Development of ultrasonic streamflow monitoring system using an existing low head broad-crested agricultural small dam

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In this study, we developed a system of continuous accurate monitoring of streamflow, which is composed of a pair of ultrasonic Doppler velocity sensors installed on an existing low head broad-crested agricultural small dam. In case of using this dam, errors in computing area are minimized due to stability of it, so that discharge can be accurately measured. In addition, by direct measurement of velocity over dam crest, this system can measure discharge not only for modular flow in which free fall occurs, but also for submerged flow affected by downstream as far as depth and velocity are measured. Preliminary results for 15 dam release events display that discharge obtained by this system is in quite good agreement with dam release and with H-Q relationship. Comparison of volumetric discharge is also made and relative difference with dam discharge is 2.7%.

Keywords: Agricultural small dam, ultrasonic, discharge measurement

1 INTRODUCTION

In this study, we developed a system of continuous accurate monitoring of streamflow. This system is composed of stable cross-section provided by small dam and direct measurement of water velocity passing the crest of the dam. Discharge measurement in the natural river section is affected by instability or fluctuation of bed. On the contrary, this system uses pre-existing or newly made concrete finished small dams which give much more accurate cross-section area than normal riverbed. Since up-looking ultrasonic sensors installed upon the crest of the dam provide accurate vertical velocity profile, mean velocity can be computed. Real-time monitoring of discharge is possible by this system [1].

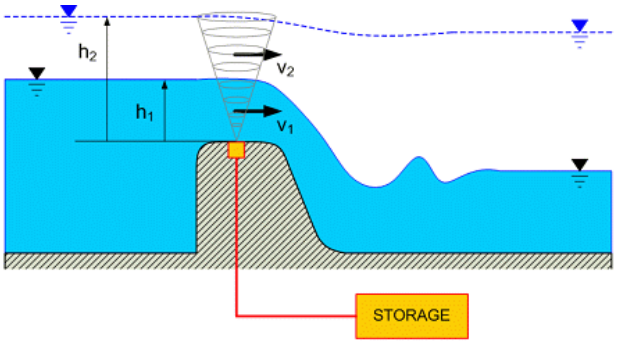

Figure 1: Conceptual view of the automatic velocity measurement system using the low-head broad-crested agricultural dam

2 OUTLINE OF THE SYSTEM

2.1 Composition of the system

The concept of the system is shown in Fig. 1. In the system, ultrasonic sensors installed upon the dam crest measure both water velocity and depth. With use of separate pressure level sensors, flood flows of depth up to 10 m may be measured. Fig. 2 shows an ultrasonic velocity sensor and a data logger (model Q-Eye PSC made by German company Hydrovision) used in this study. General specification of the system is given in Tab. 1.

Figure 2: Ultrasonic velocity sensor (Q-Eye PSC)

Table 1: General specification of the sensor

Item	Specification
Velocity measurement	Ultrasonic Pulse Doppler
Water level measurement	Ultrasonic method
Sensor Frequency	1.04MHz
Sensor surface material	Polyurethane, Teflon
Range (velocity)	-6 ~ 6m/s
Range(water depth)	0.04~1.5m(~10m, optional)

The system is composed of three elements as below.

① A couple of single-beam / single-direction pulse Doppler velocity sensor installed at 20 m and 70 m from the right edge of a 130 m wide Daesu-bo (including water level sensor)

② A central controller unit

③A field box (including data loggers, uninterrupted power supply, automatic recovery system, et.al.)

2.2 Installation of the system

This system is installed at the Dalcheon experiment river reach located near the center of South Korea. The experimental river is located near the center of Korea (South). It is about a 3.3 km long and stable cobble-bed river reach downstream of the Goesan dam. Catchment area of the reach is 675.2 ㎢ at the Goesan dam. The river reach is an typical cobble-bed stream and its mean width is about 120 m and its bed slope is about 0.0015. Flow regime of the experiment river reach is entirely controlled by upstream dam other than natural hydrological condition. The dam supplies so wide range of reference discharge up to 1,400 m^3/s during the rainy season that the inter-comparison of various kinds of discharge measurement methods is possible [2].

