

REAL-TIME DISCHARGE MONITORING DURING FLOOD SEASON USING BROADBAND H-ADCP AT HUANGLING TEMPLE HYDROLOGY STATION DOWNSTREAM THREE GORGES DAM IN YANGTZE RIVER

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ABSTRACT

A 300 kHz H-ADCP (horizontal acoustic Doppler current profiler) based real-time flood monitoring system was established at the Huangling Temple hydrology station since March 2004. It is the first such system in Yangtze River and the second one in China. The system measures two-dimension horizontal velocity profile up to 200m across the river and employs the so-called index-velocity method to calculate discharge. Extensive field data collection was conducted during March to June, 2004, from which an initial index-velocity rating was developed. The rating was improved with more data collected during a flood period in September 2004. The real-time discharge data obtained by the H-ADCP based system at the Huangling Temple hydrology station is transmitted to a hydrological information network in the Yangtze River region. The network utilizes LAN, satellite, and VHF for data transmitting and receiving. The discharge data can be reviewed by the hydrologists and managers in real-time at the Three Gorges hydrology office and the regional hydrology office. The success at the Huangling Temple site proved that the H-ADCP based system with the hydrological information network provides a total solution to the flood monitoring in the Yangtze River reach.

INTRODUCTION

The Huangling Temple hydrology station (Figure 1) is located between the two major dams in Yangtze River, about 26 kilometres upstream of Gezhou Dam and about 12 kilometres downstream of the Three Gorges Dam. It is one of the most important hydrology stations in Yangtze River as well as in China. During flood seasons, the Yangtze River discharge may be as high as 30,000 to 80,000 m³/s. The Huangling Temple hydrology station is responsible for monitoring of the discharge during flood seasons and reporting to the Chinese centre government in real-time.

The Yangtze River reach at the Huangling Temple site is within the back flow region of the Gezhou Dam reservoir. Both of the water level and discharge at the site are affected by the joint flow regulating of the hydraulic and hydropower systems in Gezhou Dam and Three Gorges Dam, resulting in complicated flow patterns in the reach. Therefore, a single stage-discharge relation does not exist and discharge data cannot be obtained from the water level measurement. This situation challenges the real-time discharge monitoring during the flood season and in the other seasons.

In 2004, the Huangling Temple hydrology station started to experiment the use of the state of the art broadband H-ADCP (horizontal acoustic Doppler profiler) for real-time flood monitoring. A 300 kHz ChannelMaster H-ADCP was installed and in operation since March 2004. Extensive field data collection was conducted from March to June 2004 and in September 2004 to develop an index velocity rating. This paper describes the H-ADCP based flood monitoring system and presents the rating development and monitoring results.



Figure 1 The Huangling Temple hydrology station by the Yangtze River

THE H-ADCP BASED FLOOD MONITORING SYSTEM

Figure 2 shows a diagram of the H-ADCP based flood monitoring system at the Huangling Temple site. The system consists of a 300 kHz ChannelMaster H-ADCP, a water level sensor, a power and communication cable, a desk-top computer, and software. The discharge data obtained from the system is transmitted to a hydrology information network in the Yangtze River region.

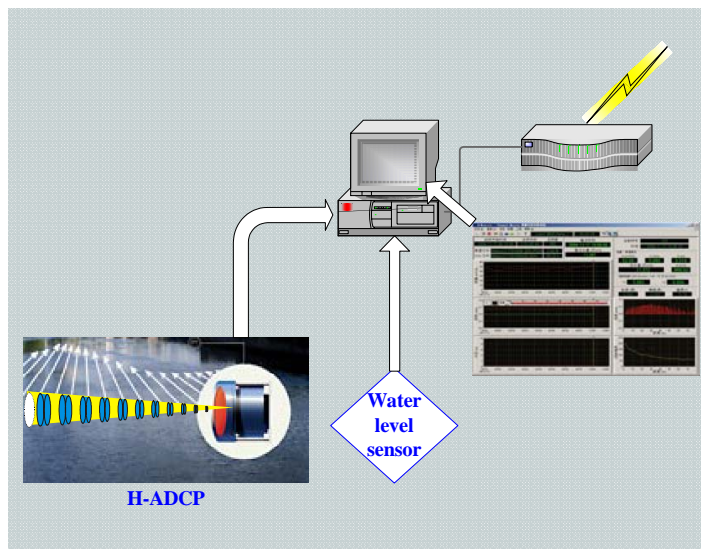


Figure 2 Diagram of the H-ADCP based flood monitoring system at the Huangling Temple site

