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Detailed observation of water level variation at the mouth of Natori River, Japan

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Abstract

In the present study, detailed measurement of water level variation is carried at the Natori River mouth in Miyagi Prefecture, Japan to find quantitative relationship between water level variation and river mouth morphology. For this purpose, the water level is measured with the interval of one minute, whereas conventional measurement system obtains data every one hour in general. It is observed that the water level inside and outside the river mouth shows distinct difference after the formation of sand spit at the river entrance, although the difference is not so remarkable after complete flushing of the spit during a flood.

1 Introduction

Water level variation in a river is commonly measured every one hour in general. Since the time-variation water level in a river is not so rapid except a period of flood, the measurement interval of one hour might be enough for practical purposes. Even during a flood, one-hour interval is normally sufficient for detecting the shape of hydrograph. At a river mouth also, it is recommended to obtain water level data every one hour [1]. It is noted, however, that there exist different time scale at a river mouth, characterized by tidal motion. Therefore, it might be plausible to assume that there might be a measurement interval of water level which should be specially used in a river entrance, being different from one used in upper or middle reach in a river system.

One of the authors has shown that the water level variation in a river mouth can be used for estimating river mouth morphology (Tanaka and Ito [2]). Thus, it is supposed that the water level measurement is more detailed, the information of river mouth morphology detected from the water level data will

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also be more. In this study, a field measurement of water level variation is carried at the Natori River mouth in Miyagi Prefecture, Japan to find quantitative relationship between water level variation and river mouth morphology.

2 Study area and field observation

A map of the study area is shown in Fig.1. The catchment area of the Natori River basin is 938.9km^2, with the length of 55.0km. A numerical model for the river mouth topography change during a flood has already been developed by one of the authors (Tanaka et al. [3]). The present study deals with water level variation and river mouth morphology under predominant tidal motion with smaller amount of fresh water discharge.

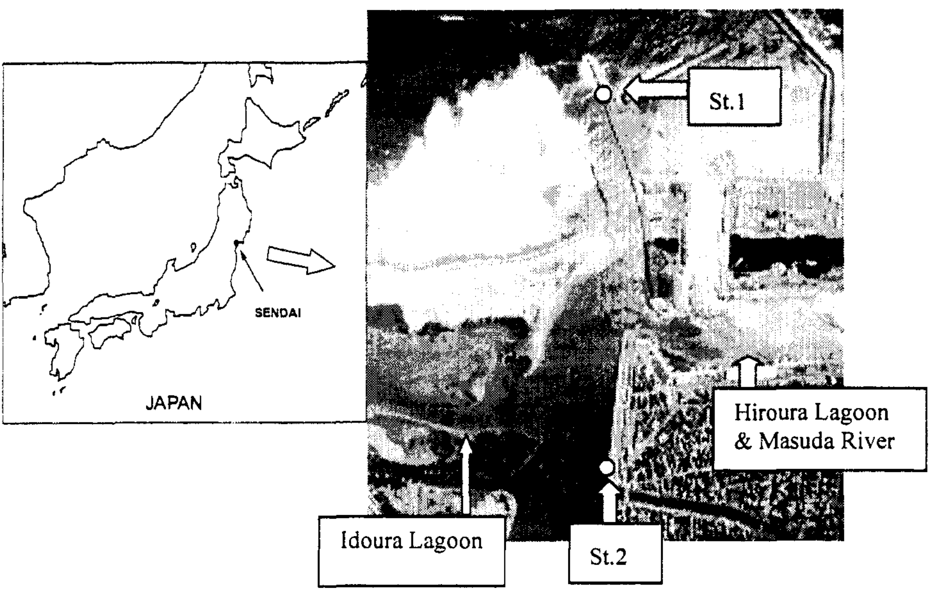

Fig.1 Map and aerial photograph of the Natori River mouth

The water level variation is measured at St.1 and St.2 shown in Fig.1. St.1 is located at the tip of the jetty on the right hand side (see Photo 1(a)), whereas St.2 is in the river mouth, about 940m upstream from St.1 (Photo 1(b)). In the next section, the difference of the water level at St.1 and St.2 will be discussed to correlate it with river mouth morphology. The interval of the data acquisition is 1 min, much smaller than conventional one such as 1 hr.

