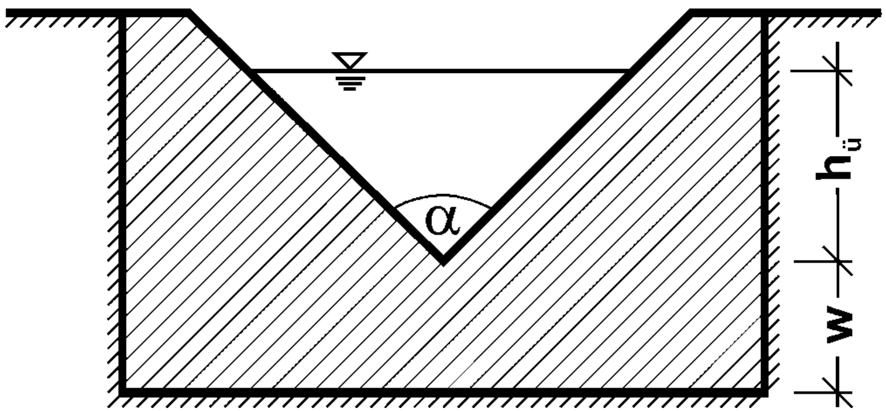

$$Q = \frac{2}{3} \cdot \mu \cdot \varphi \cdot \sqrt{2g} \cdot b \cdot h_{ü}^{\frac{3}{2}}$$

**Poleni formula for estimating discharge**

$$Q = C_h \cdot \varphi \cdot b \cdot h_{ü}^{\frac{3}{2}}$$

- Q Discharge ($m^3/s$)
- b Width of the weir (m)
- $\varphi$ reducing factor
- $h_{ü}$ upstream head

# Hydrometric Practical Training: Measuring Weirs




**V-Notch weir or Thomson measuring wear**

**Triangular orifice**

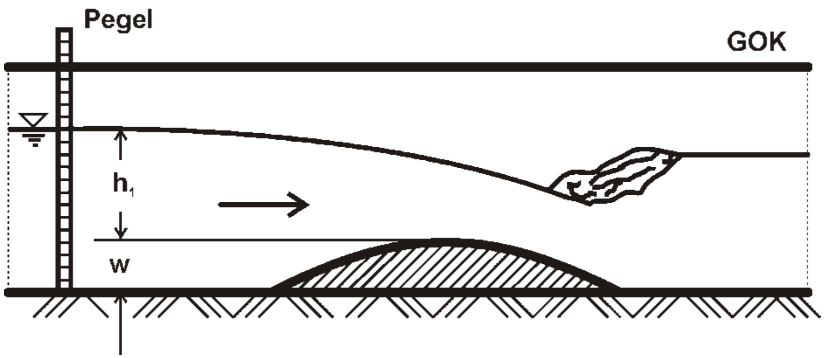
$$Q = 0.553 \cdot \sqrt{2g} \cdot \mu \cdot \tan\left(\frac{\alpha}{2}\right) \cdot h_ü^{\frac{5}{2}}$$

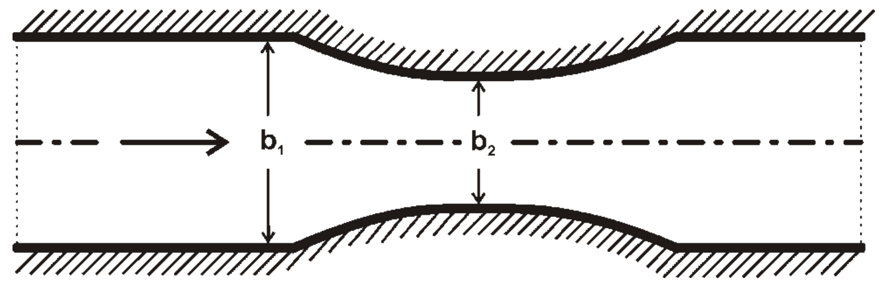
α angle of V-notch (°)

| $h_ü$ (m) | 0.05 | 0.10 | 0.15 | 0.20 | 0.25 |
|---|---|---|---|---|---|
| μ (-) | 0.597 | 0.590 | 0.586 | 0.584 | 0.582 |

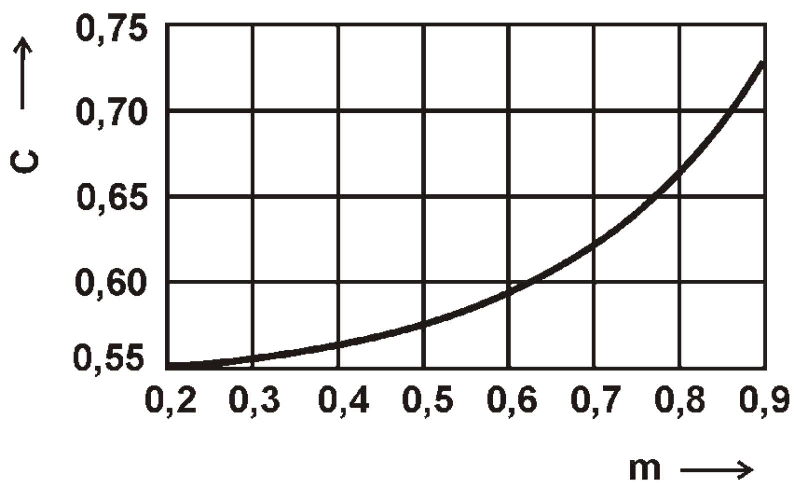
Discharge coefficient for weirs with triangular orifice of α = 90°

# Hydrometric Practical Training: Venturi Flume




$$Q = 0.985 \cdot \sqrt{g} \cdot b_2 \cdot c \cdot h_1^{3/2} = 3.085 \cdot b_2 \cdot c \cdot h_1^{3/2}$$




c Coefficient from diagram with

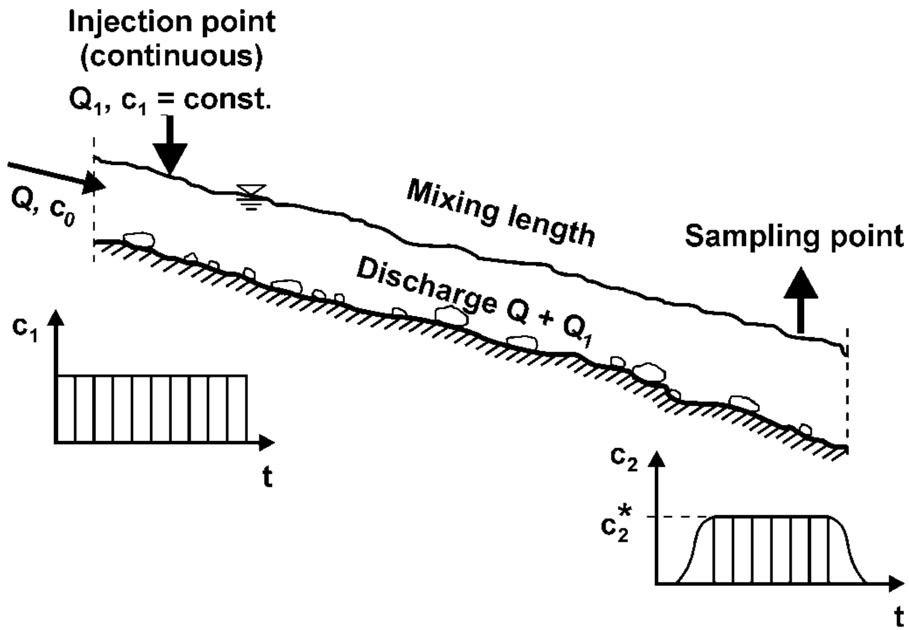
$$m = \frac{b_1}{b_2} \cdot \frac{h_1}{(h_1 + w)}$$

