River flow (discharge) measurement

vodoprivredno projektni biro

Zagreb, 29.11.2019.

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Services offered by VPB d.d.

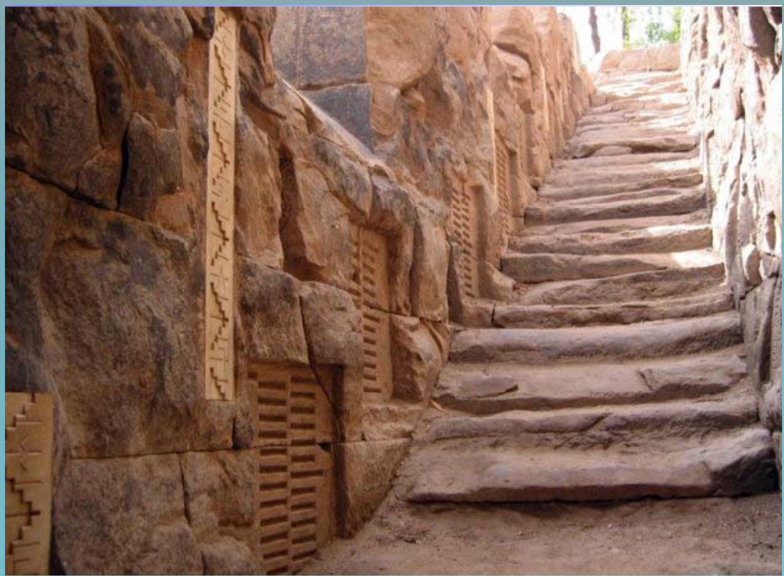
- Flood control projects
- Water management projects
- Sanitary engineering projects
- Waterways projects
- Environmental protection projects
- Geodetic survey

A stream gauge

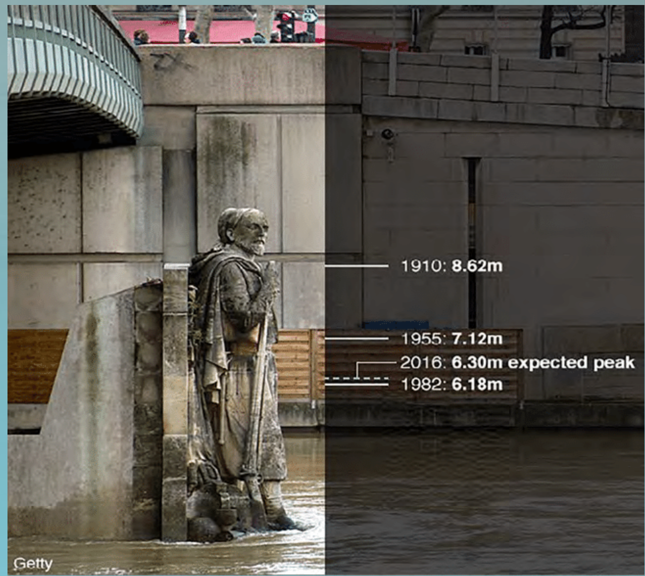
- A stream gauge or gauging station is a location used by hydrologists to monitor terrestrial bodies of water. Hydrometric measurements of water level surface elevation ("stage") and/or volumetric discharge (flow) are generally taken.
- Stage is generally directly measured continuously while discharge only occasionally.

Water level (stage) measurement

- Water level is much easier to gauge than discharge and therefore it has been more common historically, but nowdays also.