Measurement has been carried out three time from the beginning of 2002, as given in Table 1. Before No.1 measurement, there was a big sand bar between two jetties as seen in Photo 2(a). Due to a flood occurred between No.1 and No.2

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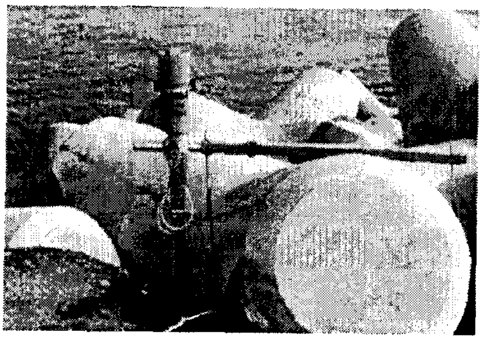
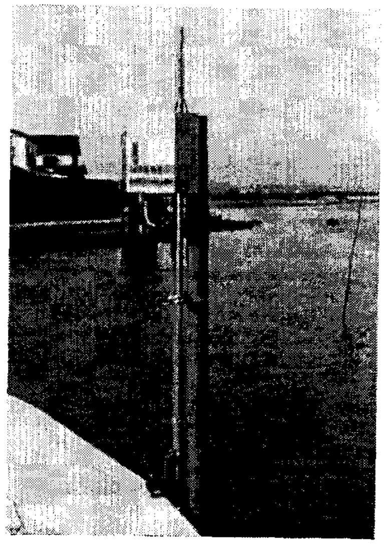
measurements, the sand bar was completely flushed away as illustrated in Photo 2(b). Difference of fluctuation characteristics in water level in each measurement will be discussed in connection with morphological change.



(a)St.1



(b)St.2

Photo 1 Water level measuring stations

Table 1 Periods of measurements

Meas. No.	Period	Remark
No.1	13:00 Jan. 14, 2002 □10:08 Jan. 18, 2002	A flood occurred between these two measurements (between No.1 and No.2)
No.2	13:00 Jan. 31, 2002 □10:05 Feb. 8, 2002	
No.3	10:00 Feb. 15, 2002 □10:08 Mar. 1, 2002	

Photo 2 Aerial photographs at the river mouth (a) January 7, 2002

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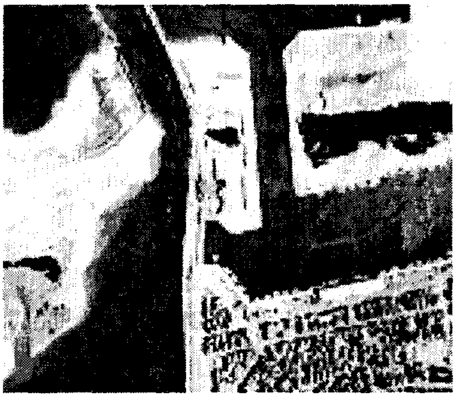

(b) March 1, 2002

3 Results and discussions

3.1 Water level variation

The whole of the data sets are plotted in Fig.2 It is seen that the phase shift is more predominant in the data No.1, as compared with other data sets. In order to investigate more detailed correlation of water level between St.1 and St.2, Fig.3 is plotted to show more straightforward relationship between these two measuring stations. It is noted that it shows a loop in Fig.3(a) indicating phase difference, while they are changing almost simultaneously in Fig.3(b) and a loop can again be observed in Fig.3(c).