# Hydrometric Practical Training: Tracer-Dilution Methods

**Applications**: Running waters in low or high mountain ranges

**Conditions**: Turbulences in the water e. g. by big stones,
good mixing of water and tracer,
other methods are not suitable
(irregular cross section, intense sediment transport,
flow velocity too high to be measured with normally used methods)

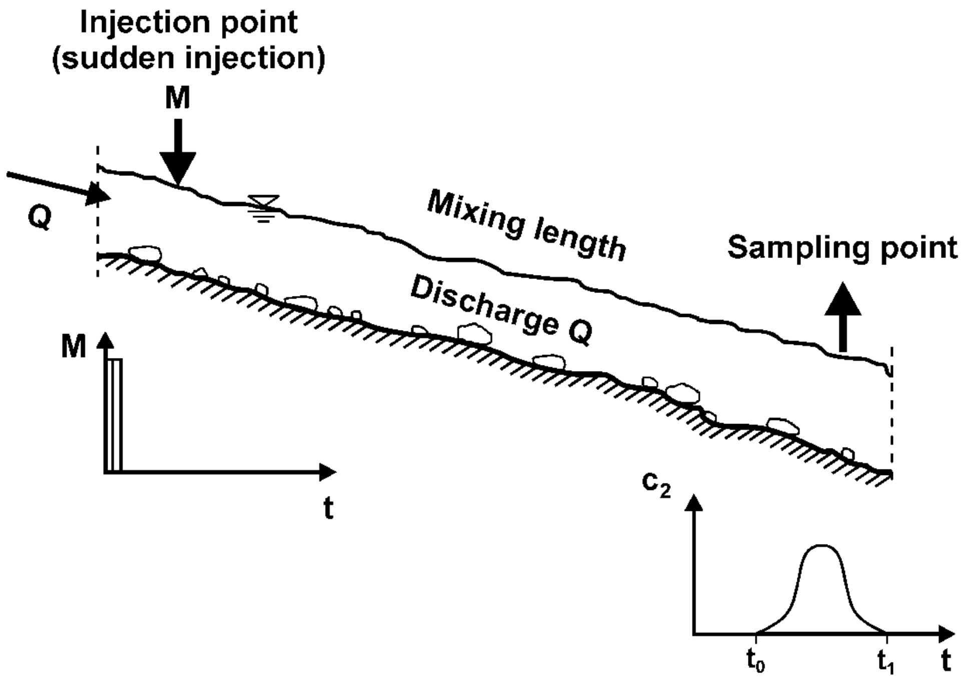
Tracer material: Colouring matter, salt or very limited radioactive tracer




**Constant rate injection method**

$$Q = Q_1 \cdot \frac{c_1 - c_2^*}{c_2^* - c_0}$$

# Hydrometric Practical Training: Tracer-Dilution Methods




## Sudden injection method (Integration method)

$$M = \int_{t_0}^{t_1} (Q \cdot c_2)\,dt$$

$$Q = \frac{M}{\int_{t_0}^{t_1} c_2\,dt}$$

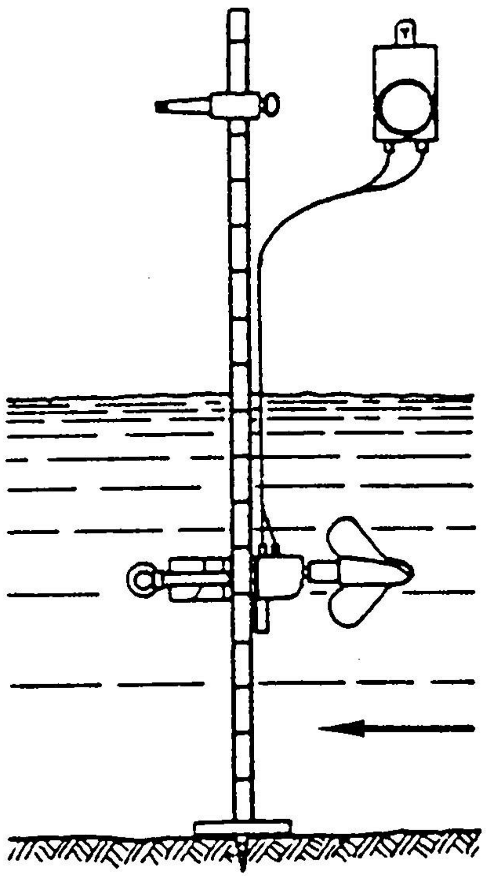
**Sudden injection of all the tracer at one moment**

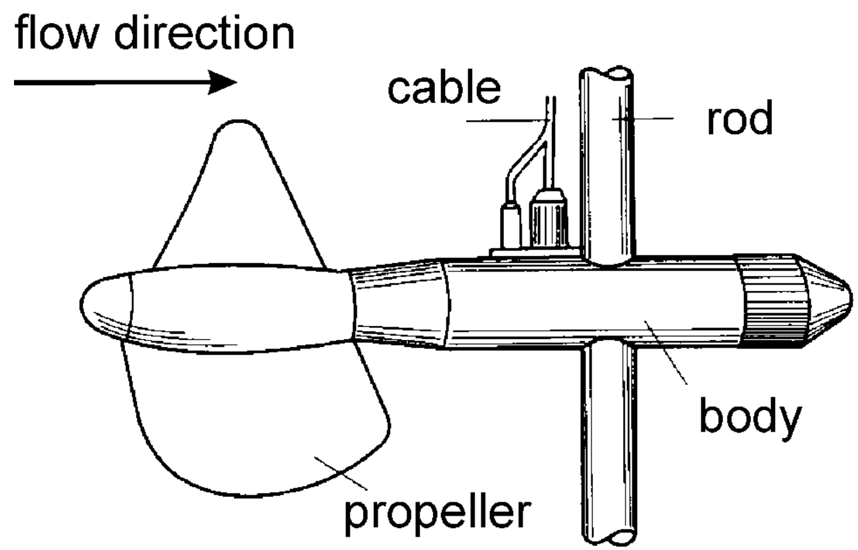
Injection is relative simple,

sampling is of great effort, while it has to be done for a long period

# Hydrometric Practical Training: Propeller Current Meter

**Velocity of the water** is determined by measuring the propeller revolutions
**Discharge calculation** with the relation Q = v · A