Nilemeter, Egypt



The statue on the Alma Bridge, Paris, as a flood gauge

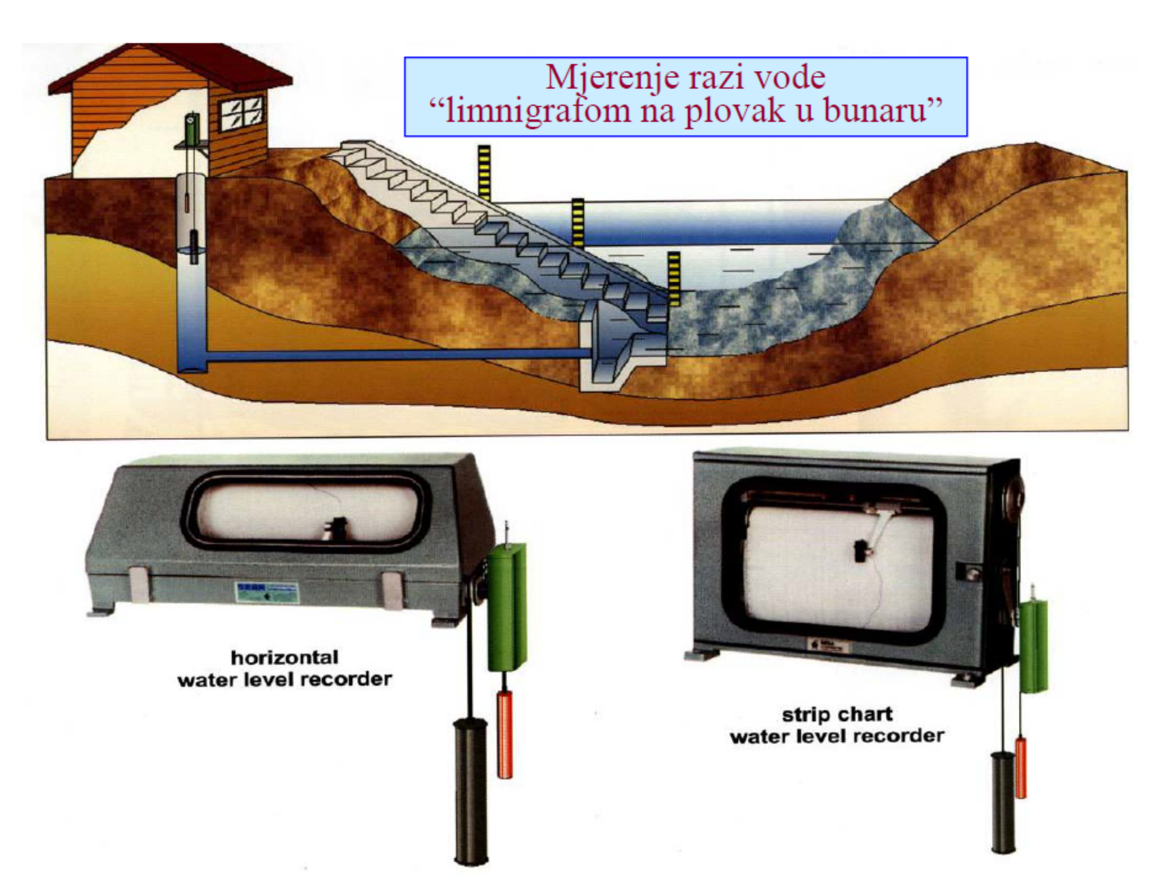
Water level (stage) measurement

- Some of the more recent options

- Simple water level gauge

Water level (stage) measurement

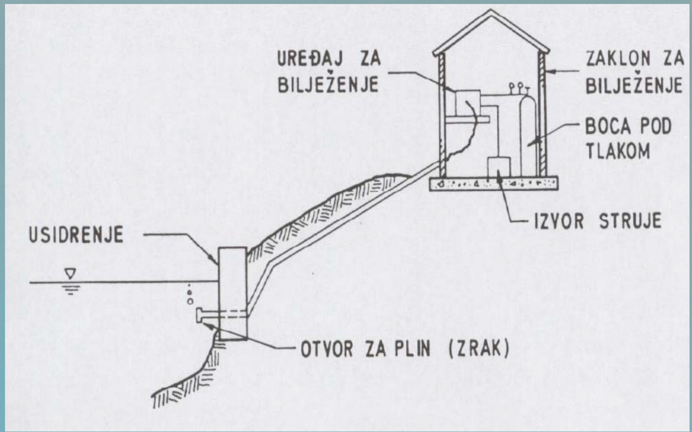
- Some of the more recent options



Limnigraph, well with the float

Water level (stage) measurement

- Some of the more recent options



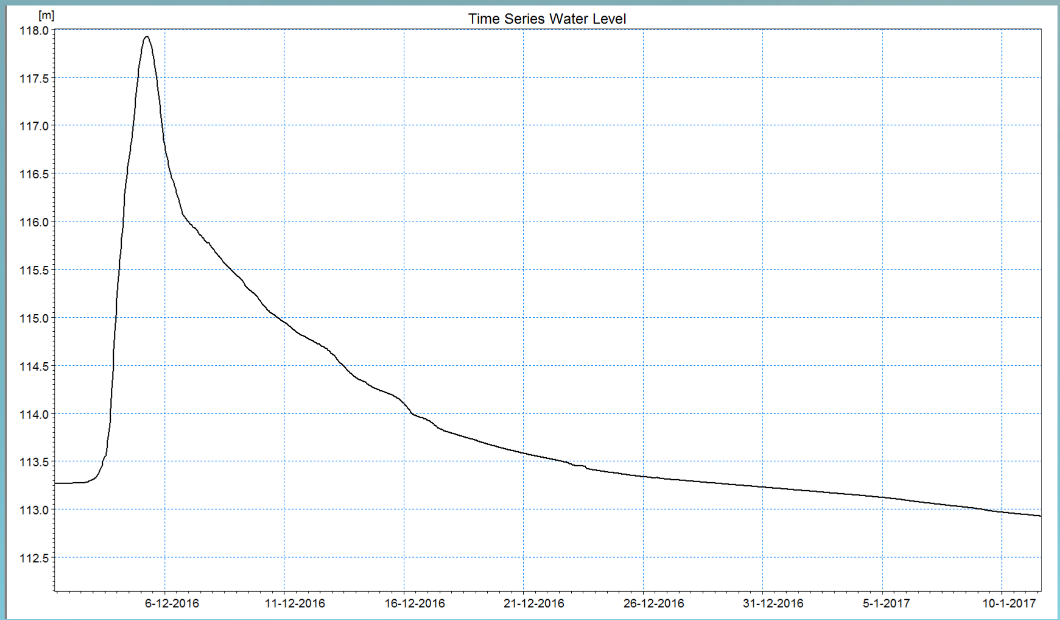
Gas limnigraph

Water level (stage) measurement

- Some of the more recent options

Water level (stage) measurement

- Water level is nowdays usually continously gauged
- Golden standard in Croatia is one hour frequency data
- The result of contionous gauging is water level as a function of time H=f(t).



Discharge „measurement”

- More complex than water level gauging
- As a result of complexity - discharge is rarely continously gauged (to be precise it is water velocity which is gauged, discharge is always calculated)

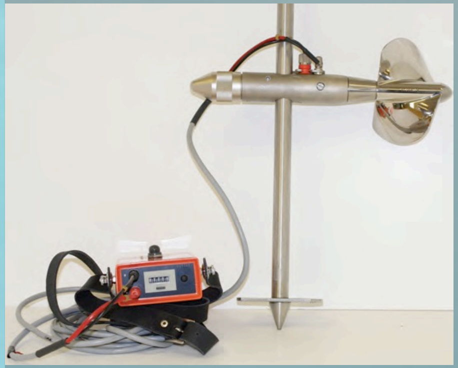
Various different methods for velocity/discharge measurement have been developed, some of which are:

- Current meter
- ADCP – vertical
- ADCP – horizontal
- Radar

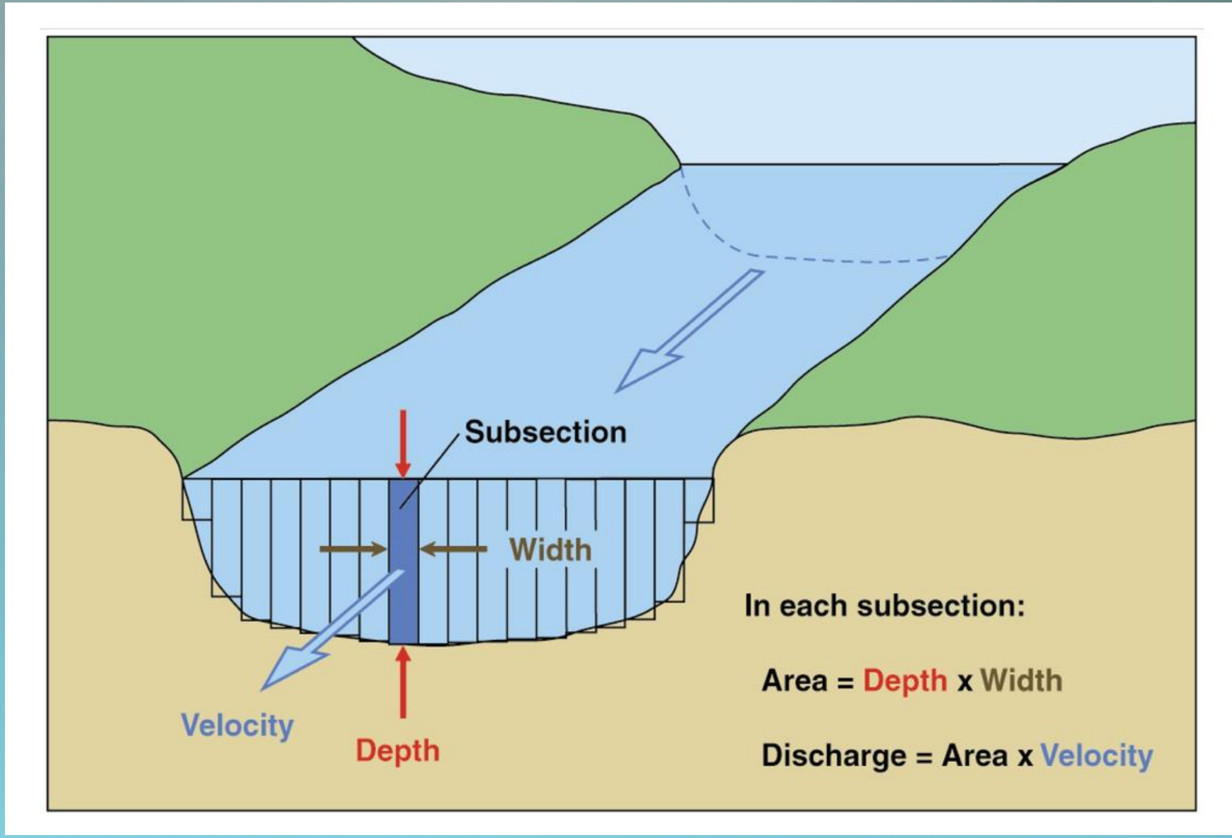
Basics of discharge calculation

- $Q\ [m^3/s] = v\ [m/s] \times A\ [m^2]$

- Discharge
- velocity
- Cross section area



Current meter

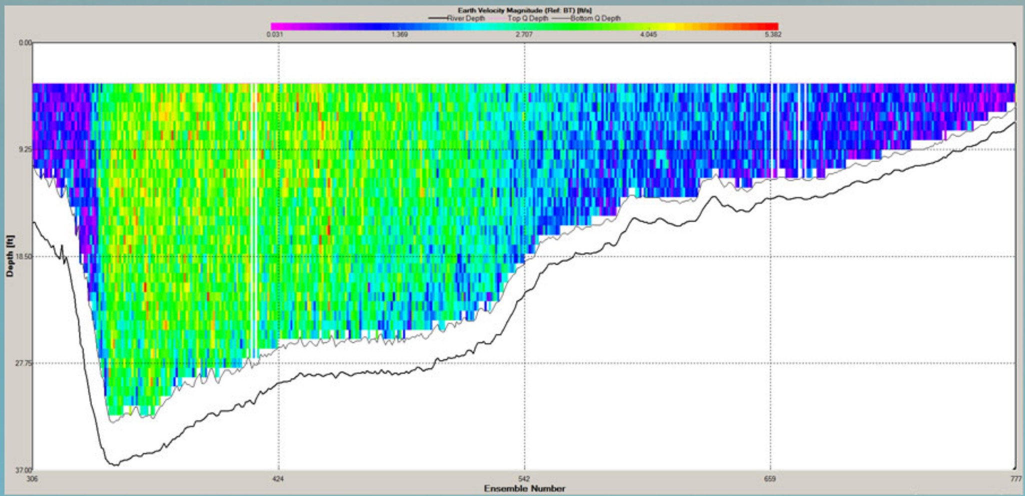


In the simplest method, a current meter turns with the flow of the river or stream. The current meter is used to measure water velocity at predetermined points (subsections) along a marked line, suspended cableway, or bridge across a river or stream. The depth of the water is also measured at each point. These velocity and depth measurements are used to compute the total discharge. Usually a river or stream will be measured at 25 to 30 regularly spaced locations across the river or stream.