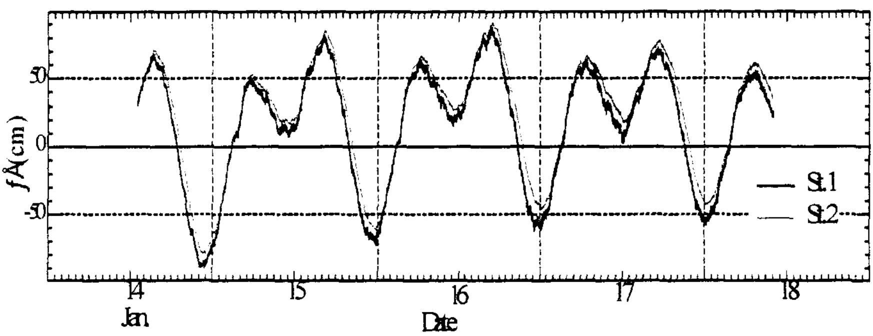

Fig.2 Measured water level variation (a) Meas. No.1

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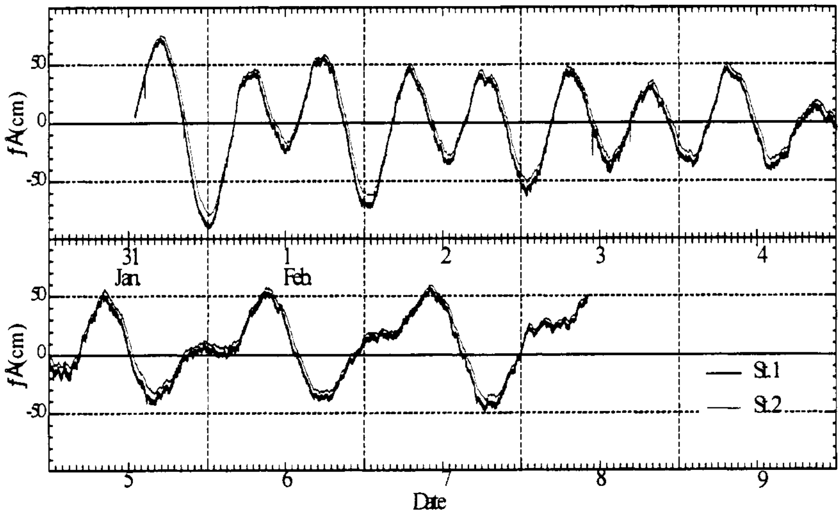

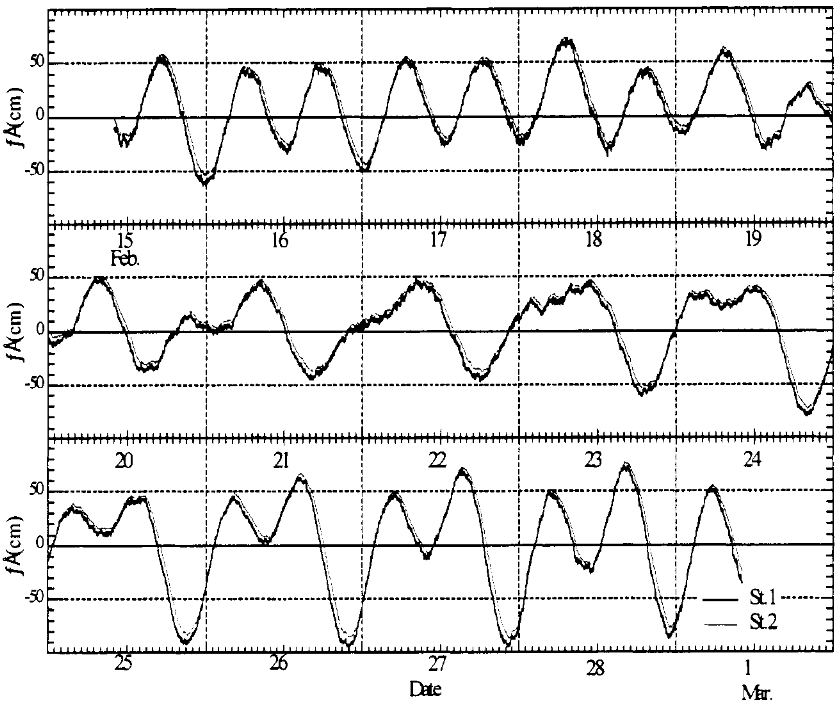

Figure 2(b) Meas. No.2
(c) Meas. No.3

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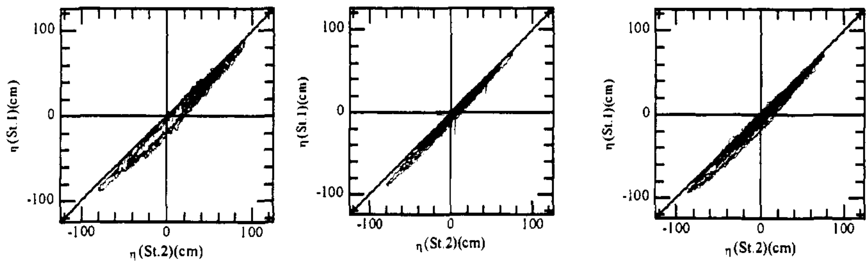
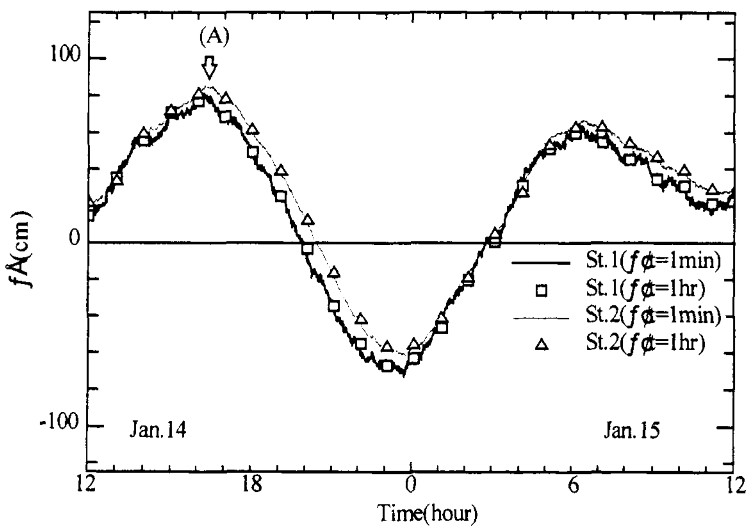


