Field observation of the river flood flow and suspended sediment distribution using ADCP

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The authors conducted an Acoustic Doppler Current Profiler (ADCP) measurement with observing profiles of flow velocity and echo intensities during flooding with moving bed condition in actual a river. An observing system composed with a boat-mounted ADCP of 1200kHz, Real-Time-Kinematic Global Positioning System (RTK-GPS). Since the system synchronized ADCP to RTK-GPS, it is capable to measure the water flow velocity, the echo intensities and the bedload velocity during the moving bed condition. Mooring observation using ADCP mounted boat showed to repeat a periodically change of river bed height. It showed possibility of the river bed wave moving. Regarding to suspended sediments, the authors implemented the sonar equation with echo intensity correcting about the attenuation by the distance and absorption of the ultrasonic wave. Firstly, the velocity profile changes periodically according to the bed forms. Actually, the vertical velocity profile differ in large extent between upper and lower layer at the crest, but in the small extent at the trough. Secondary, regarding to movements of river bed, the bed load velocity was lower at the trough and it was faster at the crest. Thirdly, we observed that the suspended sediment also corresponded to the vertical velocity of water as well as the bed form.

Keywords: ADCP, Moving bed condition, Echo intensity, Bedload velocity, Suspended sediments

1 INTRODUCTION

River flow observation using ADCP (Acoustic Doppler Current Profiler) has been generally accepted in recent years.
Because ADCP measurement can obtain data in a short period of time with high resolution, it is effective observation technique for high runoffs.
Due to the recent studies, it has been tried to observe the river bed erosion using ADCP and GPS. [1], [2], [3], [4]
The authors conducted an Acoustic Doppler Current Profiler (ADCP) measurement with observing profiles of flow velocity and echo intensities during flooding with moving bed condition in actual a river.
Then, we implemented the sonar equation with correcting about the attenuation by the suspended sediment of the ultrasonic wave.
As a result, we tried to get a time series change about flow profile, erosion and sedimentation.

2 ADCP IN FIELD OBSERVATION

2.1 Field information

Figure 1 shows the gauging point. This is located in the Ishikari River in Hokkaido, Japan. It's total catchment area of 14300km^2. This gauging point located in the middle of the river, distance from the sea is 93.9km away.
Observations were carried out on September 17, 2013 during the flood situation. Figure 2 shows the hydrograph of this flood. The calculated discharge used by river management was provided from water level and measured discharge, and the maximum calculated discharge was 1700 m^3/sec. Our observation was done at the time of 1000 m^3/sec. As for the width of the river about 100m, the maximum depth of water is 6m.

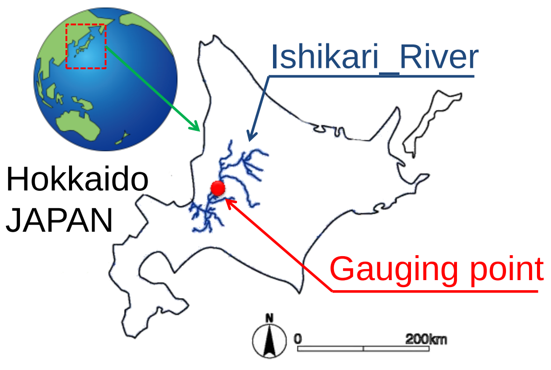

Figure 1: Gauging point

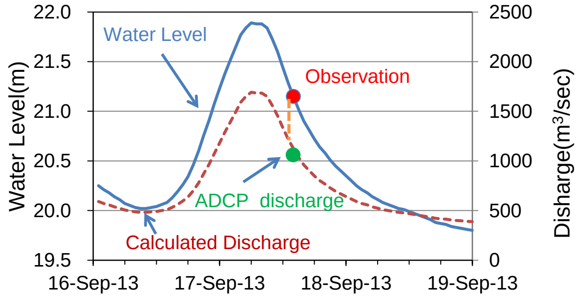

Figure 2: Hydrograph of the flood in Ishikari River

2.2 Measurement procedure and configuration

An observing system composed with a boat-mounted ADCP of 1200kHz: *Teledyne RD Instruments*, Real-Time-Kinematic Global Positioning System (RTK-GPS)): *JAVAD*.
Data Transporting is WIFI communication system: *Hydro system development, inc*. Remote operation is possible from a distant laptop-PC.
Since the system synchronized ADCP to RTK-GPS, it is capable to measure the water flow velocity, the echo intensities, depth, and observation during the moving bed condition.