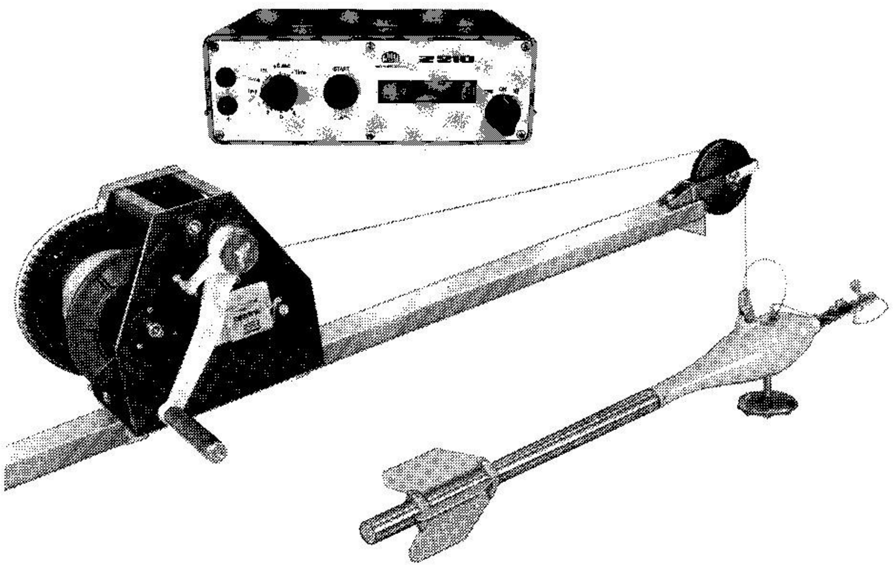


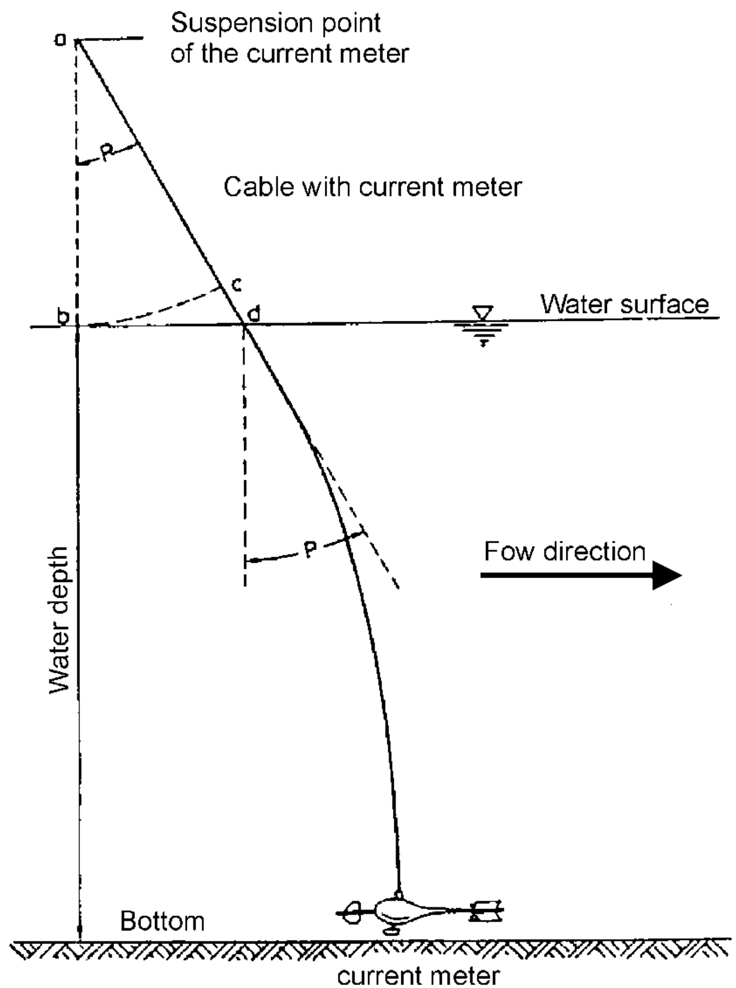

**Current meter on a rod**: **hand-held rod**
**body**
**propeller**
**counter set**

# Hydrometric Practical Training: Propeller Current Meter

**Cable current meter parts:**

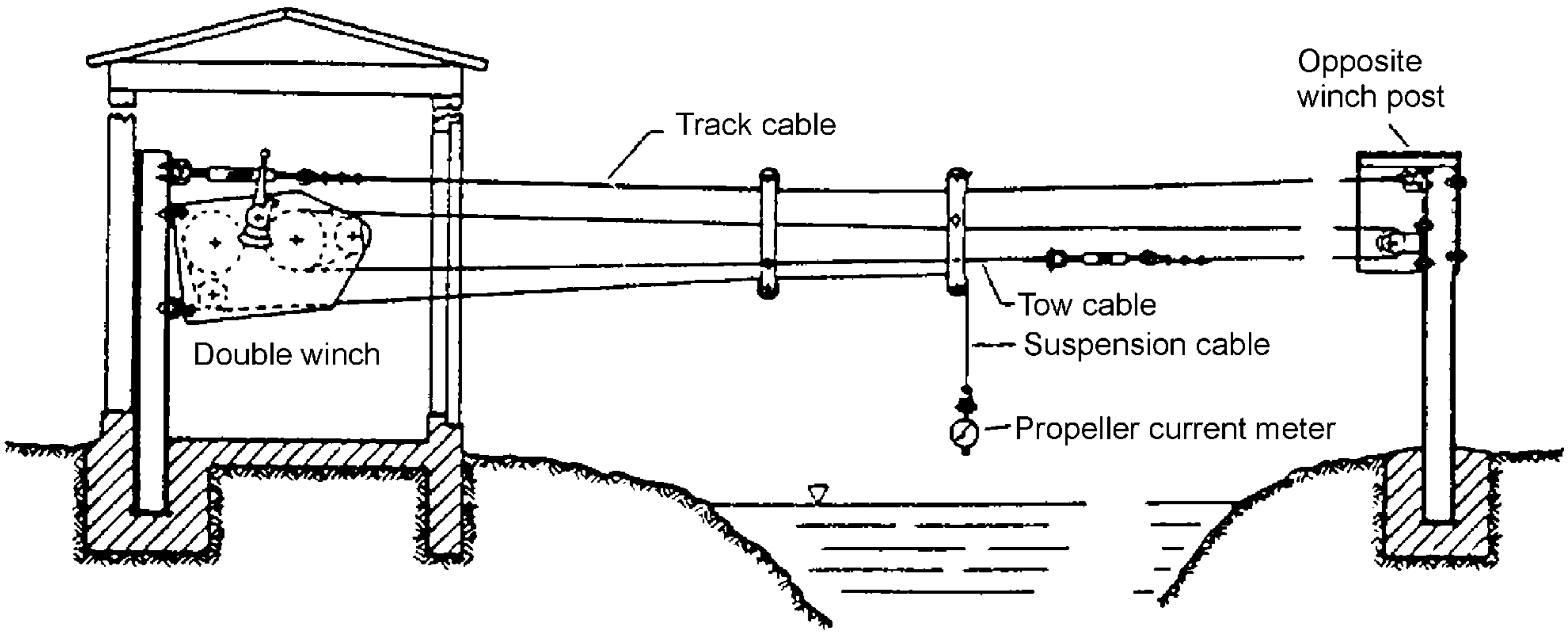
**cable drum winch**
**propeller current meter**
**counter**