ADCP

The ADCP (Acoustic Doppler Current Profiler) uses the Doppler Effect to determine water velocity by sending a sound pulse into the water and measuring the change in frequency of that sound pulse reflected back to the ADCP by sediment or other particulates being transported in the water. The change in frequency, or Doppler Shift, that is measured by the ADCP is translated into water velocity. The sound is transmitted into the water from a transducer to the bottom of the river and receives return signals throughout the entire depth. The ADCP also uses acoustics to measure water depth by measuring the travel time of a pulse of sound to reach the river bottom at back to the ADCP.

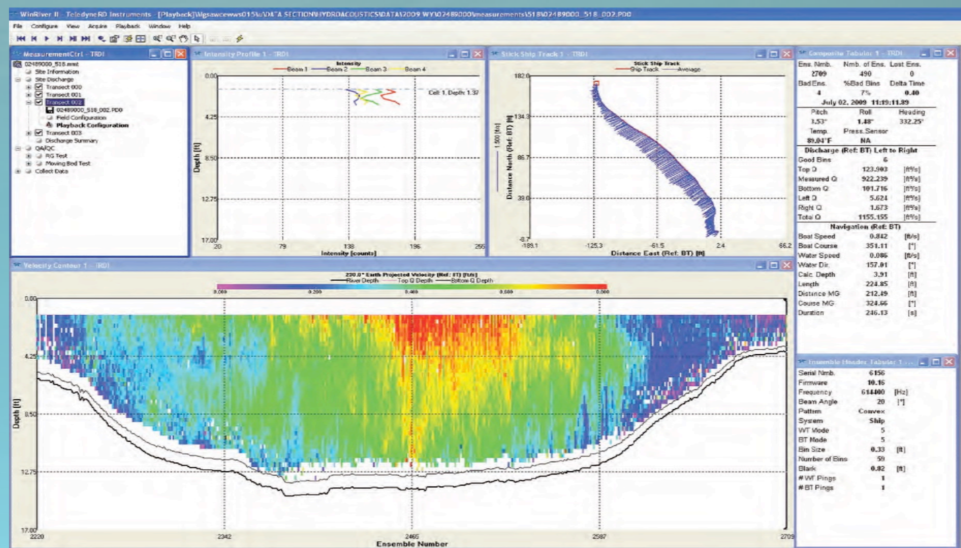
ADCP



To make a discharge measurement, the ADCP is mounted onto a boat or into a small watercraft with its acoustic beams directed into the water from the water surface. The ADCP is then guided across the surface of the river to obtain measurements of velocity and depth across the channel. The river-bottom tracking capability of the ADCP acoustic beams or a Global Positioning System (GPS) is used to track the progress of the ADCP across the channel and provide channel-width measurements. Using the depth and width measurements for calculating the area and the velocity measurements, the discharge is computed by the ADCP using discharge = area x velocity, similar to the conventional current-meter method.

ADCP

Figure 43. Examples of acoustic Doppler current profilers (ADCPs) used to measure discharge at gaging stations; *A*, Teledyne RD Instruments 600 kHz Rio Grande ADCP; *B*, Teledyne RD Instruments 600 kHz RiverRay phased array ADCP, and *C*, closeup view of phased array transducer; *D*, SonTek/YSI RiverSurveyor S5; *E*, SonTek/YSI RiverSurveyor M9; and *F*, Teledyne RD Instruments StreamPro ADCP.

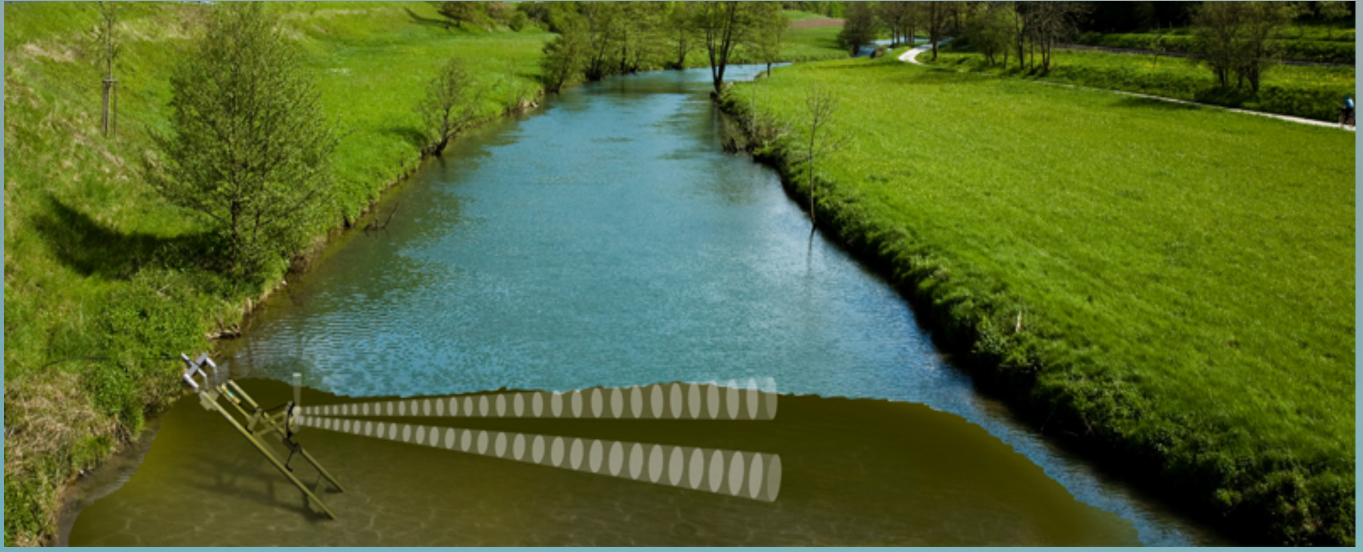


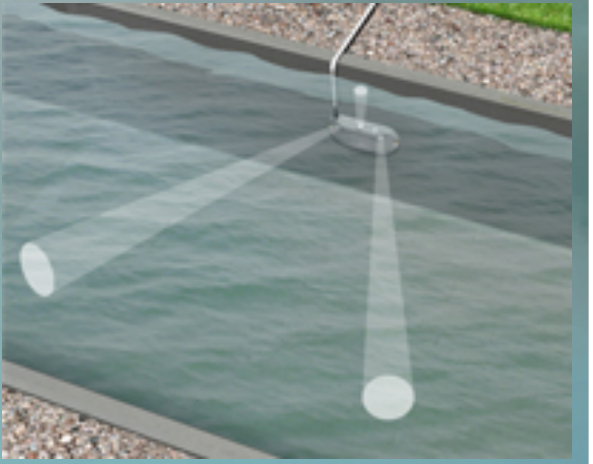
ADCP

- The ADCP has proven to be beneficial to stream gauging in several ways. The use of ADCPs has reduced the time it takes to make a discharge measurement. The ADCP allows discharge measurements to be made in some flooding conditions that were not previously possible. Lastly, the ADCP provides a detailed profile of water velocity and direction for the majority of a cross section instead of just at point locations with a mechanical current meter; this improves the discharge measurement accuracy

- Measurement precision can be positively affected by selection of a measurement location with minimal flow variations, and negatively affected by instrument- and boat-operation factors.