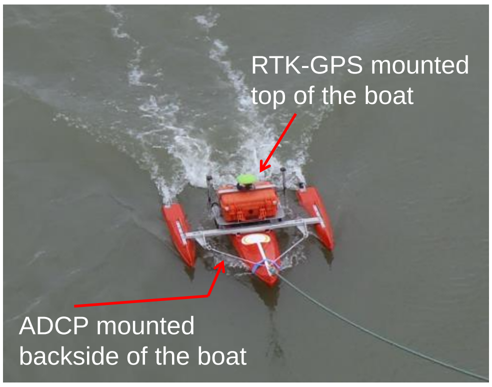

Figure 3: ADCP Boat system

2.3Moving bed measurement

The cross section velocity distribution shows Figure 4. At this time, ADCP discharge was 1059.31 m^3/sec. This result accorded with calculated discharge. In addition, central part of the river had the fastest velocity 2.8 m/sec. The boat mounted ADCP was fixed a rope to central part on the bridge during about 10minute. Figure 5 shows ADCP bottom tracking and RTK-GPS tracking during observation. The bottom tracking greatly changes toward downstream, and, as for the RTK-GPS, it was only a lateral little change. The boat could be connected by the rope, therefore, there was little movement of ADCP only in a horizontal direction. For the boat tracking, RTK-GPS tracking was probably right. When the bottom tracking captured the movement of the riverbed and deducted the movement of the boat with the RTK-GPS, We understand that we could calculate the movement speed of the riverbed. [2]

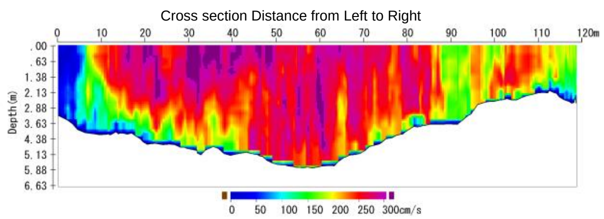

Figure 4 cross section velocity distribution

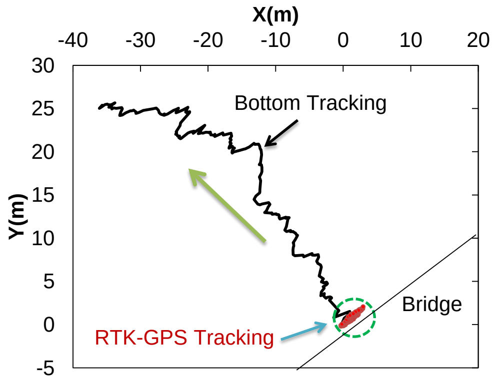

Figure 5: Bed moving observation

3 CALCULATED SUSPENDED SEDIMENT

ADCP is possible to measure the flow velocity and direction and to measure echo intensity of suspended sediments at the same time. It is known that echo intensity was proportional to the concentration of the suspended sediments.
Relationship of the echo intensity and the concentration of the suspended sediments is expressed by the sonar equation (eq.(1)).
In particular , calculation of the instrument coefficient K_c and backscatter coefficient S is not easy. Therefore, as shown in equation (2), Yokoyama et al [5] showed to summarize as variable *dB'* from echo intensity. Because the relationship between echo intensity and turbidity concentration was linear, we could calculate a primary correlation of *logC* and *dB'*. Then, we determined slope is S and intercept is K_s as Figure 6.

$$\log C = S(K_c I + 20\log r + 2\alpha r) + K_s \quad (1)$$

$$dB' = K_c I + 20\log r + 2\alpha r \quad (2)$$

Where S is the backscatter coefficient
K_c : the constant value from echo intensity to backscatter(at this time K_c=0.43)
I : echo intensity(count)
r : the distance to the transducer
α: acoustic reduce ratio on the water (at this time α is 2), K_s transducer coefficient