# Hydrometric Practical Training: Propeller Current Meter

**Cable way systems** for standard measuring profiles



# Hydrometric Practical Training: Propeller Current Meter

**Process of measurement**:

The propeller current meter is kept opposite to flow direction into the water
The propeller is rotating according to the flow velocity
The number of revolutions are recorded by an electro-magnetic contact mechanism to the counter set
Duration of measurement is held by a stopwatch (at least 30 seconds)

**Flow velocity v** (calibration equation)

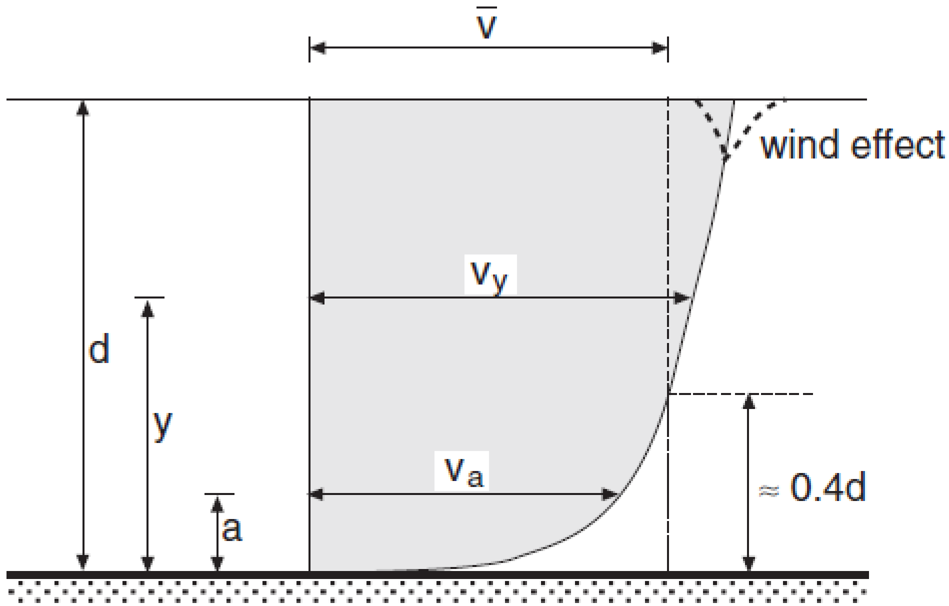
| | |
|---|---|
| n | Propeller revolutions per second |
| k, $\Delta$ | Calibration constants (m) or ($m \cdot s^{-1}$) |

$$v = k \cdot n + \Delta$$

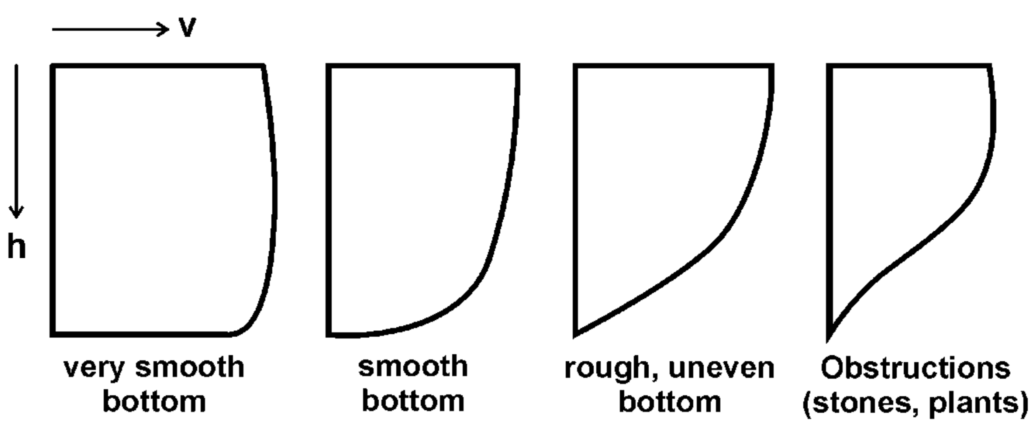
## Point method

## Integration method

# Hydrometric Practical Training: Propeller Current Meter

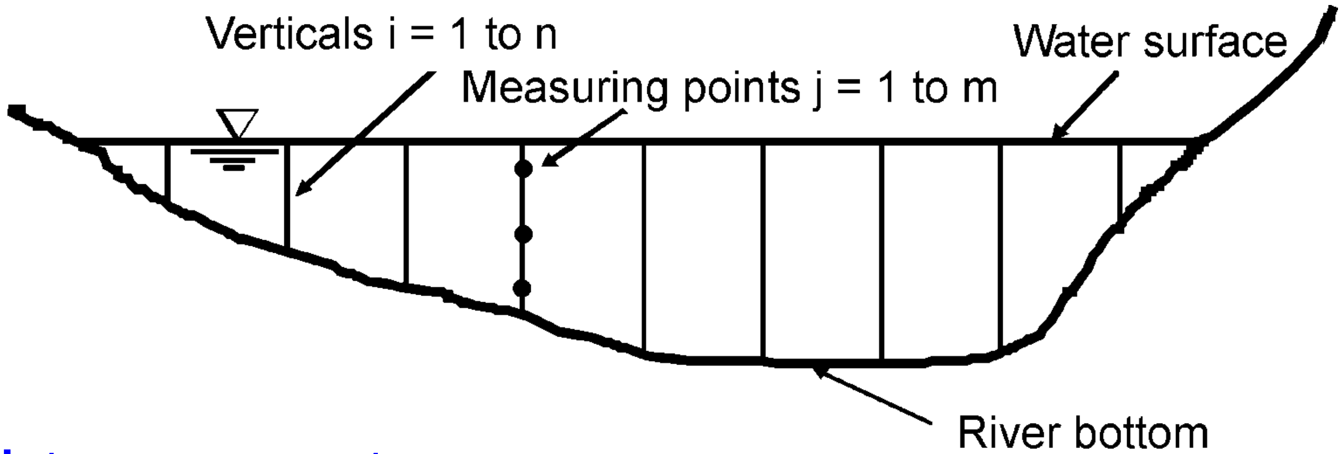



River flow velocity profile
(laminar flow)




Dependency of roughness
on the river bottom

# Hydrometric Practical Training: Propeller Current Meter




**<u>Point measurements</u>:**

**One point method: Measurement in a distance of 0.6 h from water surface**

$$v_m = v_{0.6h}$$

**Two point method: Measurement in a distance of 0.2 h and 0.8 h**

$$v_m = 0.5(v_{0.2h} + v_{0.8h})$$

$v_m$ mean flow velocity ($m \cdot s^{-1}$)
$h$ water depth (m)

# Hydrometric Practical Training: Propeller Current Meter

**Full measurement: Measurement at more than 2 points in a vertical**

Other methods after EN ISO 748 (2000):