Horizontal ADCP





Horizontal Acoustic Doppler Current Profiler (H-ADCP) is a narrow beam acoustic monitoring system that “looks” out horizontally from an offshore or coastal to measure near-surface water currents and multi-directional waves.

The H-ADCP measures up to 200 meters horizontal range, offering a clear illustration of the complete flow structure.

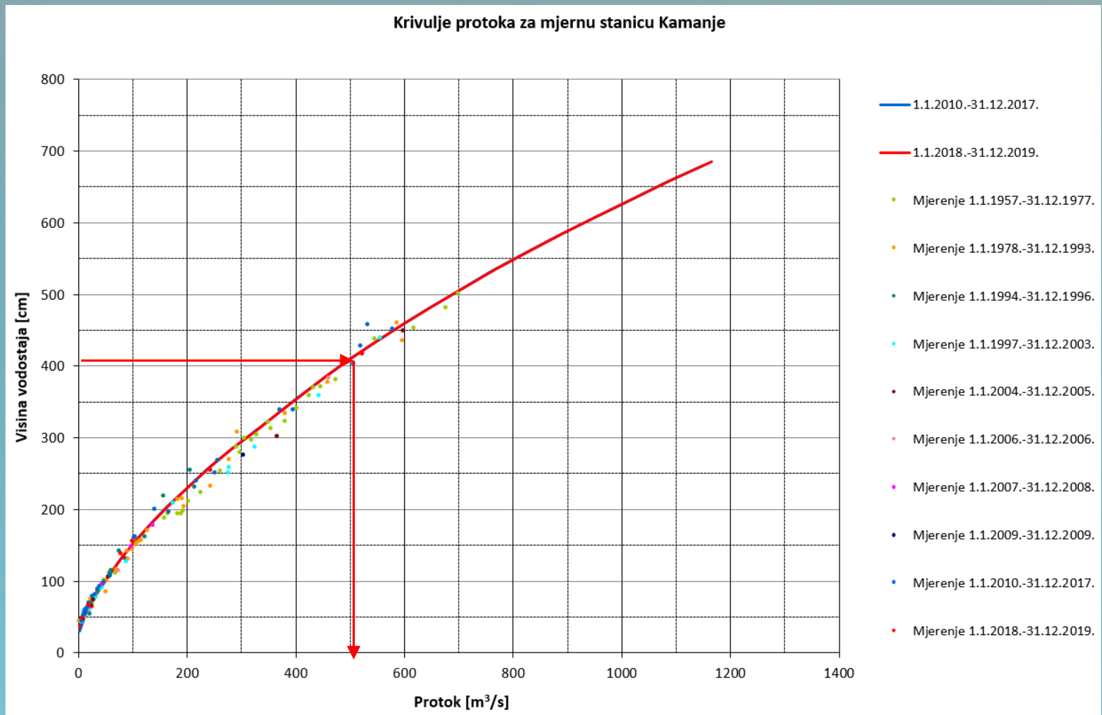
It is a long-term monitoring solution

Streamgauging generally involves 3 steps:

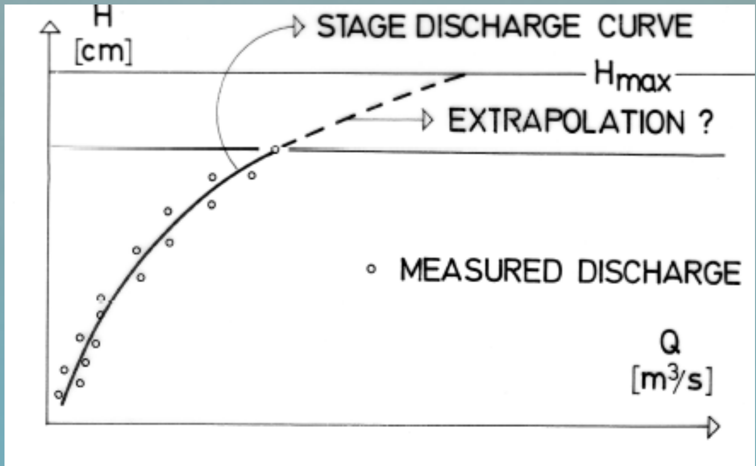
- Measuring stream stage—obtaining a continuous record of stage—the height of the water surface at a location along a stream or river
- The discharge measurement—obtaining periodic measurements of discharge
- The stage-discharge relation (rating curve) - defining the natural but often changing relation between the stage and discharge; using the stage-discharge relation to convert the continuously measured stage into estimates of streamflow or discharge

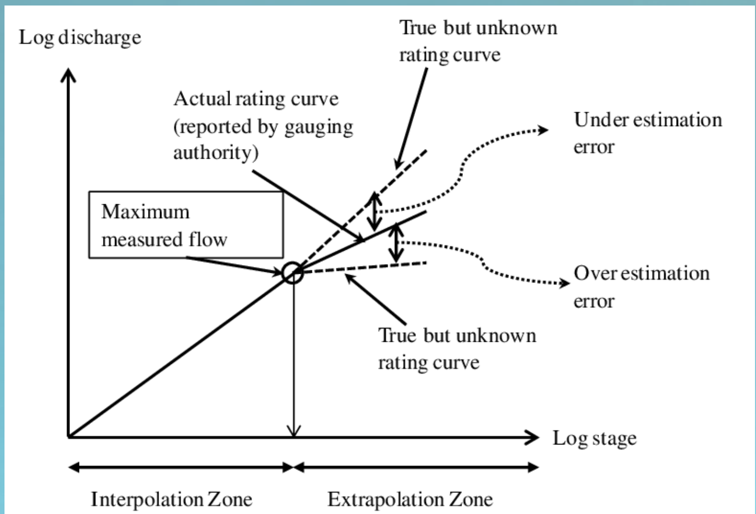
Rating curve

In hydrology, a rating curve is a graph of discharge versus stage for a given point on a stream, usually at gauging stations, where the stream discharge is measured across the stream channel. Numerous measurements of stream discharge are made over a range of stream stages. The rating curve is usually plotted as discharge on x-axis versus stage (surface elevation) on y-axis.



TROUBLE WITH THE CURVE





Extrapolation

A rating curve is generally constructed based on the assumption that a one to one correlation exists between the river discharge and stage, which is generally referred to as the “true rating curve”. However, the true rating curve is unknown and the standard method of constructing a rating curve consists of taking field measurements of water stage h, and river discharge Q.

These measurements help to identify discrete points (Q, h) that are subsequently interpolated through an analytical relationship that generates the rating curve. Then the rating curve extension is needed to get the discharge value for the larger floods, which can introduce systematic uncertainty, either over or under estimation of true river discharge.

The rating curve uncertainty is generally unknown but can be expected to increase as the water level rises above the highest measured flow. It could be as high as 30% in the extrapolation zone. In the interpolation zone, the uncertainty would be smaller (e.g. 1-5%) where the fitted rating curve is well supported by discharge-stage measurements.

TROUBLE WITH THE CURVE

Hysteresis

Very important source of complexity, peculiar of some streams during unsteady flow, is hysteresis which results when the water surface slope changes due to either rapidly rising or rapidly falling water levels in a channel control reach. Hysteresis is most pronounced in flat sloped streams. On rising stages the water surface slope is significantly steeper than for steady flow conditions, resulting in in greater discharge than indicated by the steady flow rating. The reverse is true for falling stages.

