LOW FLOW DISCHARGE MEASUREMENTS USING AN ADCP (ACOUSTIC DOPPLER CURRENT PROFILER) IN THE FENTON RIVER, CONNECTICUT

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Summary. Accurate measurement of low flow discharges is critical for in stream flow studies. Traditional methods, including weirs and current meters, cannot be applied under all conditions and may by costly in terms of time. The application of an alternative method, Acoustic Doppler Current Profiler (ADCP), is reported for a study of the Fenton River in Connecticut. Examples of the velocity profiles are given, as well as the advantages and limitations compared to the traditional methods.
Keywords: Stream, Discharge Measurement, Doppler.

MĂSURĂTORI DE DESCĂRCARE DE DEBIT SCĂZUT FOLOSIND UN ADCP (ACOUSTIC DOPPLER CURRENT PROFILER) ÎN RÂUL FENTON, CONNECTICUT

Rezumat. Măsurarea exactă a descărcărilor de debit scăzut este critică pentru studiul fluxurilor de apă. Metodele tradiţionale, inclusiv deversoarele, nu pot fi aplicate în toate condiţiile și pot fi costisitoare în termeni de timp. În această lucrare sunt prezentate rezultatele aplicării uneo metode alternative, Acoustic Doppler Current Profiler (ADCP), pentru studiul râului Fenton din Connecticut. Sunt prezentate exemple ale profilurilor vitezelor, precum și avantajele și limitele metodei aplicate în comparație cu metodele tradiţionale.
Cuvinte-cheie: Fflux, măsurătoare de descărcare, Doppler.

INTRODUCTION

The Fenton River is one of three tributaries that feed the Mansfield Hollow Lake basin in Mansfield, Connecticut. During low flow periods in summer, pumping from the University of Connecticut wells near the Fenton River potentially impacts the amount and the temperature of the stream flow and consequently reduces the fisheries habitat. The University of Connecticut has funded an intensive, detailed study of the flow in the Fenton River near the well field in order to quantify the impacts. As part of that study, discharge measurements were taken at various points along the river in order to develop rating curves, perform flow statistics and assess the impact of pumping on river flows. One technique used for measurements of stream flow in the study was an Acoustic Doppler Current Profile (ADCP) device. This paper describes the background of ADCP and its application to low flows in the Fenton River.

METHODS

ADCP Theory

The Austrian mathematician and physicist Johann Doppler (1803-1853), was the first to explain the Doppler Effect that is the shift in frequency and wavelength of waves which results from a source moving with respect to the medium, a receiver moving with respect to the medium, or even a moving medium Roguin (2002).

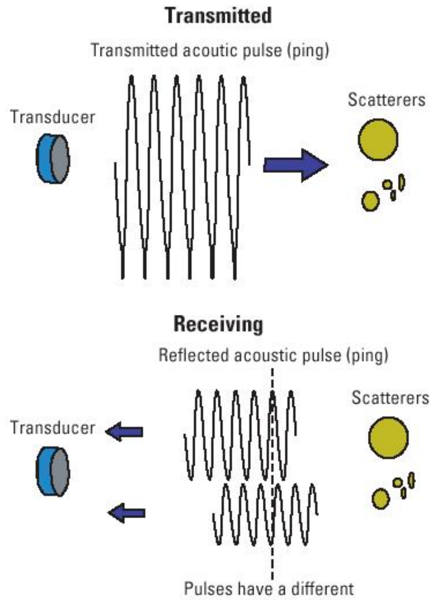

Figure 1. Beam transmitted and received Simpson (2001)

The Doppler effect is applied as show in the Figure 1, where a signal is being backscattered from scatters (particles) of different sizes that are moving at different speeds, which results in the arrival of signals at differing phases. This method uses an autocorrelation technique that needs accurate phase information to calculate frequency shift. The spreading effect causes random error in the determination of Doppler shift Simpson (2001).

In natural waters such as rivers, lakes and sea, the reflected signal is affected by scattered velocities in the cloud of particulate matter that is "illuminated" by the ultrasonic pulse, Figure 2, Simpson (2001).