**Three point method:**

$$v_m = (v_{0.2h} + v_{0.6h} + v_{0.8h})/3 \qquad \text{or}$$

$$v_m = 0.25(v_{0.2h} + 2v_{0.6h} + v_{0.8h})$$

**Five point method:**

$$v_m = 0.1(v_s + 3v_{0.2h} + 3v_{0.6h} + 2v_{0.8h} + v_b)$$

**Six point method:**

$$v_m = 0.1(v_s + 2v_{0.2h} + 2v_{0.4h} + 2v_{0,6h} + 2v_{0.8h} + v_b)$$

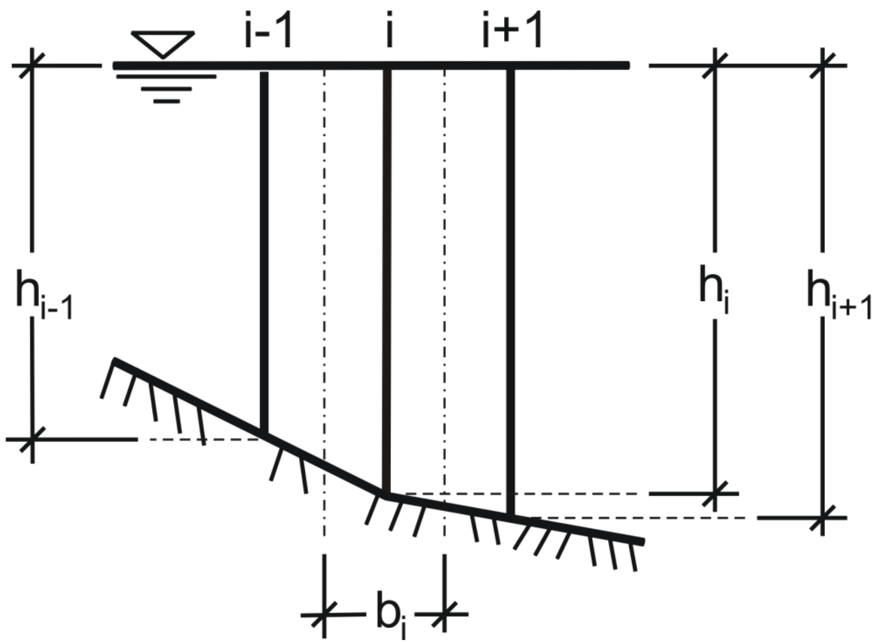
$v_s$ flow velocity at surface ($m \cdot s^{-1}$)
$v_b$ flow velocity at bottom ($m \cdot s^{-1}$)

# Hydrometric Practical Training: Propeller Current Meter

Number of verticals
in a cross section:

| River width b (m) | Number of verticals n |
|---|---|
| b < 0,5 | 3 to 4 |
| 0,5 ≤ b < 1 | 4 to 5 |
| 1 ≤ b < 3 | 5 to 8 |
| 3 ≤ b < 5 | 8 to 10 |
| 5 ≤ b < 10 | 10 to 20 |
| ≥ 10 | ≥ 20 |

# Hydrometric Practical Training: Propeller Current Meter




## Mid section method

**Calculation of discharge Q**

$$Q_i = v_{m,i} \cdot A_i$$

$$A_i = b_i \cdot h_{m,i}$$

$$h_{m,i} = 0.25\,(h_{i-1} + 2h_i + h_{i+1})$$

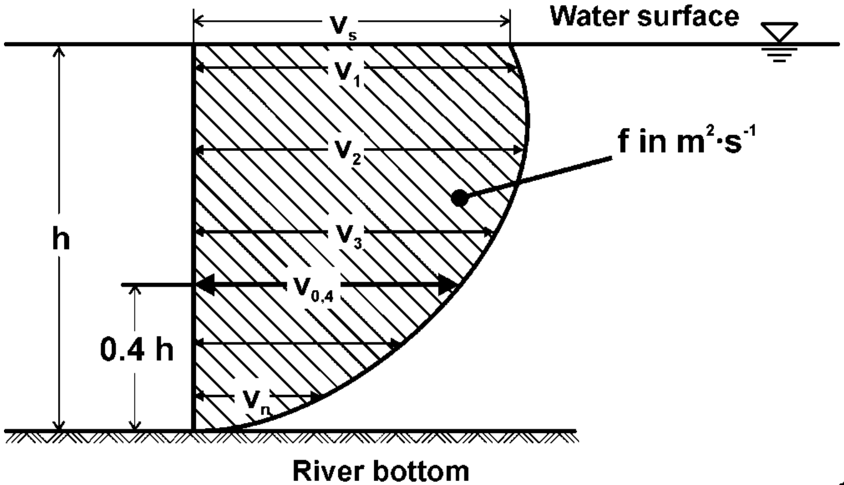
**Left bank:** $h_{m,1} = 0.25\,(3h_1 + h_2)$