(a) Meas. No.1 (b) Meas No.2 Meas No.3

Fig.3 Correlation of water level at St.1 and St.2

3.2 Effect of measuring interval

In order to evaluate effectiveness of the present measurement method with the interval of 1min., comparison is made with the hourly data. As seen in Fig.4, the overall temporal variation is of course almost identical. However, it can be concluded that detailed behavior of water level fluctuation can not be detected by the conventional measurement with $\Delta t = 1hr$, such as the periods denoted by (A) and (B). In the former period, the peak of the water level cannot well be measured, whereas the abrupt change cannot be obtained during the latter.



(a)

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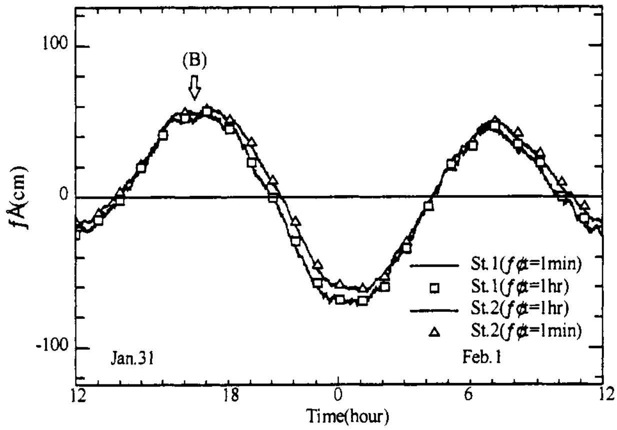
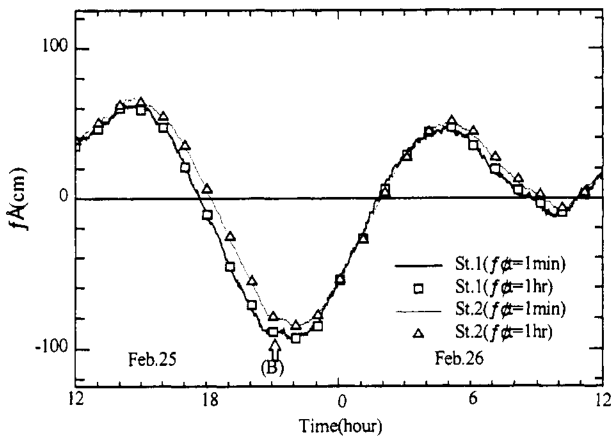


(b)



(c)

Fig.4 (continued) Effect of measurement interval

3.3 Relationship between correlation coefficient and river mouth morphology

In order to find more quantitative relationship of the water level variation at St.1 and St.2, correlation coefficient *R* is calculated for each measurement as shown in Table 2. Immediately after the flood, i.e., during the measurement No.2, the correlation coefficient shows maximum, and smaller values are obtained during No.1 and No.3.

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Table 2 Correlation coefficient of water level at ST.1 and St.2

Meas. No.	Correlation Coefficient (R)
No.1	0.9924
No.2	0.9968
No.3	0.9932

In order to investigate more detailed change in water level variation at the river mouth, correlation coefficient is calculated for individual days. The result is shown in Fig.4 for each measuring period. Although it shows daily variation, it can be confirmed that it has lowest value during the measurement No.1. The overall variation during the period No.2 is showing relatively higher value, indicating the resistance at the throat section was smaller during this period. The correlation during No.3 is showing slight decrease as compared with No.2 measurement, indicating sediment deposit at the river entrance caused by predominant tidal current.