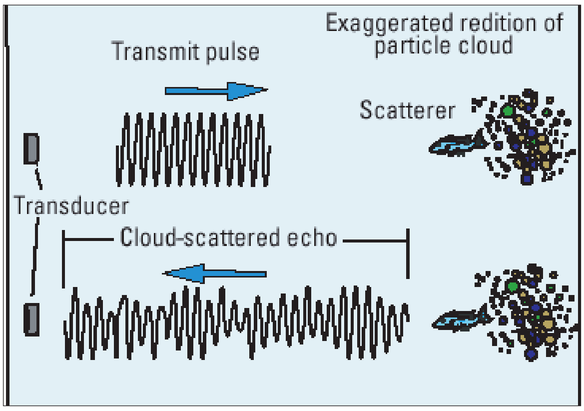

Figure 2. Scattered velocities in the water Simpson (2001)

The result of this cloud-scattering effect is to increase the spectral width of the return signal. Although the dominant source of spectral spreading is the transmitted pulse length, the measured spectral width can be an indicator of velocity uncertainty Simpson (2001). The cloud scattered echo amplitude is a function of several things such as: Transmit pulse power, transmit pulse length, reflective quality of scatterers, quantity of scatterers, absorption coefficient of the water Simpson (2001).

Description of the study site

The river reach of interest and where we made measurements with ADCP is shown in Figure 3. There were four sites where measurements were taken at different intervals. The four sites are within a reach of river that extends from the Turnpike Bridge to the Chaffeeville Bridge, 4040 meters downstream. Measurements were primarily taken at low flow since the principal objective of the project of determining the impact of pumping occurs at lower discharges. Flows were typically less than 0,5 m^3/s, but ranged from about 0,05 to 5 m^3/s. Depths were less than 1 meter in all cases and typically ranged from 0,2 to 0,5 m. Velocities at each measurement site were well within the subcritical flow regime.

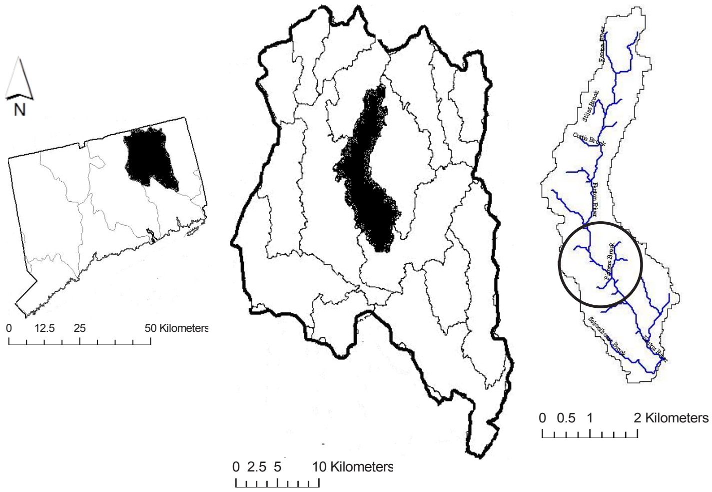

Figure 3. a) The west branch of the Thames River watershed in the State of Connecticut, b) The east branch of the Thames River watershed with the Fenton river watershed in black, and c) Fenton river watershed and the area of interest in circle

EQUIPMENT

The equipment used was the StreamPro by RD Instruments, Inc., which is a smaller version of an ADCP intended for large rivers by the same company. The StreamPro as pictured in Figure 4 consists of a Float and Boom, an Electronics Housing and the Transducer: Also shown in Figure 4 is the PocketPC that stores operational files, communicates with the float electronics and records data from the transducer. The float and deployment boom are designed to maintain the transducer at a constant depth in the water with minimal flow disturbance. The blue and white plastic Electronics Housing protects the electronics and is capable of being submerged to depths of one to two meters for short periods of time. The transducer ceramics are mounted to the transducer. A thermistor is embedded in the transducer head and also measures the water temperature. The StreamPro ADCP communicates with the Pocket PC using Blue Tooth protocols. Bluetooth must be turned on before the StreamPro can communicate with the Pocket PC, RD Instruments (2004).