**Right bank:** $h_{m,n} = 0.25\,(h_{n-1} + 3h_n)$

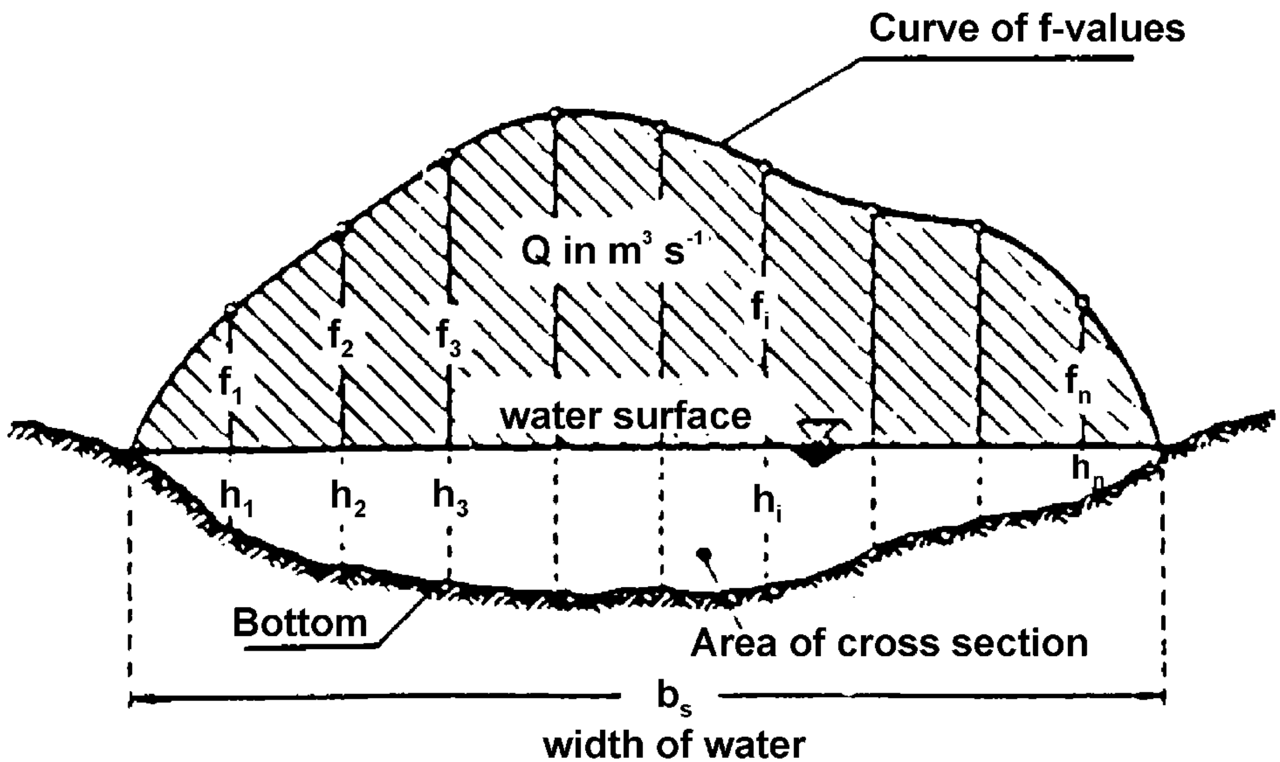
**Verticals i = 1, 2 … n**

$$Q_{tot} = \sum_i Q_i = \sum_i (v_{m,i} \cdot A_i)$$

# Hydrometric Practical Training: Propeller Current Meter



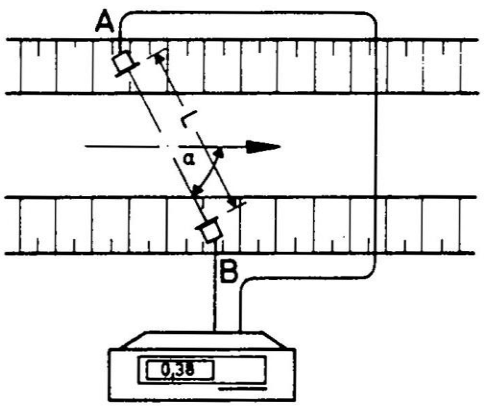

## Graphical evaluation

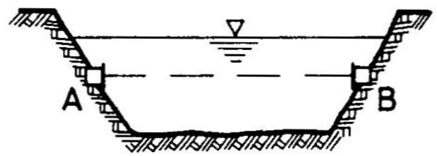



$$Q = \int_0^b f \, db$$

= hatched area

# Hydrometric Practical Training: Ultrasonic Method




**A, B** **Transducers**

**$\overline{AB}$** **Length of acoustic path**

**Also called acoustic method**

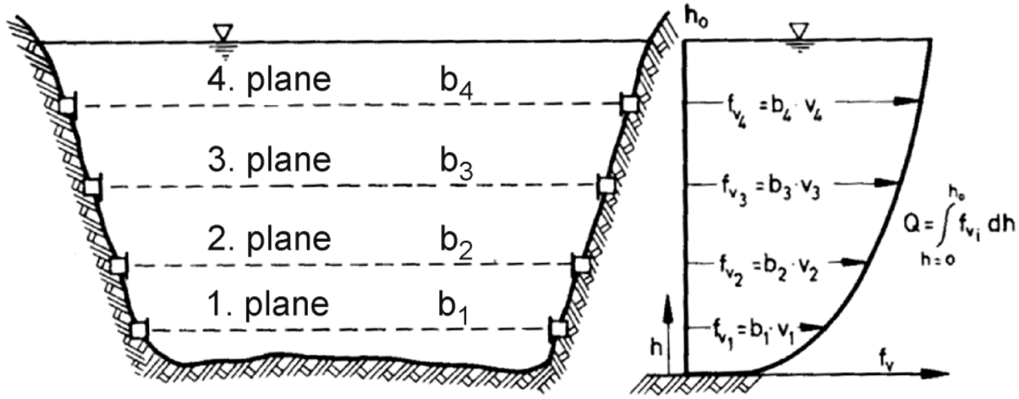
**Principle of ultrasonic method**

Measurement is performed in one or several horizontal plains

**Principle of measurement:**

- Acoustic signal is running faster with flow direction than against flow direction
- From runtime differences of acoustic pulses between two transducers on both sides of the river mean velocity is calculated