The 300 kHz H-ADCP, which is a key component of the flood monitoring system, uses the patented broadband Doppler technology (US patent Re. 35,535) to measure two-dimension horizontal velocity profile across the river. H-ADCP has become a new tool for river discharge monitoring since its introduction in 2003. Table 1 shows the velocity measurement specification of the 300 kHz H-ADCP.

Table 1 Velocity measurement specification of 300 kHz H-ADCP

Acoustic frequency	300 kHz
Cell number	128
Minimum cell size	1m
Maximum cell size	10m
Maximum profiling range	300m
Blank distance	1m
Velocity range	$\pm 5\text{m/s}$ [default] 、 $\pm 20\text{m/s}$ [maximum]
Accuracy (long term)	$\pm 0.5\% \pm 0.2\text{cm/s}$
Resolution	1mm/s

The 300 kHz H-ADCP was initially installed in March 2004. It was mounted on the side of a big floating dock (Figure 3), 3.2m below the water surface. Adjustment was made during the installation to ensure the H-ADCP was pointing to the other bank, perpendicular to the main flow direction. Pitch and roll were also adjusted within ± 1 degree. In March 2006, the H-ADCP was moved to a near by new location (Figure 4).



Figure 3 The 300 kHz H-ADCP mounted on the floating dock from March 2004 to March 2006

The H-ADCP was configured as follows:

- Cell size: 4m
- Number of cells: 50
- Blank distance: 2m
- Sampling Interval: 7.68s
- Averaging interval: 7.48s

The H-ADCP velocity profile data is transmitted in real-time through the cable to the computer at the station office. Water level is measured using the water level sensor and the data is transmitted to the computer as well in real-time. Both of the velocity and water level data are then processed and discharge is calculated in real-time by the software that employs the so-called index-velocity method (e.g., Morlock 2002).



Figure 4 The 300 kHz H-ADCP mounted on the new location since March 2006

RATING DEVELOPMENT

The index-velocity rating development is the key to the success of the H-ADCP based flood monitoring system. It involves two steps. The first step is to collect data for discharge and index-velocity. The second step is to create a relationship between the river mean velocity (or discharge) and index-velocity by regression analysis of field data. A rating should be selected that is the best fit to the field data.

In order to develop an index velocity rating for the Huangling Temple site, extensive field data collection was conducted from March 8 to June 17, 2004 and in September 2004 (a flood period). During a field operation, the H-ADCP was continuously measuring velocity profiles. Concurrently with the H-ADCP data collection, river discharge was measured either by a moving boat ADCP or by the conventional current meter method. The moving boat ADCP method took only a half to one hour to complete a discharge measurement (each may involve two to four transects), while the current meter method took two to three hours for a discharge measurement. The moving boat ADCP used for the discharge measurement was either a 300 kHz BBADCP or a 300 kHz WHM ADCP. Figure 5 shows the 300 kHz BBADCP and the 300 kHz WHM ADCP mounted on the station's survey boat. The survey boat may also be equipped with a differential GPS, a lower frequency depth sounder, and a gyrocompass. These equipments may be used in conjunction with an ADCP during a flood when the ADCP bottom tracking may be biased or occasionally totally lost due to high solids concentration in the water (as high as 20 grams/liter at the site). The differential GPS provides the over-ground velocity reference and the depth sounder provides bathymetric information. The gyrocompass provides heading information because the steel hull interferes with obtaining accurate heading data from the internal compass of the ADCP. The integration of the external sensors with an ADCP at the Huangling Temple site was described in Marsden et al (2003).

Figure 6 shows a typical WinRiver screen shot of moving boat ADCP discharge measurement in the Yangtze River reach at the Huangling Temple site. The top diagram shows the velocity magnitude contours on the river cross-section. The bottom diagram shows the depth averaged velocity vectors along the ship's track. The moving boat ADCP method has been successfully used at this site for discharge measurement since 1992.



