Discharge gauging without a hydrologist

Markus Weiler, Matthias Grether and Emil Blattmann

HYDROLOGY

Background

Discharge measurements are essential for most hydrological research. Generally discharge is determined indirectly by measuring the water level and converting this value by an empirical rating curve into discharge. To establish a rating curve or stage-discharge relationship there are different methods in use. Velocity-area methods and dilution techniques are the most common to measure discharge for a given water level. Both methods are time-consuming and are associated with high costs to generate a stable rating curve. Especially in inaccessible regions with turbulent and flashy streams it is a problem to develop a rating curve. The stage-discharge relationship in these streams is often poorly defined since the cross-section or hydraulic properties are changing and in particular at high flows a large error has to be assumed since discharge cannot be continuously observed. It is a major challenge to develop stage-discharge relationships without the need of manual discharge measurements associated with high costs and requiring a great amount of time.

Objectives

We developed and tested a new instrument for continuous discharge measurements in turbulent streams. It is designed to directly measure discharge and to attain many measurements at different water levels to create a rating curve within a couple of weeks. The Automatic Discharge Gauging System (ADiGS) is a self-controlled system, which measures discharge by dilution gauging using florescent dyes as a tracer. Because of its technical setup with low power consumption, automatic tracer injection in to the stream water, effective data storage and the possibility to transfer or receive data by wireless communication, ADiGS can be used as a stand-alone tool. It can therefore be easily deployed to establish time- and cost-effectively stage-discharge relations in low accessible regions or under financial constraints.

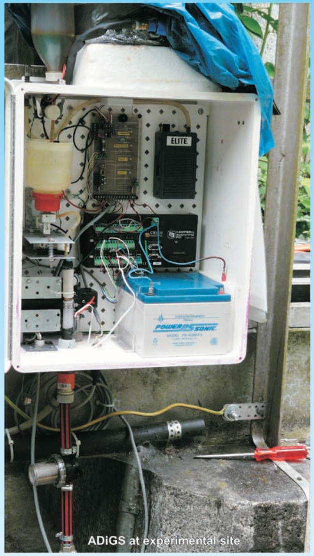
Technical Setup

Preparing an injection

An exact measurement of the injected tracer mass is required to allow a precise calculation of discharge using Eq. 1. Fluorescent tracers are used to allow a minimum of 100 injections with a storage container of 10 L. The injection process starts with mixing the tracer in the container by a stirrer to ensure a well-mixed tracer solution. Tracer solution flows to a scale, which is controlled by a pinch valve, until the desired amount of tracer is reached based on the observed water level to guarantee a maximum concentration in the stream. The injected tracer mass is weighted with a load cell with an accuracy of 0.05g.

$$Q = \frac{M}{\int (c_i - c_0)\,dt}$$

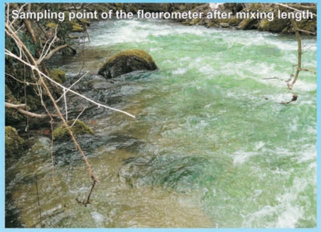
Equation 1



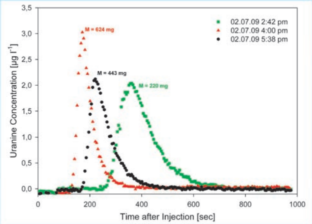
Datalogger

A data logger is controlling the injection of tracer and observation of the tracer breakthrough curve. Based on observed water level tracer injections are triggered depending on changes of water table in the stream or on a fixed time interval. The measured discharge can therefore be directly related to water level to develop a stage-discharge relationship. All data is saved in the logger that is required to calculate discharge based on the injected tracer mass and the tracer breakthrough curve.

Injection and sampling



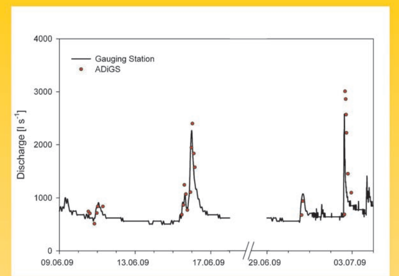
Controlled by another pinch valve and a water pump the weighted tracer is injected in the stream. The water pump pumps water from the stream and the tracer solution is sucked into the flowing current to be injected into the stream. At the mixing distance downstream of the injection point an in-situ fluorometer (Cyclops 7), which is turned on only during the injection, is recording the tracer breakthrough. Since the observed concentration of most fluorescent dyes is depended on water temperature and pH, the parameters are recorded to correct for temporal changes in the stream water.



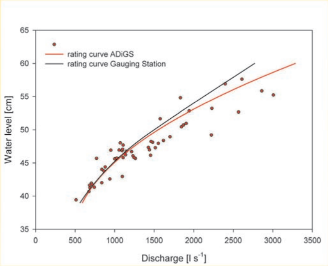
Initial problems

We had miscellaneous problems with the technical equipment. Because the temperature sensor was partly malfunctioning and pH was not continuously measured, the observed discharge is not of the potential accuracy. Furthermore there were issue with the fluorometer recording since only part of the breakthrough curve was recorded for several injections. We believe that something blocked the opening of the fluorometer housing. Another problem during the field experiment was a loose connection resulting in a loss of the fluorometer signal.

Results



Between May and July 2009 ADiGS performed over 200 measurements. A fixed time step and a sampling dependent on changing water levels were tested. To confirm the quality of the discharge measurements they are compared with an existing traditional rating curve from a well-established gauging station at the site of the trial. In May the system was operating at a fixed time interval. The calculated discharge by the ADiGS was within 20 percent compared to the gauging station. From the middle of May until beginning of June the discharge values were not reliable because of several technical problems. The measurements in June and July are very close to the observed discharge. During this time the activating of the system due to changing water levels was tested and demonstrates the potential of measuring many different discharges within a short time.



With the values from this period it is possible to create a rating curve for the experimental location.

The rating curve developed with ADiGS is very close to the existing rating curve within the observed discharge between 500 and 1500 l s-1.

Conclusions

ADiGS provides the potential to measure discharge in previously ungauged regions and to create a rating curve within a couple of months. Different water quality parameters have to be observed to correct the measured tracer concentration compared to the calibration. The accuracy of the discharge is directly proportional to the observed tracer concentration and observed tracer mass. The initial problems with the system are possible to solve and a second system is currently built with some modifications at the IHF. The complete system should be available for around $6000 and will therefore allow producing cost-effectively stage-discharge relations in low accessible regions or under financial constraints.

Institute of Hydrology, Albert-Ludwigs-University of Freiburg
markus.weiler@hydrology.uni-freiburg.de www.hydro.uni-freiburg.de