# Hydrometric Practical Training: Ultrasonic Method



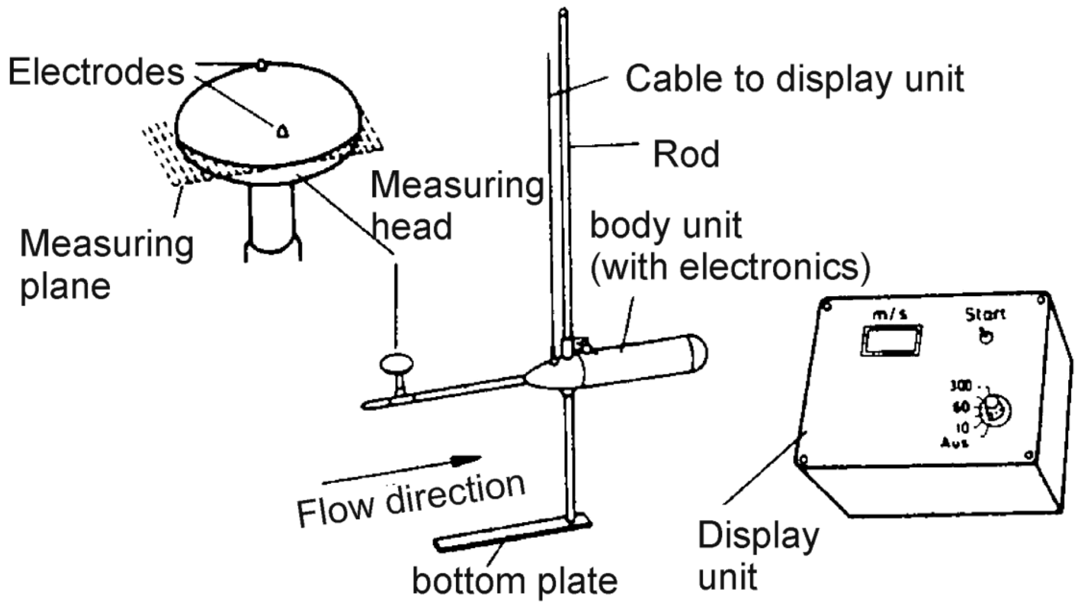

**Onelevel and Multilevel systems**

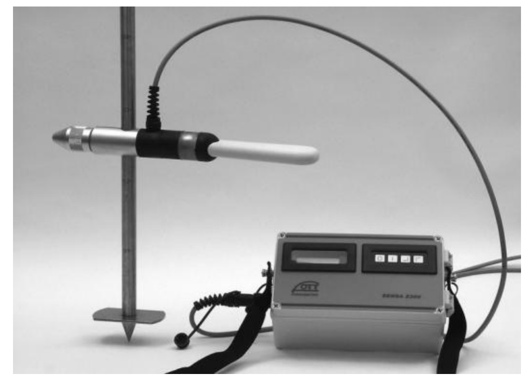

**ADC: Acoustic digital current meter: Provides point velocities just like a current meter**

ADC, company Ott

# Hydrometric Practical Training: Electromagnetic Sensor

## Principle of inductive measurement

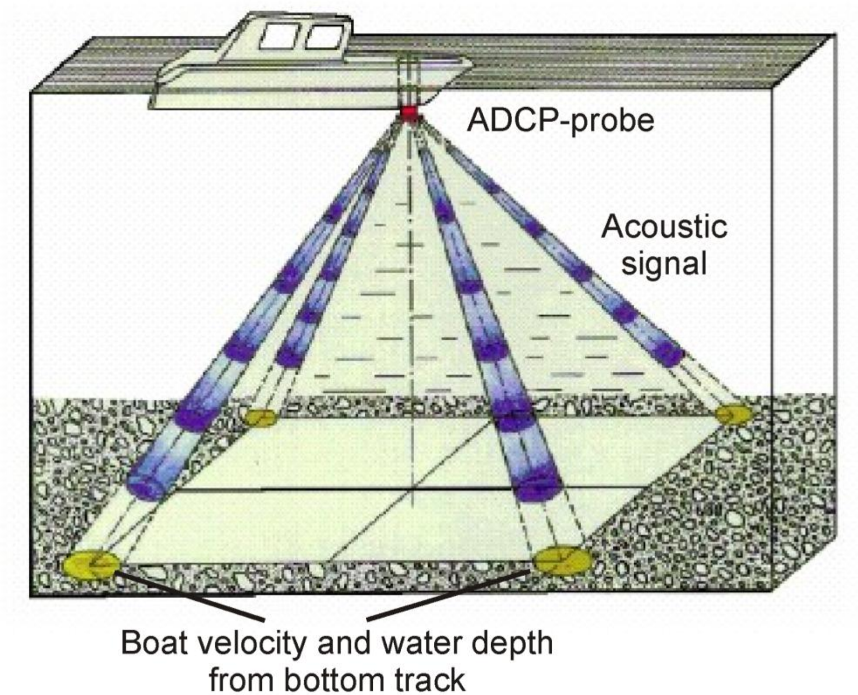


Nautilus C 2000, company Ott

According to the Faraday's law of inductivity, flow of water (a conductor) in a magnetic field between two electrodes inducts a voltage which is proportional to the flow velocity. Flow velocity in the respective measuring points is shown directly on the system.

# Hydrometric Practical Training: ADCP Method

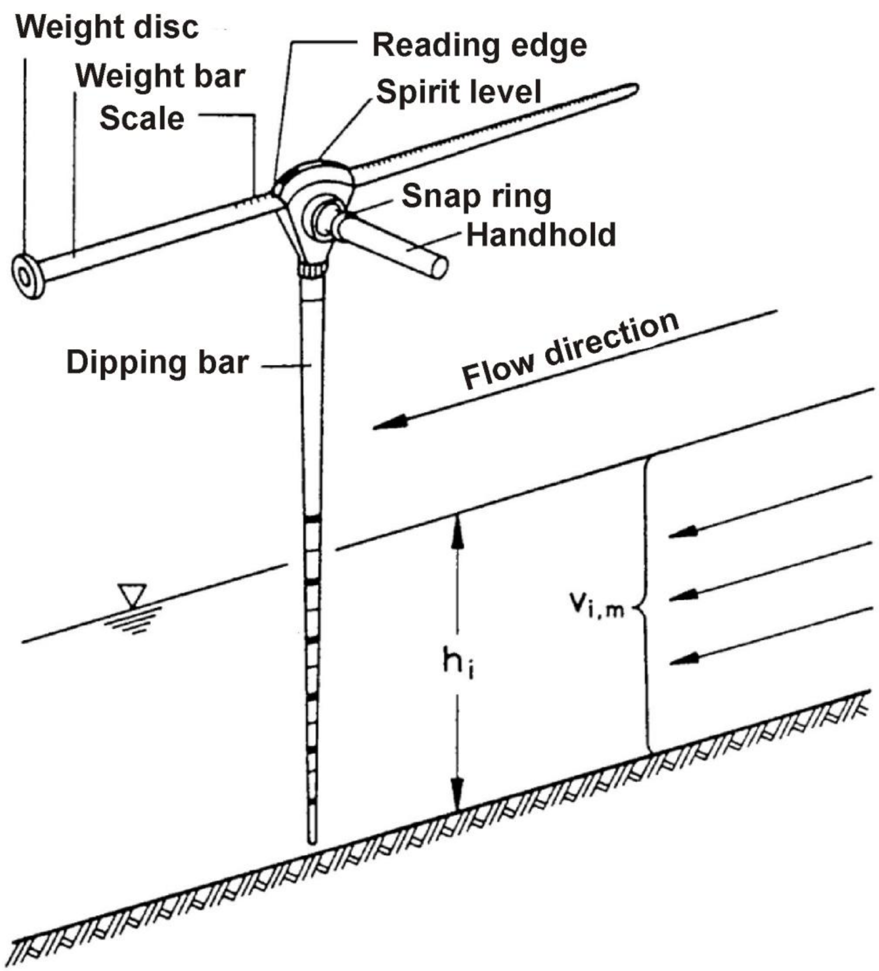



**ADCP means**
**<u>A</u>coustic <u>D</u>oppler <u>C</u>urrent <u>P</u>rofiler**

ADCP-probe scans the water body acoustically.
Acoustic signals are bounced off on suspended particles and received as an echo from ADCP-probe.

After the Doppler effect the change in frequency (Doppler shift) between transmitted pulses and received echoes (Doppler effect) can be used to measure the relative velocity between the instrument and the suspended material in the water that reflects the pulses back to the instrument (backscattering).

# Hydrometric Practical Training: Dipping Bar Acc. to Jens




**Principle: torque balance**

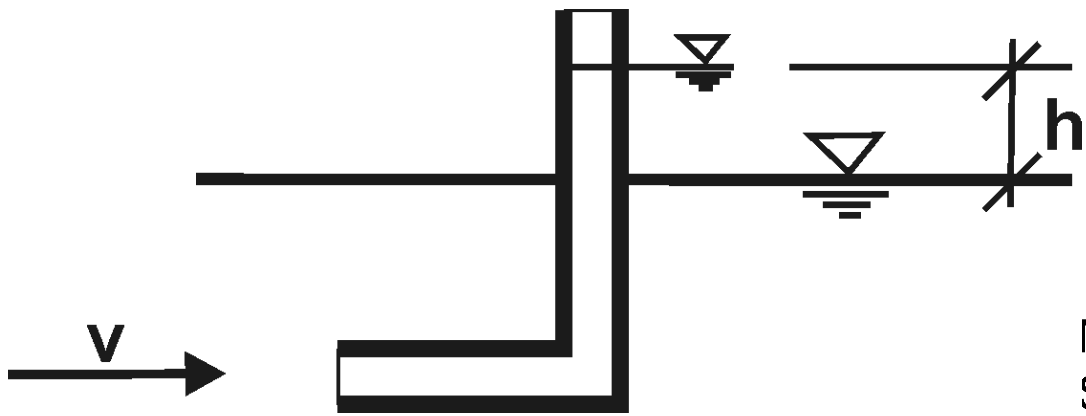
Mostly used by hydro biologists and limnologists (the average current of a vertical measuring line).