It is noted in Figs.5(b) and 5(c) that the correlation coefficient is higher when diurnal tide is predominant, due to more gradual variation of water level as compared with semi-diurnal tide. This phenomenon has already been explained theoretically by several researchers using a simple one-dimensional model for an inlet-bay system, such as Mehta and Özsoy [4]. Thus, the correlation coefficient is influenced by not only river mouth morphology, but also tidal stage. However, it will be promising to correlate river mouth morphology with correlation coefficient R between water level variations inside and outside a river entrance.

In general, cost for field surveying of river mouth morphology is more expensive as compared with that for water level measurement. Thus, an estimation of river mouth morphology from water level data will be beneficial for compensating insufficient field observation regarding cross section at a river entrance. Further investigations are required to correlate R and river mouth morphology quantitatively.

4 Conclusions

Water level variation at the Natori River mouth, Japan is measured every one minute since December 2001. Immediately after a flood that caused sufficient flushing of sediment at the river mouth, the water level in the mouth was almost identical with that in the sea, denoting negligible energy loss at the throat section, whereas they show considerable difference especially during low tide when sand bar is formed in between the river mouth jetties. This result indicates that the river mouth morphology can be estimated from measured water level fluctuation.

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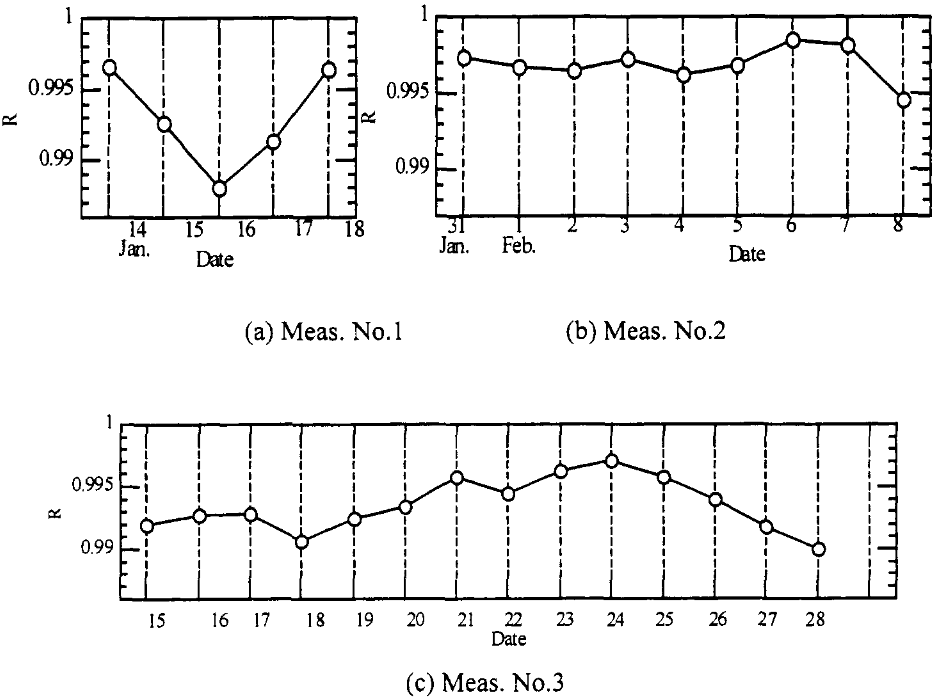

Fig.5 Correlation coefficient of water level at St.1 and St.2

Acknowledgments

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References

[1] Ministry of Construction: *Guideline for River Mouth Improvement*, 168p, 1975. (in Japanese)

[2] Tanaka, H. and Ito, T.: An estimation method of gorge section at a small river mouth. *Coastal Engineering in Japan*, **39(1)**, pp.27-38, 1996.

[3] Tanaka, H., Kuwahara, N., Sato, K. and Shuto, N.: Field application of a numerical model for river mouth topography change, *Computer Modelling of Seas and Coastal Regions III*, ed. C.A. Brebbia, Computational Mechanics Publications: Southampton and Boston, pp.151-160, 1997.

Paper from: *Coastal Environment*, CA Brebbia (Editor).
ISBN 1-85312-921-6

[4] Mehta, A. J. and Özsoy, E.: Inlet Hydraulics, *Stability of Tidal Inlets*, ed. P. Bruun, Elsevier Scientific Publishing Company: Amsterdam, pp.83-108, 1978.