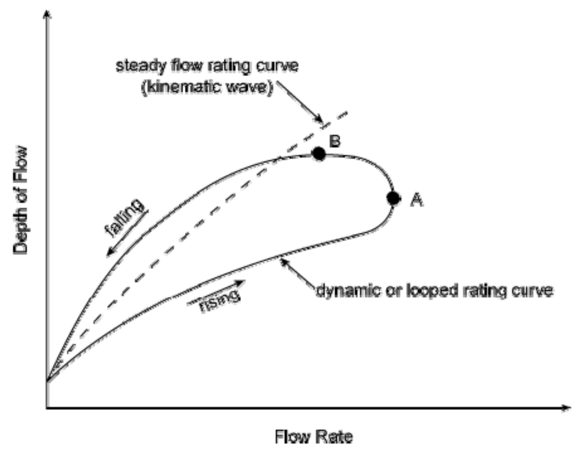
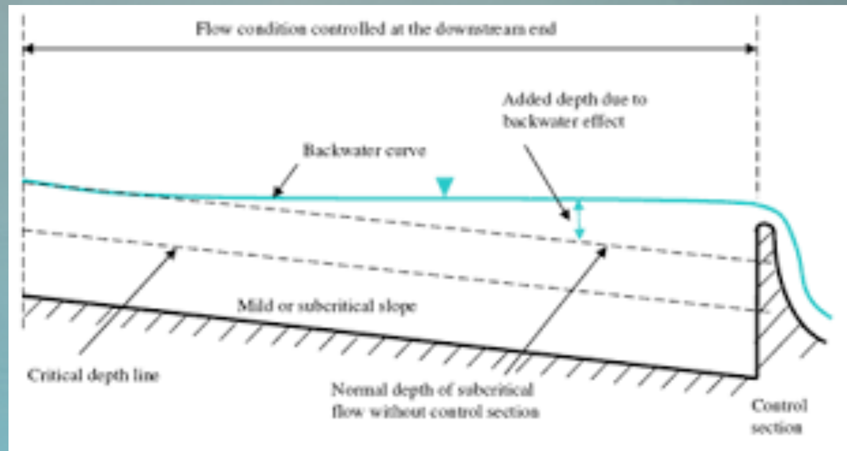


Figure 4. Example of loop rating curve (hysteresis).

TROUBLE WITH THE CURVE

Backwater

Further factor which can affect stage-discharge relations both for stable and unstable channels is variable backwater. Backwater effects occur when disturbances tend to propagate upstream. For example, the effect of a lake (slowing the flow down) or a waterfall (speeding the flow up) is felt upstream. Sources of backwater can be downstream reservoirs, tributaries, tides, ice, dams and other obstructions that influence the flow at the upstream gauging station control.



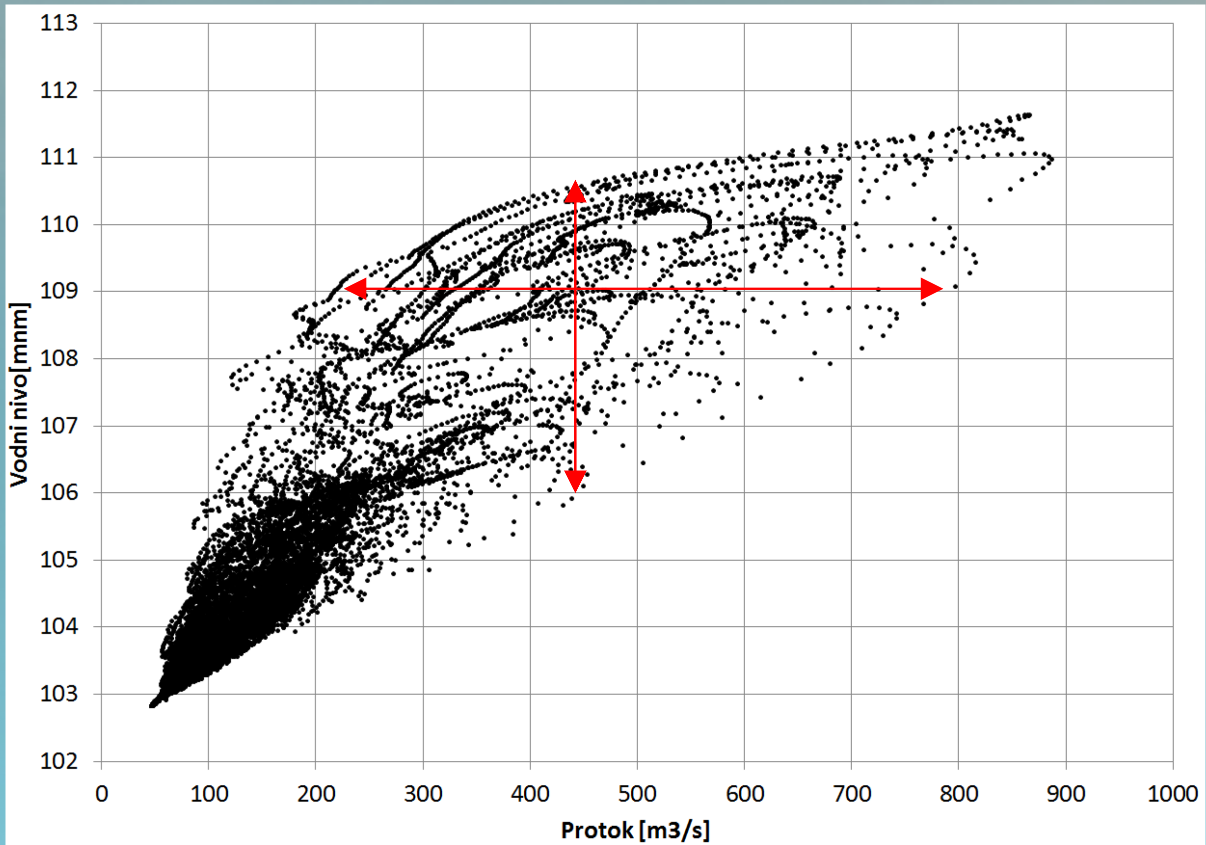
TROUBLE WITH THE CURVE

Conclusions about the rating curves

- The assumption of a unique relationship between stage and discharge is in general not justified
- Discharge is rarely measured during a flood, and the quality of data at the high flow end of the curve might be quite poor.
- It is usually some sort of line of best fit through a sample made up of a number of points – sometimes extrapolated for higher stages.
- It has to describe a range of variation from no flow through small but typical flows to very large extreme flood events