For:

**current speeds up to 150 cm/sec**

**immersion depth up to 60 cm**

# Hydrometric Practical Training: Pitot Tube

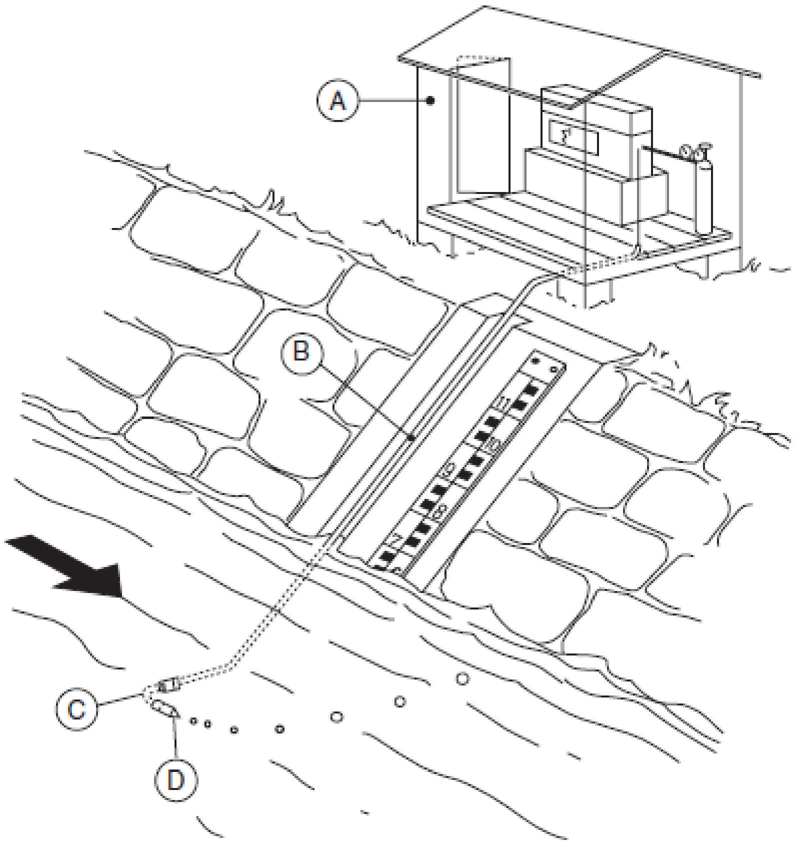



Mainly used in hydraulic laboratories
Suitable for velocities v > 1 $m \cdot s^{-1}$

After Bernoulli-equation $$\mathbf{h = \frac{v^2}{2g}} \rightarrow \mathbf{v = \sqrt{2gh}}$$

h  stagnation pressure head
(velocity head)

# Hydrometric Practical Training: Water Level



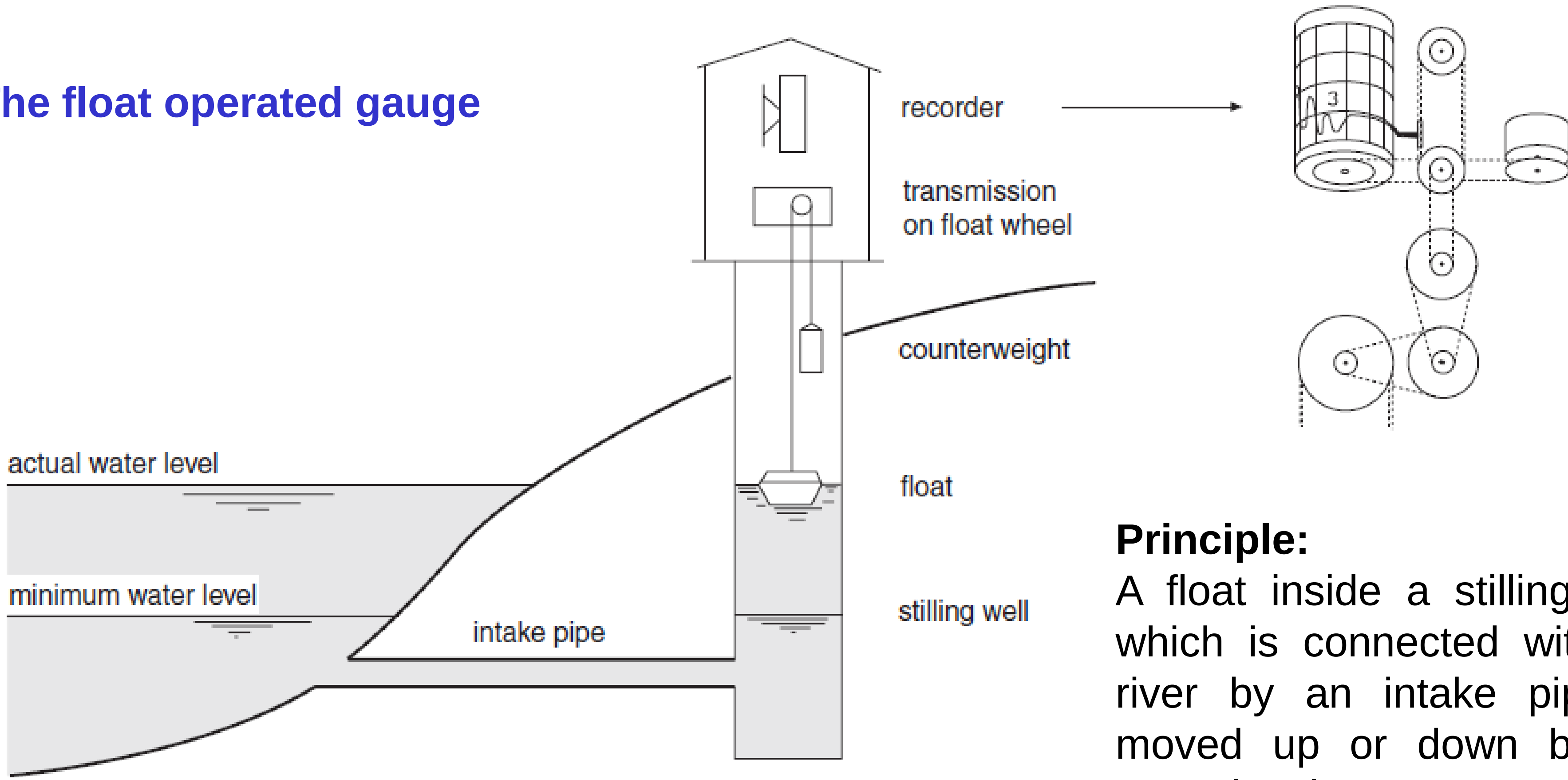

**bubble gauge or Pneumatic Water Level Gauge**

measuring range:
from 0-8.00 m to 0-30.00 m
accuracy:
error less than 1 cm over the total range

**Principle:**
The pressure in the measuring tube corresponds to the static pressure of the water column above the orifice.

# Hydrometric Practical Training: Water Level

## The float operated gauge




**Principle:**
A float inside a stilling well, which is connected with the river by an intake pipe, is moved up or down by the water level.

# Hydrometric Practical Training: Literature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