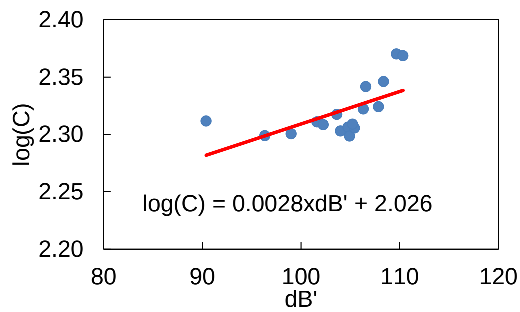

Figure 6: Relation Turbidity to Backscatter

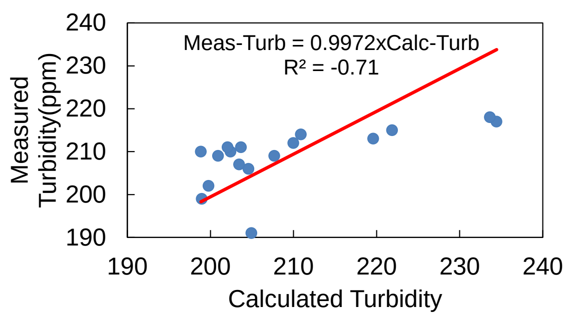

Figure 7: Measured and Calculated Turbidity

Comparing turbidity was observed at the measurement turbidity and calculated turbidity became one-to-one relationship as Figure 7.

4 MEASUREMENT RESULT

Figure 8 shows the time series measurement. The river bed height had a short term change at the time series. In addition, a long term change was seen in about 100 seconds every. This short period change was a possibility of the boat vibration, but, a long term change was a possibility that captured the movement of small-scale bed waves. The riverbed wave height was about 20cm between trough and crest.

The velocity vertical profile distribution repeated the strength and weakness periodically.

At the trough ① & ③, high flow velocity was distributed from surface to near the riverbed.

The suspended sediments tended to be higher concentration toward the lower layer. It was shown that suspended sediments distribution was related to the riverbed erosion. At the crest ②& ④, it was clear that lower layer velocity decreased