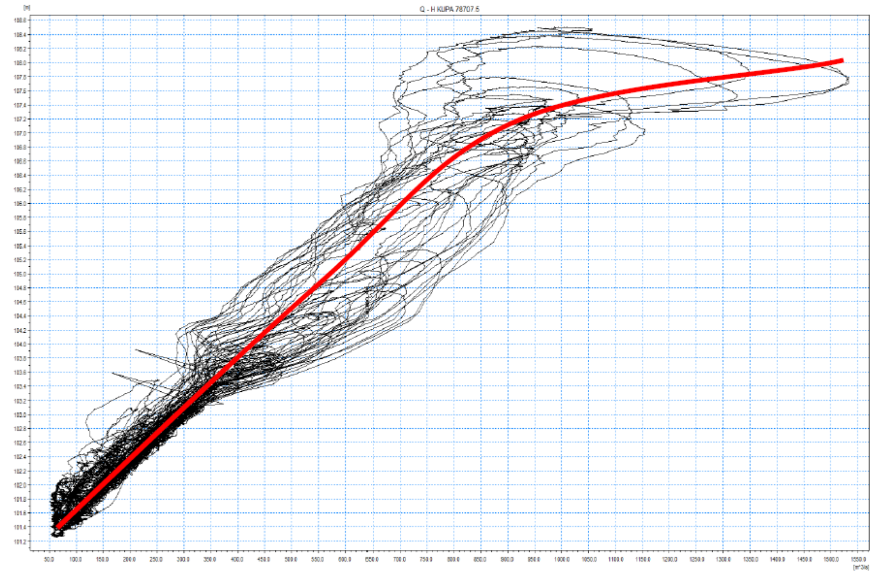
TROUBLE WITH THE CURVE

Example

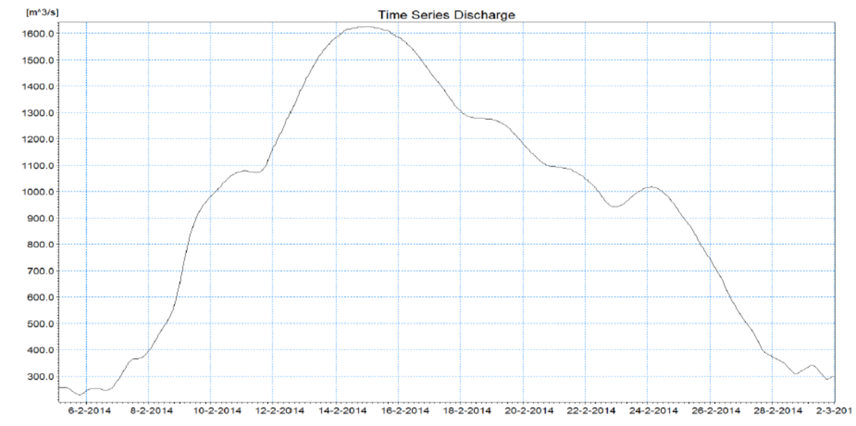


TROUBLE WITH THE CURVE

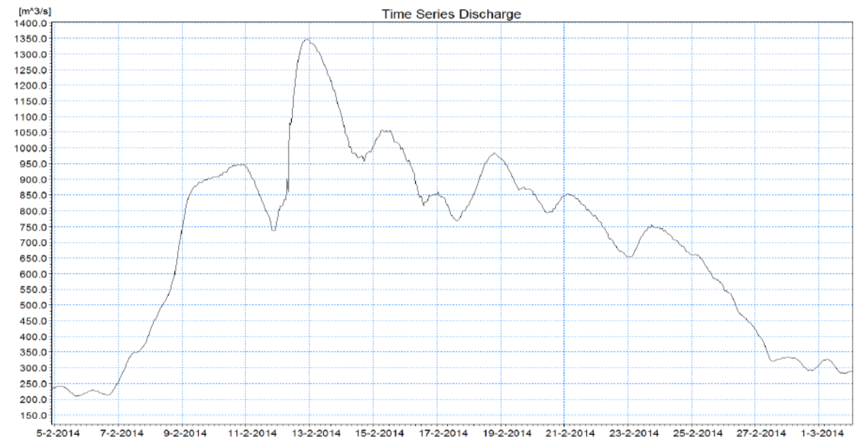
Example



Slika 52. Konsumpcijska petlja na poziciji VP J. Kiselica



Slika 53. Hidrogram na poziciji VP J.Kiselica za događaj iz veljače 2014. godine određen prema konsumpcijskoj krivulji



Slika 54. Hidrogram na poziciji VP J.Kiselica za događaj iz veljače 2014. godine proračunat na simulacijskom modelu Srednjeg pokuplja

Problem

Conventional measurements of river discharges are costly, time-consuming, and frequently dangerous. Especially floods where flow conditions or are dangerous to personnel in boats, because of high velocities and drifting logs, stumps, and debris. Direct measurement methods are increasingly subject to error and/or failure as stream depth, velocity, and bed instability increase.

Solution

- Non contact radar water level and surface velocity measurement
- Discharge calculation

Parameters necessary to compute discharge are:

- surface velocity (converted to mean velocity)
- cross-sectional area for a given stage

Workflow when using radars to calculate discharge

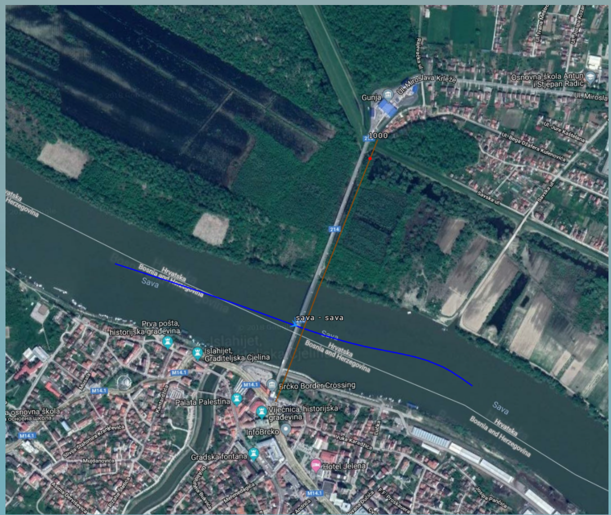
- Geodetic survey of a cross section
- Water stage and surface velocity radar operation
- ADCP gauging (mean velocity is obtained from the surface velocity on the basis of detailed velocity profiles measured by ADCP)
- Radars can then acquire a continuous discharge record

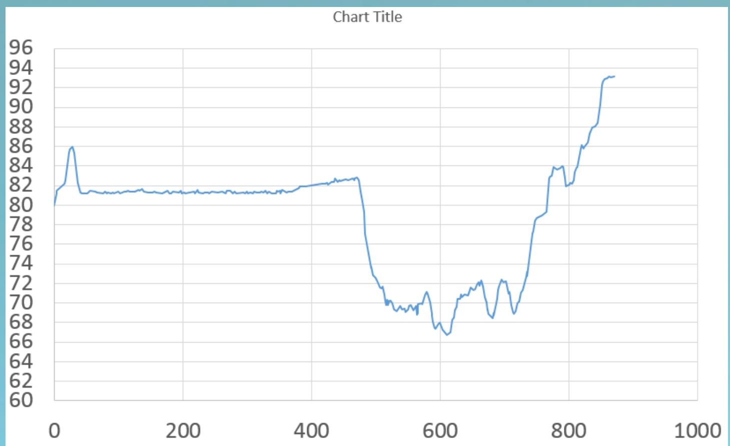
- $Q\ [m^3/s] = v_m [m/s] \times A\ [m^2]$

- Discharge at given moment
- Mean cross section velocity
- Cross section area for a given stage

Cross section area

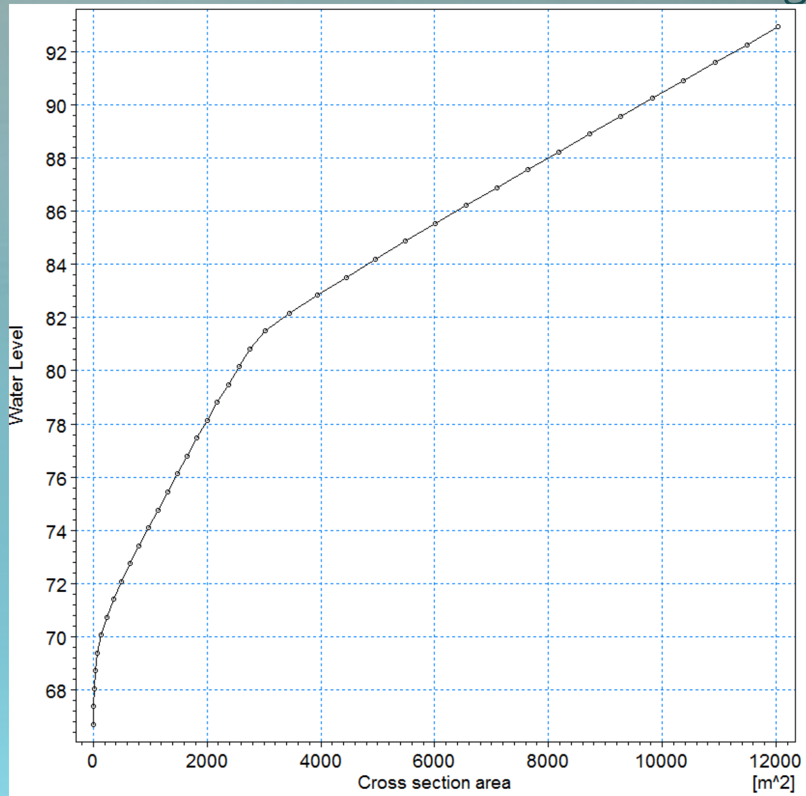
- Surveyed cross section





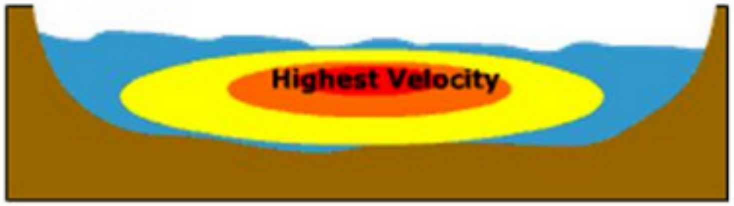
- A=f(H)