Figure 5 The 300 kHz BBADCP (left) and 300 kHz WHM ADCP (right) mounted on the Huangling Temple hydrology station's survey boat

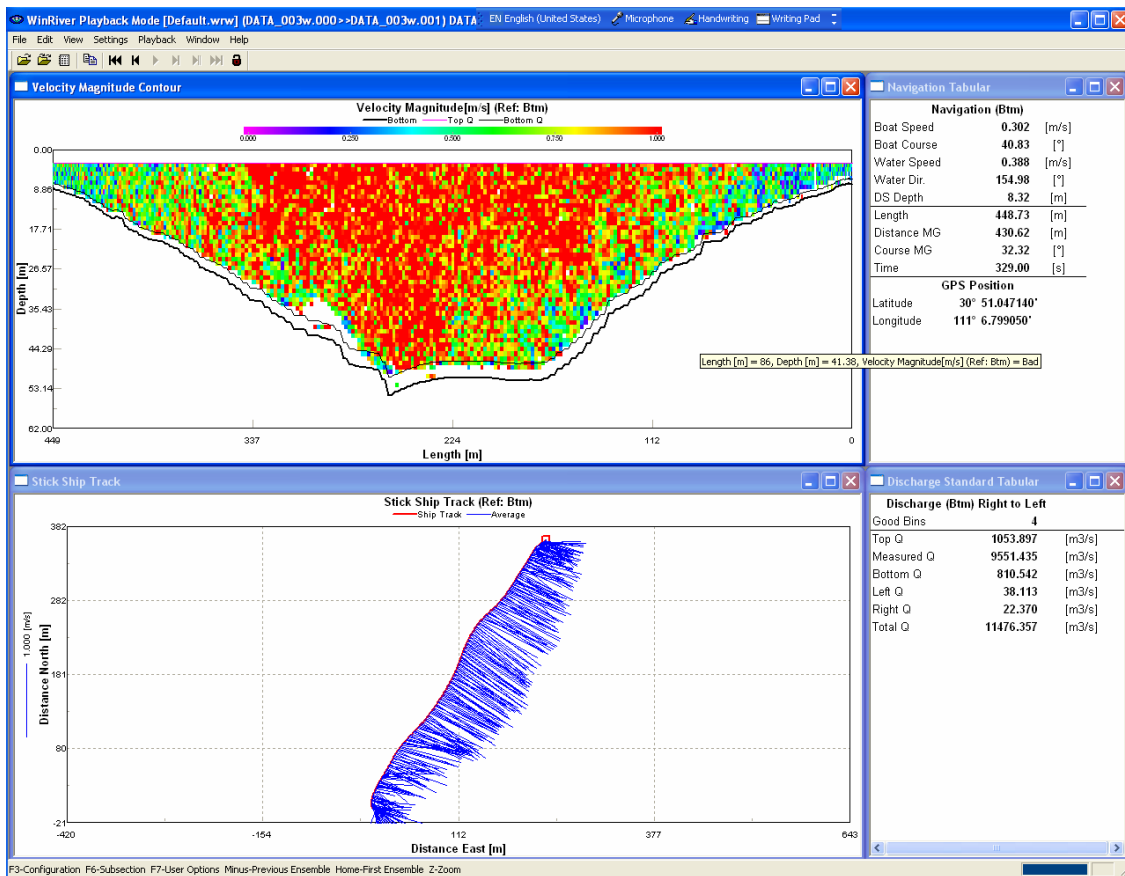


Figure 6 A typical WinRiver screen shot of moving boat ADCP discharge measurement in the Yangtze River reach at the Huangling Temple site

A total of 36 sets of data for discharge and water level were obtained during the field data collection program from March to June, 2004. The discharge ranged from 4,230 to 27,700m³/s; the minimum and maximum river mean velocity were 0.27 and 1.67m/s, respectively. Additional 16 data sets were obtained during the flood period in September 2004 when the discharge ranged from 20,400 to 60,900 m³/s.