The ultrasonic measurement system is installed upon the Daesu-bo agricultural low-head broad-crested small dam located about 3 km downstream of the Goesan dam. Measured discharge by the system can be easily compared with existing stage (head)-discharge (H-Q) relationship exists. Properties of the Daesu-bo are shown in Tab. 2. Fig. 3 displays existing H-Q relationship [3].

Table 2: Properties of the Daesu-bo

Length	130m
Breadth of crest	1.5m
Type	Concrete type dam
Attachments	1 Fishway an 1 gate

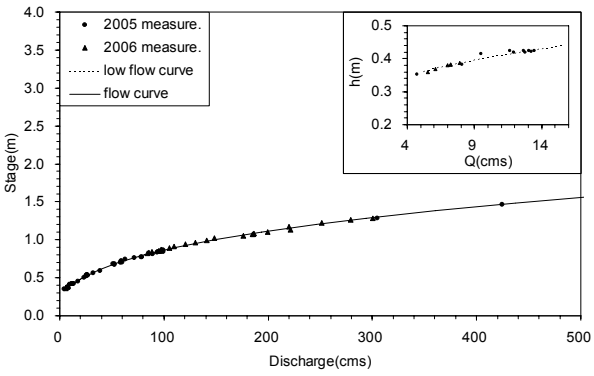

Figure 3: Existing H-Q relationship

Figure 4: Photo of the Daesu-bo viewing from downstream

Figure 5: Photo of the Daesu-bo viewing from upstream

3 RESULTS AND DISCUSSION

Using continuously recorded depth, velocity and discharge by the ultrasonic sensors, various analyses are conducted. At first, in order to test accuracy of depth and velocity measurement, comparison is performed with another water level and ultrasonic velocity meter. Inter-comparison of discharge is made with dam release, conventional velocity-area method and existing H-Q relationship. Since assessment of performance of the system is focused on discharge computation, resultant discharge values are mainly compared. Tab. 3 gives dam release events used for discharge comparison of preliminary test of this system.

Table 3: Dam release events for discharge comparison

Event No.	Dam release time	Peak discharge (㎥/s)
1	2007-12-11 09:00~11:00	16.2
2	2007-12-11 16:00~19:00	16.3
3	2007-12-12 16:00~20:00	17.0
4	2007-12-13 13:00~19:00	17.0
5	2007-12-14 09:00~12:00	17.3

6	2007-12-15 14:00~17:00	17.2
7	2007-12-16 16:00~18:00	17.0
8	2007-12-18 11:00~13:00	15.8
9	2007-12-20 16:00~20:00	16.5
10	2007-12-21 17:00~19:00	16.4
11	2007-12-24 09:00~11:00	15.9
12	2007-12-24 17:00~19:00	16.5
13	2007-12-26 17:00~19:00	15.6
14	2007-12-27 17:00~19:00	14.9
15	2007-12-28 17:00~19:00	15.6

3.1 Discharge comparison with dam release

For each dam release event, computed discharge by the Q-Eye system is compared with dam discharge. Lag time and peak discharge are also examined. Since the system is located about 3 km downstream of the dam along the river reach, arrival (lag) time occurs according to discharge.

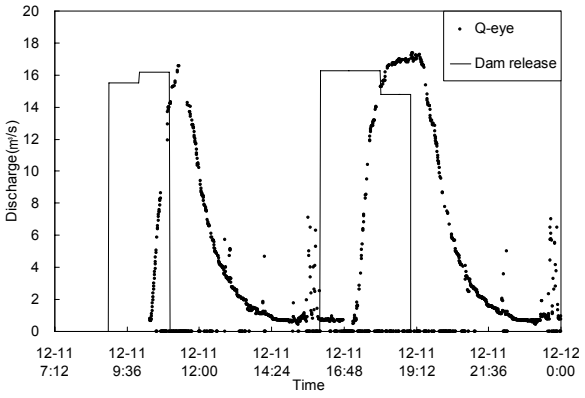

Figure 6: Comparison of discharge hydrograph by the dam and the system (Event 1, 2)

3.2 Discharge comparison with existing H-Q relationship

H-Q relationship upon the small dam is established based on its property as a control and discharge is calculated from the relationship. Consequently, loop phenomenon so hardly occurs that calculated discharge by it becomes more accurate than H-Q relationship of natural river section.