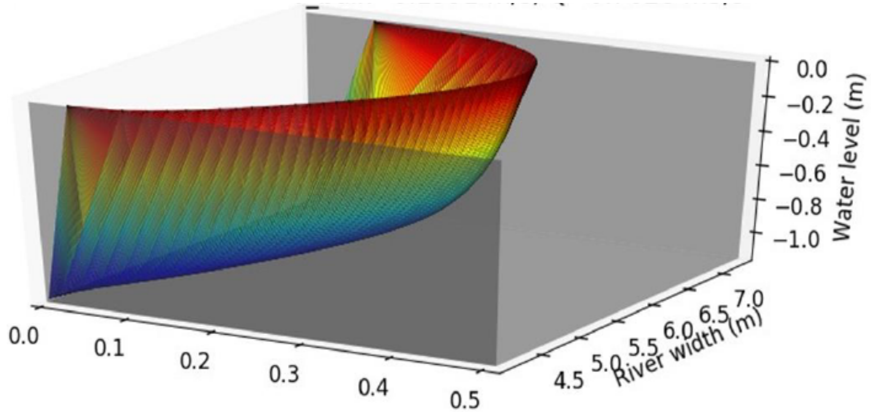
- Cross section area
- Function of a stage

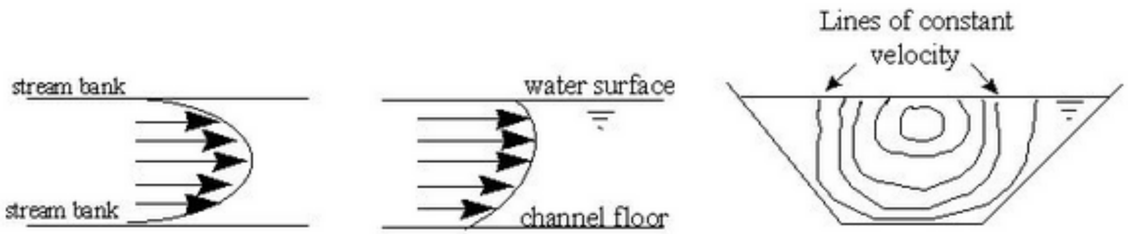


River Velocity Within its Channel

For a river with an even channel, the water flows fastest in the centre, near the top. In deeper places the flow is faster while in shallower places the flow is slower because there is more surface contact and friction in shallower places.







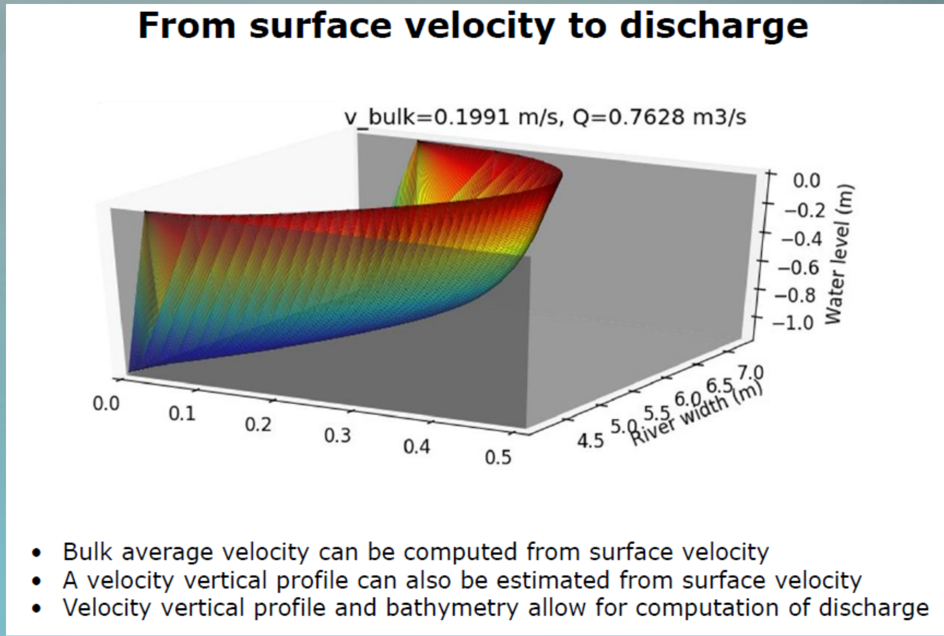
Velocity Profile Plan View

Velocity Profile Profile View

Velocity Profile Cross-Sectional View

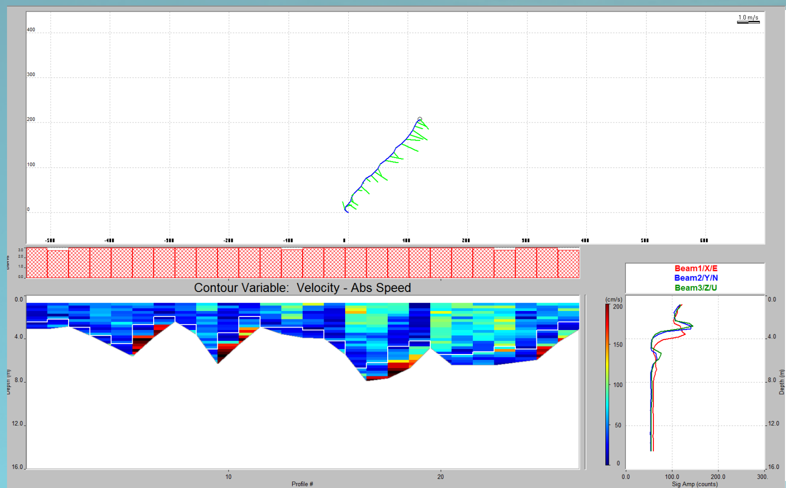
If ADCP gauging is not applicable

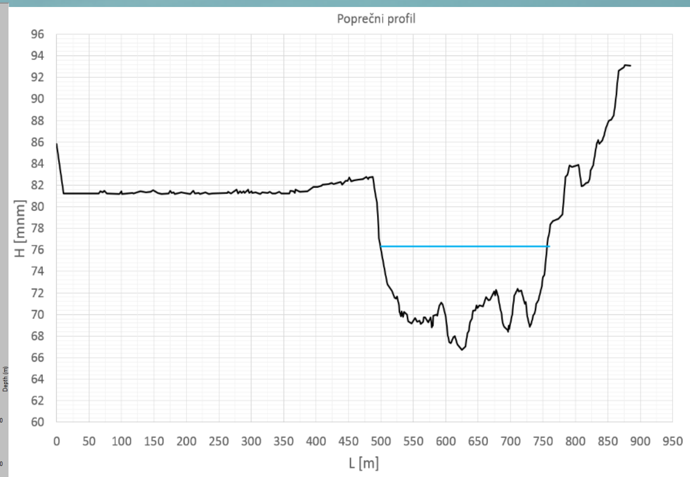
- Measurement at field sites confirm that lognormal velocity profiles exist for a wide range of flows in rivers, and mean velocity is approximately 0.85 times measured surface velocity.
- The mean velocity in small streams is approximately 0.55 times measured surface velocity which is quite less.



