RESTRICTIONS ON DISCHARGE AND VELOCITY MEASUREMENTS AND UNCERTAINTIES OF METHODS FOR THE ESTIMATION OF PEAK DISCHARGES IN TORRENTS

EXPERIMENTAL STUDIES, CALIBRATION METHODS AND RESULT COMPARISON FOR THE DISCHARGE GAUGING STATION SCHÄCHEN-BÜRGLEN

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The extreme flood event in August 2005 entailed huge inundations and damages in Switzerland. At the example of the discharge gauging station Schächen-Bürglen (near Lake Luzerne, Switzerland), there is the possibility to show some restrictions in measuring the water levels and water velocities and in estimating the peak discharges in torrents.

Measurement and registration of the water levels during flood events in torrents

For the registration of the water levels and the calculation of the discharges, a bubble gauge is installed at the measuring station in Bürglen. In consequence of the high amounts of bed loads and suspended sediments, the nozzle of the bubble gauge was clogged. Luckily for us, there is installed a radar probe as a supplementary water level measuring apparatus. With the radar gauge, the hydrograph during the flood event is registered and storaged.

Measurement of the discharges during flood events in torrents

The torrent Schächen included huge amounts of bed loads and floating logs, so that discharge measurements by current meters of ADCP appliances would lead to enormous loss of materials. The discharge measurements during extreme flood events could perform only with tracer dilution measurement with fluorescent dyes (Fiber optic Fluorimeter or Marriott bottle), but the injection of the tracer, the taking of water samples and stream water and the fixing of the fiber optic probes in the torrent bed contain serious perils for the measuring crew. Therefore, there are rarely existing discharge measurements in the peak range of flood events in torrents with small catchments.

Measurement of the water velocities during flood events in torrents

During flood events in torrents, it is rarely possible to measure the flow velocities of the water. The extrapolation of the measured velocities to estimate the peak velocities contains uncertainties. This is the reason for the additional installation of a surface velocity radar apparatus (measuring range: 0 – 4 m/s, uncertainty: ± 20 %, information by the manufacturer). With this additional data, the quality of the flood estimation by the Manning/Strickler method could be improved and the SIMK®-calibration method could be applied.

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Projects for an improvement of peak discharge estimation

To improve the data basis, the Swiss Federal Office for the Environment FOEN gave 2 orders. On the one hand, the Laboratory of Hydraulics, Hydrology and Glaciology VAW of the Swiss Federal Institute of Technology Zurich ETH built a hydraulic model to simulate the flood event of the "Schächen" in August 2005. On the other hand, the engineering enterprise ISAR CONSULT GmbH computed a flood calibration by the SIMK®-method.

Physical hydraulic model of the VAW

The physical hydraulic model of the discharge gauging station in Bürglen is built in the river engineering channel as an idealized hydraulic model (scale of 1:15). For the calibration, discharge measurements (maximum: 24.5 m^3/s) and 5 cross sections were available. The hydraulic model shows, that there are huge bed load depositions in the bubble gauge cross section, which increase the water levels considerable. The consequences are too high discharges. In contrast to this, the water level measurements in the Radar profile are more reliable.

SIMK®-calibration method

The SIMK®-procedure from the ISAR CONSULT GmbH is a method for the water and profile related calibration of discharge measuring stations and is based on the continuous equation and the numerical simulation of the velocity relation factor $k = v_m/v_i$ by the aid of a finite-element flow model. To carry out the calibration by the SIMK® method, cross sections, photos (to fix the k-value), the range of the water levels and the position and angle of the velocity measuring instrument has to be known.
Because the surface velocity radar is operating only since 2006, it isn't possible the calculate peak discharges for the flood event in August 2005 by the SIMK® method directly. But with the physical hydraulic model, the surface velocity at the peak discharge was measured. The multiplication of the surface velocity at peak discharge (6.4 m/s) with the velocity relation factor (k = 76.4 %) and the discharge cross-section (A = 18.4m^2) results in the peak discharge of 90 m^3/s.

Result comparison – estimation of the peak discharge of the Schächen in August 2005

tab.1 peak discharges (right column, in brackets: estimated confidence bands)

Type of calculation or estimation	**Peak discharge** [m^3/s]
Peak discharge by the "extrapolation of the rating curve with extrapolated velocities" (measuring profile: radar gauge)	**124** (109 – 139, ± 12%)
Peak discharge by the "extrapolation with the Manning-Strickler formula" (using k-value, measuring profile: radar gauge)	**165** (145 – 185, ± 12%)
Peak discharge, calculation by the physical hydraulic model (measuring profile: radar gauge)	**120 - 130** (115 – 135, ± 8%)
Peak discharge, calculation by the SIMK® method (measuring profile: radar gauge)	**90** (83 – 97, ± 8%)

The big range of the different peak discharges gives a general view about the dimensions of the uncertainties by the estimation of extreme flood peaks in torrents. If there would be no discharge measurements available, the range of uncertainty would be much larger.

Conclusion

To improve the data basis for extreme high water discharge, two aspects are important:

- Supplementary installations of measuring-, memory- and transmission apparatus to have measuring data at our disposal during the extreme conditions of floods.
- Selection of well suited measuring profile without hydraulic instabilities. This could lead to the necessity of separated measuring profiles for low water and high water.

Keywords: Hydrometry, torrent, discharge measurement, peak discharge.