H-Q relationship is only available for free fall modular flow. But direct measurement of velocity over dam crest, this system can measure discharge not only for modular flow in which free fall occurs, but also for submerged flow affected by downstream as far as depth and velocity are measured.

3.3 Comparison of volumetric discharge

Discharge calculated by this system indicates fairly good agreement with dam release and H-Q relationship. In order to compare discharge by three methods more accurately, volumetric discharge for each release event is quantitatively evaluated. Since the Goesan dam releases water for hydroelectric power generation for several hours and then in turn stops release, it is possible to calculate volumetric discharge for specific periods. Fig. 8 and Tab. 4 show comparison of volumetric discharge for two event occurring from 9 AM Dec. 11th. to 12 PM Dec. 12th. in 2007.

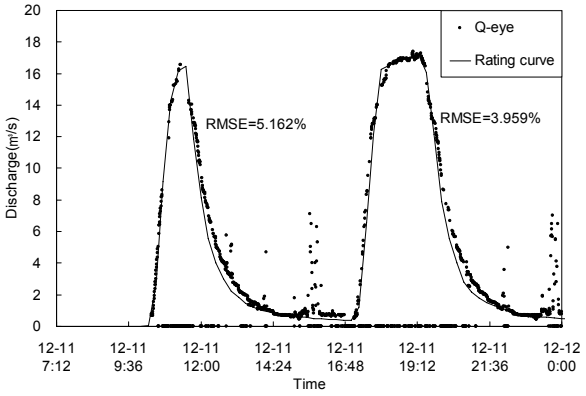

Figure 7: Comparison of discharge hydrograph by H-Q relationship and the system (Event 1, 2)

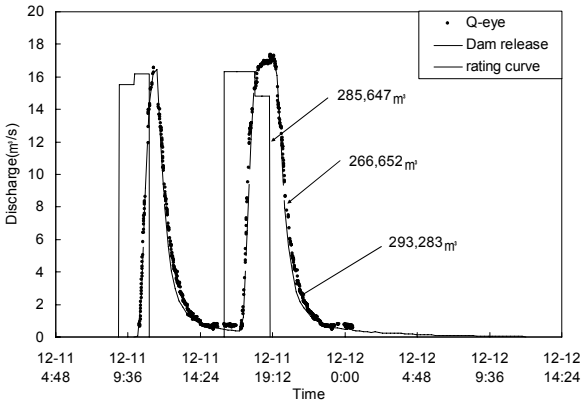

Figure 8: Comparison of volumetric discharge (Event 1, 2)

Table 4: Comparison of volumetric discharge (Event 1, 2)

Method	Volumetric discharge(㎥)	Relative difference (%)
Dam release	285,647	100.0
This system (Q-Eye)	293,283	102.7
H-Q relationship	266,652	93.3

4 CONCLUSIONS

This ultrasonic velocity measurement system is designed to measure wide range of discharge from low flow to high flood flow and it becomes possible by maintaining stable measurement section of dam crest and operating accurate velocity sensors. This system may also be applicable to open-channel sections of little bed change. Consequently, this system will be a practicable and economical method for measuring discharge at many other existing

agricultural small dam widespread in Korea. If the velocity sensor is installed beneath crest surface to reduce blanking distance, it is expected to measure low flow more accurately. Furthermore, if we can measure deep and fast flood flow with this system without any modification, it will be quite suitable solution for discharge monitoring. With a real-time data transfer system, real-time streamflow monitoring will be possible.

ACKNOWLEDGEMENT

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REFERENCES

[1] Seo, JW: Ultrasonic Doppler flowmeter for flowmeter for waste drainage system, Monthly Mag. in Auto. Con. Mea. (2007)
[2] Lee, CJ, Kim W, Kim CY, Kim DG: A comparative study on discharge measurement methods at a river downstream of a dam, Proc. HMEM2007 (2007)
[3] MOST of Korean Government: Final report for technology for surface water investigation (2007)