- $v_m[m/s] = k \times v_s[m/s]$

Gunja, Croatia example

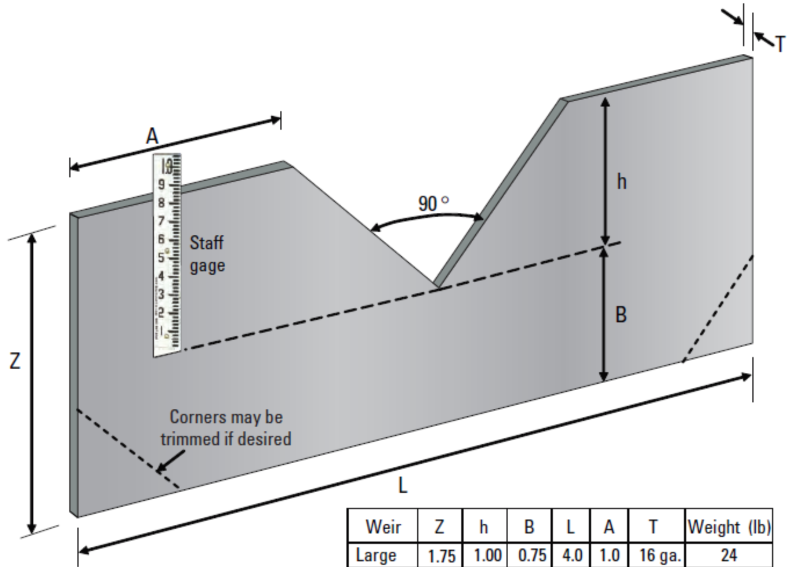




Portable Weir-Plate Measurements

Current-meter measurements made in shallow depths and low velocities are usually inaccurate, if not impossible, to obtain. Under these conditions, a portable weir plate is a useful device for measuring the discharge. A 90-degree V-notch weir is suitable because of its favorable accuracy at low flows. The notch is cut, without sharpening, leaving a flat, even edge.

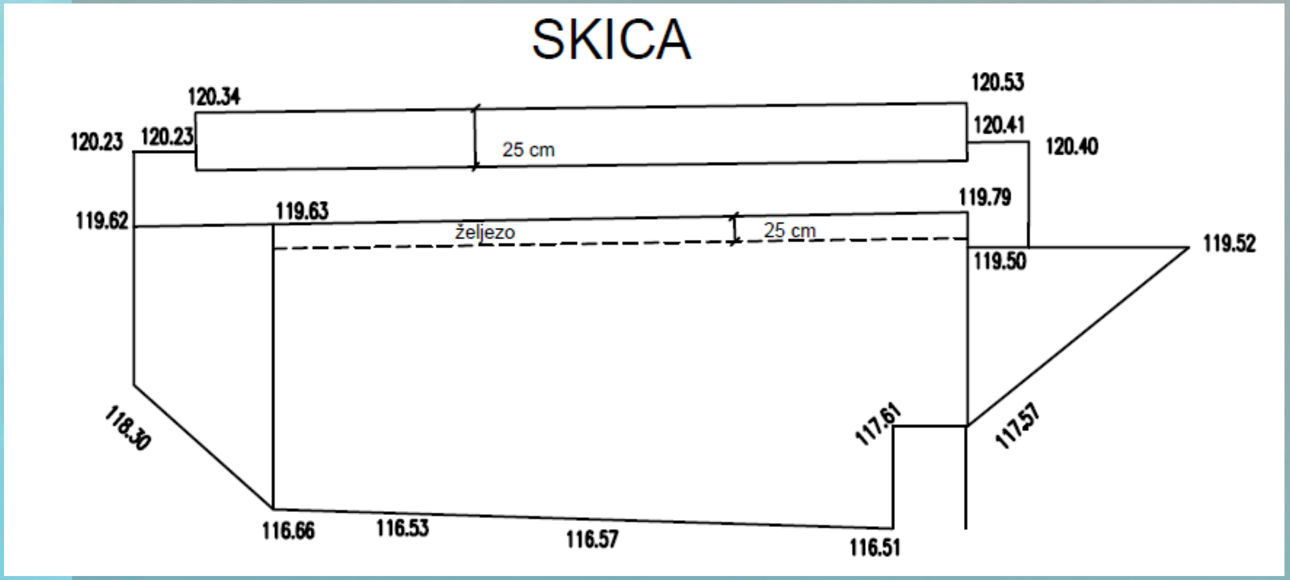
Gage is attached to the upstream face of the weir plate, with the zero point at the same elevation as the bottom of the weir notch. The gauge should be far enough from the notch to be outside of the zone of drawdown, which is a distance greater than twice the head on the notch. The gage is used to obtain head on the weir.

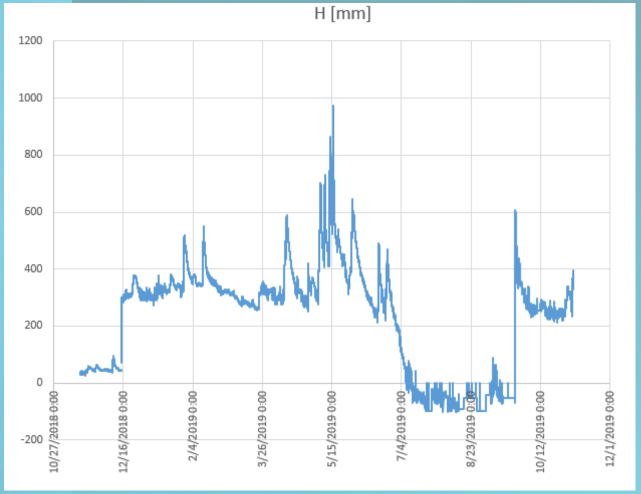


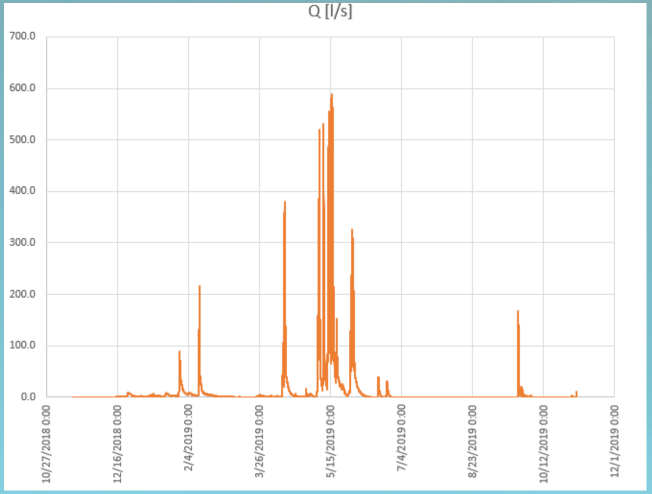
Weir	Z	h	B	L	A	T	Weight (lb)
Large	1.75	1.00	0.75	4.0	1.0	16 ga.	24
Medium	1.25	0.80	0.45	3.0	0.7	14 ga.	17
Small	0.75	0.47	0.28	2.0	0.53	10 ga.	8

Figure 76. Portable weir plate.

Ludinica stream, Croatia







Conclusions:

- Conducted experiments in various studies have shown that noncontact radar methods of flow measurement appear to be as accurate as conventional methods and obtain data when standard contact methods are dangerous or cannot be obtained.
- With non-contact radar technologies there is no reason why streamflow information should be degraded as flow rate or stage increases.

Thank you for attenetion !

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