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Morphological changes at the Nanakita River mouth after the Great East Japan Tsunami of 2011

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ABSTRACT

This study investigates the morphological changes near the Nanakita River mouth in Japan. The morphology of the river mouth was greatly influenced during the Great East Japan Tsunami of 2011. The gradual morphological changes at the river mouth were investigated using two sets of data, of which, one was the continuous water level measurement data in the river entrance and in the sea, and the other being the intermittent aerial-photographs. The statistical parameters, viz., the correlation coefficient and the linear gradient between the two water level data, were analyzed, which formed as the basic for understanding the behavior of the river mouth, like river mouth closure or opening detected by the analysis of the water level variation. The proposed method is found efficient and effective in the evaluation of the morphological changes near a river mouth.

1. Introduction

The 2011 Tohoku Earthquake triggered a huge tsunami wave on 11 March 2011 as high as 40 m in Iwate Prefecture, Japan (Mori et al., 2012), resulting in the tremendous casualties as well as the structural damages along the coast, which are reported by Suppasri et al. (2012). In addition, it has resulted in a massive morphological change along the sandy coast of the Sendai Plain (Tanaka et al., 2012; Tappin et al., 2012; Udo et al., 2012). Adityawan et al. (2012) detail the tsunami propagation process over land and the tsunami intrusion into rivers in Sendai Plain. According to Tanaka et al. (2012), breaching of coastal barriers is one of the typical features of tsunami-induced morphological changes along the Sendai Coast. The breaching caused devastating damages to the lagoon area along the coast. Besides being a natural environment, the lagoon area on the Sendai Coast has additional importance for breeding of the juvenile fish within the area (Malloy et al., 1996; Omori et al., 1976; Yamashita et al., 2000). For example, Yamashita et al. (2000) indicated that estuaries on the Sendai Coast play a significant role as nursery grounds for stone flounder, producing about half of the stock in spite of the small and restricted area compared to a wide expanse of the exposed inshore area.

The Gamo Lagoon is one of the lagoons on the Sendai Coast that was severely affected by the tsunami. The lagoon is located on the left side of the Nanakita River mouth. The lagoon and the river mouth experienced various morphological changes during the post-tsunami period. These changes include the reformation of the sand barrier, the complete closure of the river mouth, the reformation of the river mouth in the lagoon, and an artificial straightening of the river mouth. Tanaka et al. (2012) reported the morphological changes during the period after the tsunami until the river mouth closure, whereas the present paper focuses mainly on the morphological changes after the river mouth blockage. Aerial-photographs as well as the water level data were used to monitor the morphological changes at the river mouth. The results showed that the water level data are highly effective for a detailed assessment of the morphological changes at the river mouth.

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2. Study site and methodology

The rivers in Japan are classified into Class A and Class B depending on their dimension as well as their social importance. The former belongs to the national government, while the latter belongs to the prefectural government. The study area is the Nanakita River classified as Class B that flows through the Sendai City in the Miyagi Prefecture located in the north-east of Japan as shown in Fig. 1. The length and catchment area of the river are 229 km^2 and 45 km, respectively. The flood discharge of a 100-year return period is 1650 m^3/s and the average river discharge is about 10 m^3/s. Aerial-photos around the Nanakita River mouth have been being continuously taken at one or two-month interval for monitoring the morphological changes after the Great East Japan Tsunami of 2011 (Tanaka et al., 2012).

Fig. 1. Study area.

The Nanakita River mouth is located at the coast of Sendai City. The coast is a sandy beach and stretches about 12 km from Sendai Port at the north until Natori River at the south. It has northward littoral sediment movement due to predominant wave direction from ESE to SE (Tanaka and Takahashi, 1995). Pradjoko and Tanaka (2010) analyzed a series of aerial photograph using Empirical Orthogonal Function (EOF). They concluded that the shoreline dynamics were affected by the seasonal changes with the south of the river mouth being more stable. The shoreline at the north side of the river mouth was more dynamic since it is bounded by the breakwater near the Sendai Port (Ritphring and Tanaka, 2007).

Gamo Lagoon is located at the north of the river mouth. This lagoon is separated from the sea by a sand barrier. Wave overtopping occasionally occurs and brought sediment deposits into the lagoon as reported by Tanaka and Suntoyo (2002). However, the sand barrier was never completely flushed as it was due to the tsunami of 2011, which is described later in this study.

The locations of the water level measurement stations G2, X1, and Yuriage, and availability of the data, are shown in Fig. 2 and Table 1 respectively. Unfortunately, tidal measurement station at the Sendai Port was damaged by the tsunami. In this study, the water level data at Yuriage Station in the Natori River mouth, at approximately 10 km from the Nanakita River mouth, is regarded as the sea tide. The Natori River mouth has no obstruction such as elongated sand spit, and it connects directly to the sea through the training jetties, which allows the tidal level to propagate into the river without significant changes (Tanaka et al., 2000). A comparison of the water level at Sendai Port and the measurement at the Yuriage station as shown in Fig. 3 is found to be good.

The Nanakita River mouth and the Natori River mouth are connected to each other by the Teizan Canal as also shown in Fig. 2. Although the two rivers are connected, a lock gate separated them as can be seen in Figs. 2 and 4(a). Tanaka and Shuto (1992) made a detail measurement of the water level and the velocity at the Nanakita River mouth. At the time of the study, the lock gate was kept partially opened. Thus, a part of the river discharge was diverted into the Teizan Canal. Moreover, the wave set-up caused the water level in the Nanakita River mouth to rise higher than that in the Natori River, resulting in a unidirectional flow along the Teizan Canal to the Natori River. For this reason, sediment flushing at the river entrance was not effective. In addition, the residual tidal flow may cause sediment deposits in the river mouth. Because of which, the river mouth blockage at the Nanakita River occurred frequently until the 1990s (Tanaka et al., 1996). The blockage was significantly reduced after the full closure of the lock gate.

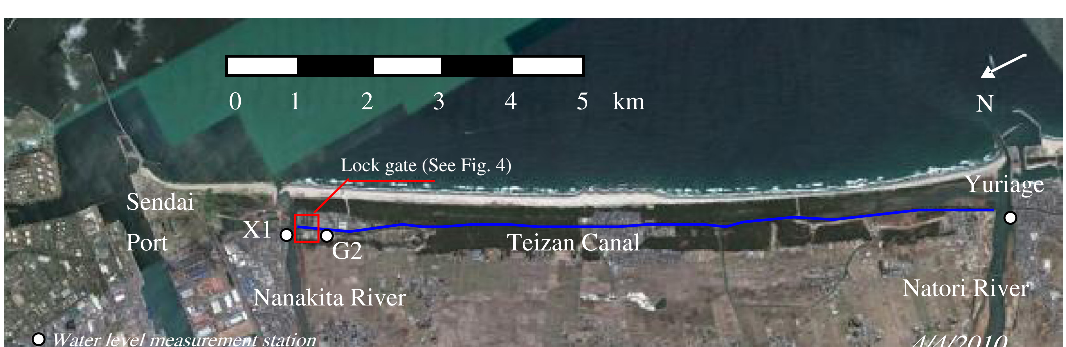

Fig. 2. The Nanakita River mouth geographical feature and water level observation position (Google Earth).