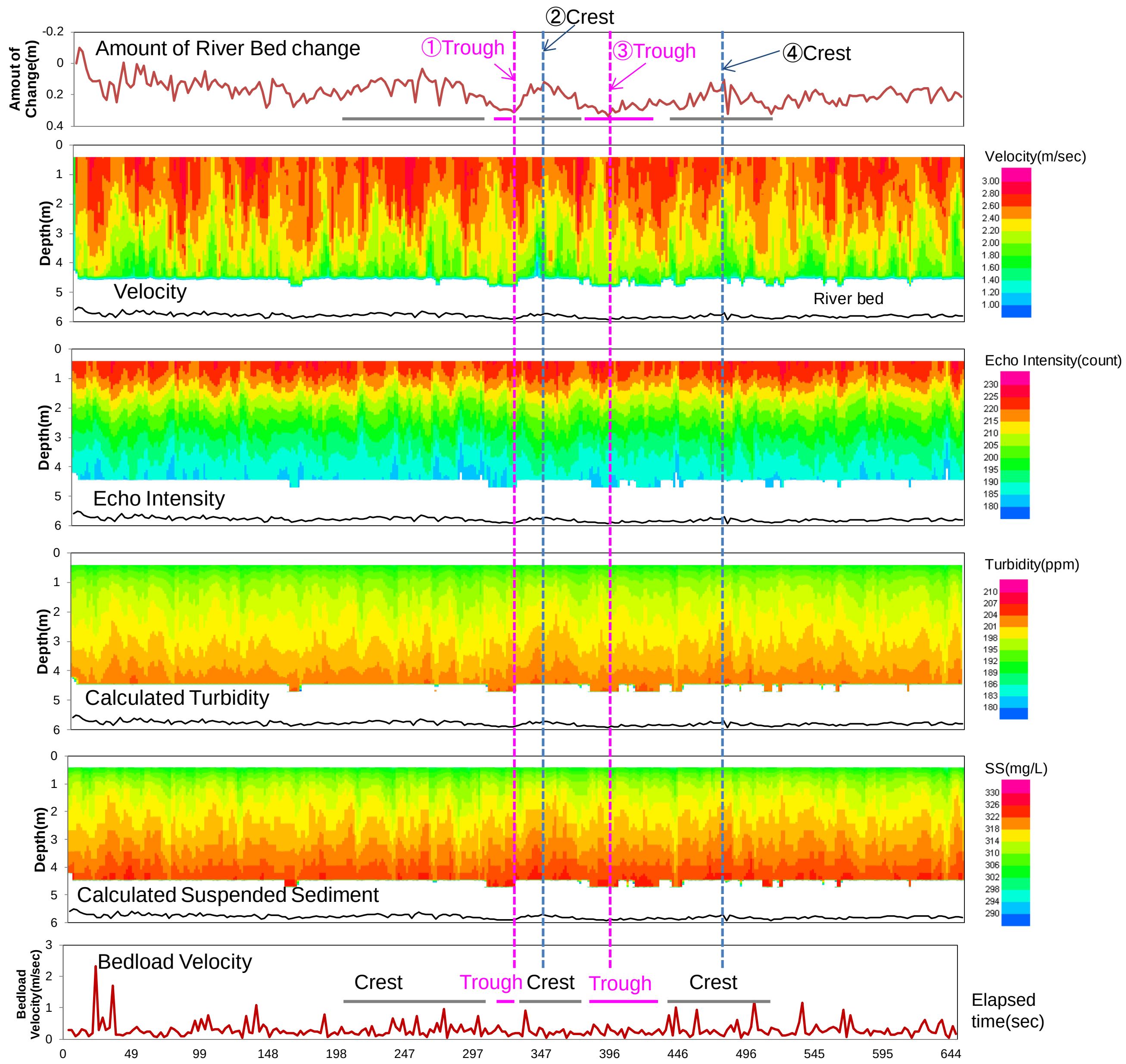

Figure 8: ADCP time series observation during flood

against upper layer velocity. But, the suspended sediments concentration was showed to roll up to the upper layer than at the trough.
And the bedload velocity which was obtained by ADCP and RTK-GPS [1], [2] were tended to show high value at the crest than trough.

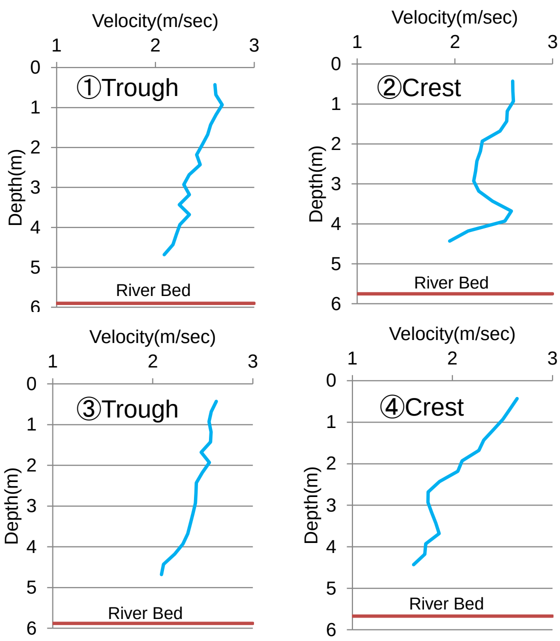

Figure 9: Velocity Vertical profile

At the crest ② & ④, velocity vertical profile showed characteristic shape as shown at Figure 9. Velocity vertical profile was faster about 1.5 m from riverbed than close upper layer. This phenomenon was seemed to be related to the change of riverbed roughness. At the trough ①& ③, velocity vertical profile was not characteristic but tended to be upstanding.

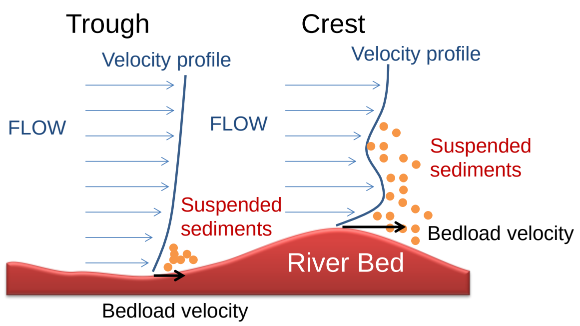

Figure 10: Estimation of flood phenomena

5 DISCUSSION

As shown at Figure 10, firstly, because of velocity profile was upstanding tendency at the trough, it was considered that suspended sediments were flow down near the river bed without rolled up. At the crest, It seemed to show the phenomena which riverbed sediments were rolling up by separation vortex generated at the crest behind. Secondary, it was considered to possibility that bedload velocity which was caused to move the riverbed sediments at the crest was higher than at the trough. This result was the same tendency as Yorozuya et al. [4]

6 CONCLUSIONS

1) Mooring observation using ADCP mounted boat showed to repeat a periodically change of river bed height. It showed possibility of the river bed wave moving.
2) We could show that the characteristic velocity vertical profile changes according to the river bed form of trough and crest during the riverbed moving.
3) Suspended sediments was higher concentration in the lower than the upper. At the crest, suspended sediments showed to roll up to the upper layer than the trough. It was suggested the difference of velocity vertical profile shape would cause to bedload velocity or sediment moving. We could show the possibility of the suspended sediment monitoring during moving bed condition at the flood.

7 ACKNOWLEDGEMENT

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