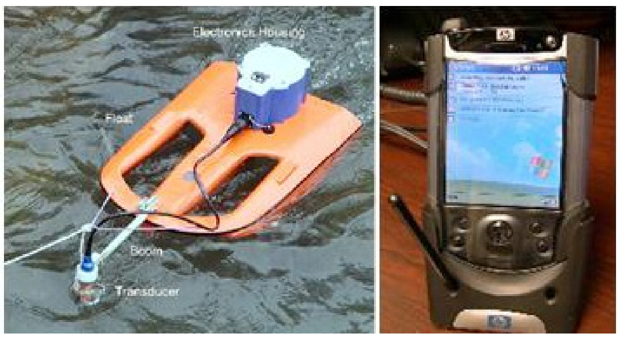

Figure 4. ADCP and Pocket PC

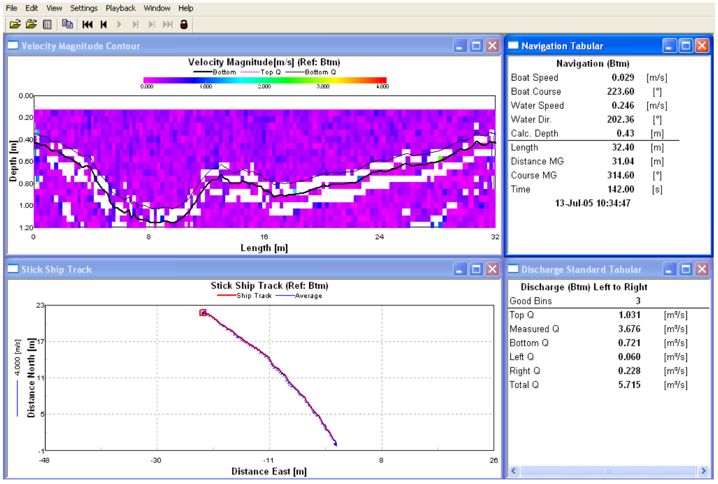

Figure 5. PC screen obtained from the program Win River

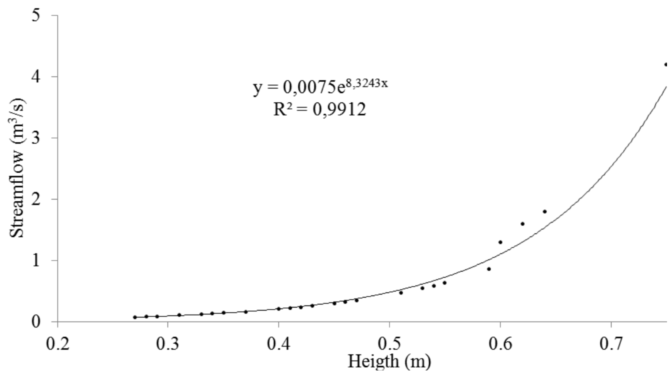

Figure 6. Example of a rating curve (stream flow vs. height) obtained for the Fenton River

RESULTS AND DISCUSSION

The Pocket PC creates one file for every transect conducted; this file can later be downloaded from the Pocket PC to a computer to work with the computer program, WinRiver that is supplied with the instrument. The WinRiver program can be used to analyze the results of the measurements conducted in the river.

An example of the WinRiver display is shown in Figure 5 for a transect obtained with the ADCP on the Farmington River in Connecticut. The display consists of four parts or screens. The left bottom screen shows the path followed by the ADCP in the River, while the upper left screen shows the velocity of the stream flow for different "bins" or cells and the geometrical cross section of the transect. The upper and lower right screens give the statistics of flow and the length of the river measured with the ADCP.

Figure 6 shows the rating curve obtained at one transect on the Fenton River through repeated application of the StreamPro.

CONCLUSIONS

Use of the ADCP for stream flow measurements has several advantages, as well as some disadvantages, and limitations. Advantages include the ease of use (after some initial training) and the ability to take several repeated cross sections in a short time. The repeated transects can be compared to provide an assessment of the accuracy. The overall accuracy appears to be quite high compared to other techniques when used under appropriate flow conditions and if proper measures are taken in the processing and analysis of the data files. An additional advantage is the ability to take flow measurements without entering the water. This provides greater safety to the users under high flow, fast velocity conditions. The ADCP used also provides cross-section information and two dimensional (vertical and horizontal) velocity distributions. It can be used for very low velocities in contrast to propeller type velocity meters such as the standard Price or pygmy meters.

One disadvantage is the initial cost. The 2004 cost of the StreamPro used in this study was approximately $15 000 US dollars for all the equipment. There are some limitations. The instrument cannot be used in water with high waves that can occur in runs or rapids areas of smaller rivers because of the inability to control the float and because the transducer will bounce out of the water. Its use is limited to fairly slack pool areas for these reasons. It is also limited to a minimum depth of about 0,2 m. It is best used (as with other meters) in fairly uniform flow transects without large eddies.

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