The initial index-velocity rating development was based on the data collected in the March to June period. In order to develop the best rating equation for the site, a total of eleven alternatives with different averaging ranges and/or range positions for the index-velocity were evaluated. The time averaging interval for the index-velocity was chosen to match the period of the corresponding discharge measurement. The initial index-velocity rating was improved with more data collected during the flood period in September 2004. Figure 7 shows all of the 52 data sets. The final rating equation is obtained as follows:

$$Q = 964.34 V_I^2 + 11763 V_I + 2468.4 \quad (1)$$

where: V_I = index-velocity, which is the average velocity of the first 50 cells. Q is in m³/s and V_I is in m/s.

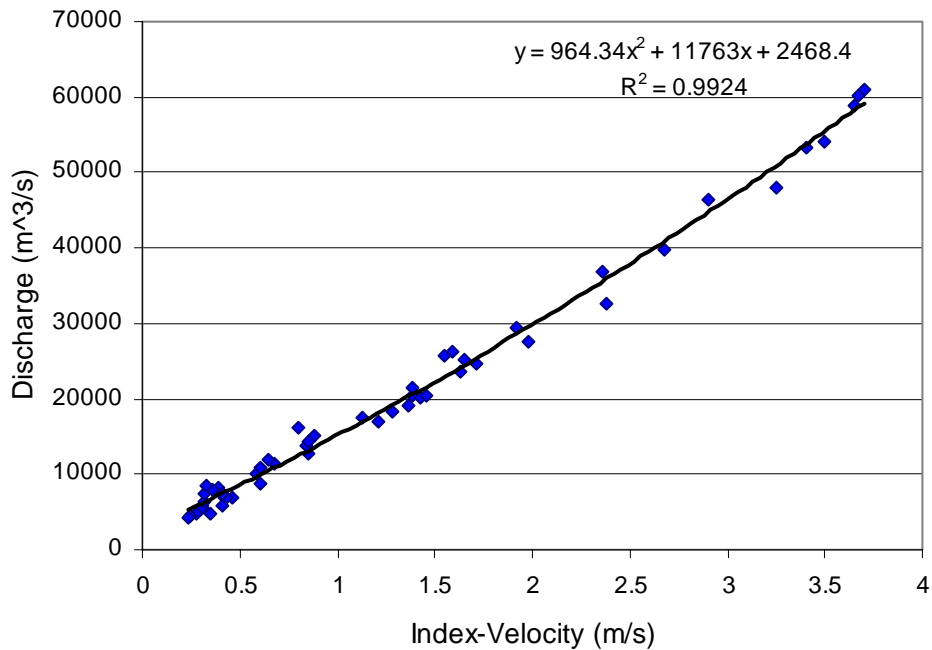


Figure 7 All of the 52 field data sets for discharge and index-velocity (dots) and the final rating equation (solid line)

THE TOTAL SOLUTION TO FLOOD MONITORING

The H-ADCP based system was first used to monitor flood in September 2004. Figure 8 shows the real-time monitoring results of the September 2004 flood in the Yangtze River reach at the Huangling Temple site. The H-ADCP based system used the initial index-velocity rating for the discharge calculation during this period. As mentioned before, the rating was improved later using the moving boat ADCP or current meter measured discharges during the flood period.

The H-ADCP based flood monitoring system at the Huangling Temple site is in operation since it has been established in March 2004. It becomes part of the hydrological information network in the Yangtze River region (Figure 9). During a flood period, the real-time discharge data obtained from the H-ADCP based system is transmitted to the hydrological information network. The network utilizes LAN, satellite, and VHF for data transmitting and receiving. The discharge data can be reviewed by the hydrologists and managers in real-time at the Three Gorges hydrology office and the regional hydrology office. The success at the Huangling Temple site proved that the H-ADCP based system with the information network provides a total solution to the flood monitoring in the Yangtze River reach. The Huangling Temple site becomes a model that is followed by two other H-ADCP based flood monitoring systems established in the upstream reaches of the Yangtze River in 2006 and several more at other sites to be in operation in 2007.

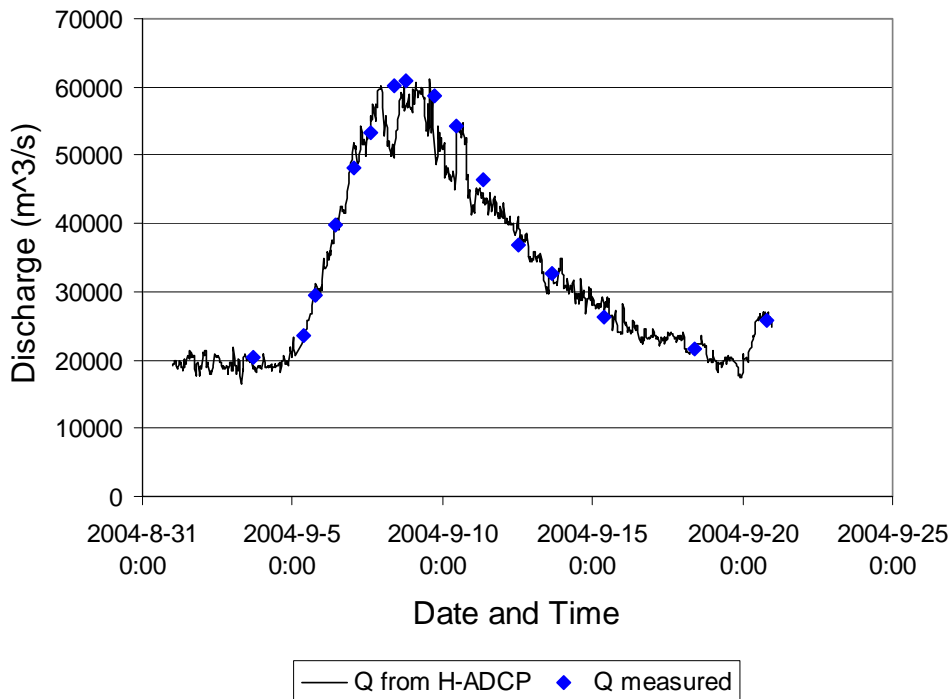


Figure 8 Real-time monitoring of the September 2004 flood in the Yangtze River reach at the Huangling Temple site using the H-ADCP based system (solid line). The dots are the measured discharges using either moving boat ADCP or current meter method

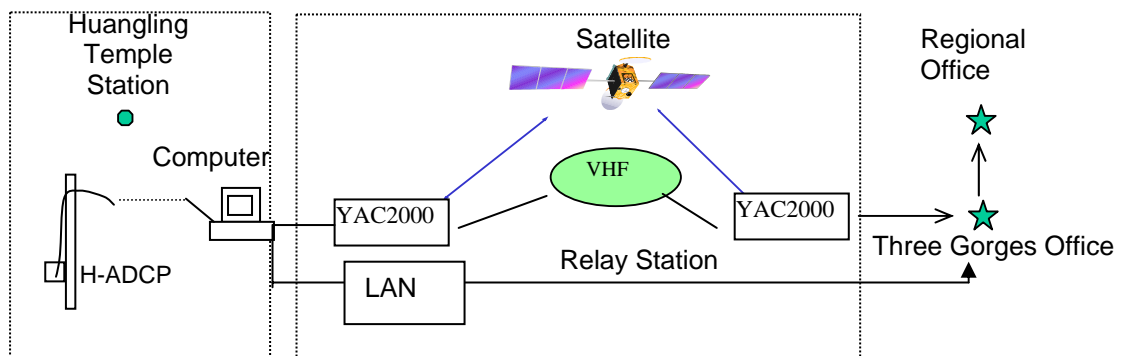


Figure 9 Diagram of a hydrological information network for flood monitoring in the Yangtze River region. The H-ADCP based system at the Huangling Temple site becomes part of the network.

CONCLUSION

The broadband acoustic Doppler technology, in conjunction with the index-velocity method, makes it possible for flood monitoring in difficult situations such as that in the Yangtze River reach at the Huangling Temple site. The success at the Huangling Temple site proved that the H-ADCP based system with the hydrological information network provides a total solution to the flood monitoring in the Yangtze River reach. The Huangling Temple site becomes a model that is followed by two other H-ADCP based flood monitoring systems established in the upstream reaches of the Yangtze River in 2006 and several more at other sites to be in operation in 2007.

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