INVESTIGATION OF SHORELINE CHANGE TRENDS AROUND THE NANAKITA RIVERMOUTH USING AERIAL PHOTOGRAPH

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ABSTRACT

The shoreline is dynamic feature in the coastal area. It always changes in respond to natural forces. As a border between land and sea, the stable shoreline is more preferable due to a lot utilization of coastal area. This study attempts to analyze the shoreline change trends around the Nanakita River mouth by utilizing the aerial photograph which has been taken regularly in that area. The results show that the shoreline around the Nanakita River mouth is moving dynamically during the time with maximum-minimum range is about 70 m and standard deviation is about ± 14 m. The shoreline change trends was retreat from 1990~1999, change to advance in 2000~2005 and back to retreat again in 2006~2009. The left side has bigger changes than the right side due to the effect of port breakwater. Additionally, the shoreline around the Nanakita River mouth is considered in condition "dynamic stable".

1. INTRODUCTION

The shoreline is the border between land and sea. The shoreline is influenced by natural process such as wave, tide and current which exist in sea area. The shoreline responds those processes by moving advance to the sea or retreat to the land. However, the stable shoreline is more preferable due to a lot utilization of coastal area as human living, various kind facility, and environmental preservation. Therefore, the study of shoreline change is important for managing the utilization of coastal area.

This study attempt to investigate the shoreline condition around river mouth specially at the Nanakita River Mouth. The Nanakita River is located at Sendai City in Miyagi Prefecture Japan. The length of river is 45 km and the basin area is 229.1 km2. Flood discharge of 100-years return period is 1,650 m3/s and typical river discharge is 10 m3/s. The Nanakita river mouth is located at east side of Japan Coast, facing to the Pacific Ocean. Tidal range at Sendai Coast is about 1.5 m at spring tides and most prevailing incoming wave is from south-east direction. These wave conditions generate longshore current and sediment transport from south to north direction for overall coast. The location of study can be seen in Figure 1.

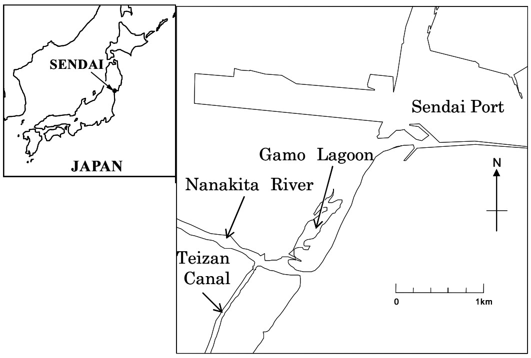

Figure 1: *Study area*

In the late of 1960's, there was construction of Sendai Port at 2 km north of the Nanakita river mouth. Large port basin had been excavated and almost 2 km long breakwater had been built. This huge structure had given a large impact on the surrounding coastal area (Tanaka and Srivihok, 2004). Since then the attention to shoreline around the Nanakita River mouth has increased and it is supported by the existence of Gamo Lagoon behind the shoreline. In terms of environmental reason, the lagoon is very important place for resting of migration bird. Moreover, the area behind this shoreline is highly utilized. There are human living area, agriculture, and waste water treatment facility. According to planning plan of Sendai Port Authority, there will be development of port facility to south ward close to the Nanakita River mouth by reclamation in

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the future. Therefore, the investigation of shoreline behavior around this river mouth is very important in order to anticipate the future changes.

2. DATA COLLECTION

The aerial photograph is one kind of remote sensing data which taken by airplane and special camera. The utilization of aerial photograph in shoreline change analysis has been used by a lot of researches. The general explanation about shoreline mapping techniques by using aerial photograph can be found in Moore (2000). The study utilizes image data from aerial photograph which have taken regularly in the study area. The aerial photograph has been taken every two months since 1990 until 2009. In order to analyze by using aerial photograph, firstly the image should be rectified, detect and delineate the shoreline. Then, the shoreline is measured from baseline and corrected with tide data for getting same datum level for all images. The detail process is explained below :

Image Rectifying

Aerial photograph of Sendai Coast has 1 : 8,000 scale in print format 9 x 9 inches. The aerial photograph should be scanned by machine to make it become digital format. The scanning resolution will influence the accuracy of image digitizing. The high resolution will increase the accuracy of digitizing. However, the resolution quality should in balance with the file size. The image is scanned in 400 dpi (dot per inch) resolutions. That resolution will give :

9 inches x 400 dpi = 3,600 pixels so 1 pixel = 0.0025 inch = 0.0064 cm

Photo has 1 : 8,000 scale, therefore in reality :

1 pixel = 0.0064 x 8,000 = 51.2 cm = 0.512 meter.

So the scanned result of photograph in 400 dpi give resolution 1 pixel = 0.51 meter and it save in JPEG file type due to make small file size.

The images data have many variant and discrepancies both in temporal and spatial. The digital images have pixels system which it will give little difficulties when measuring the shoreline. Therefore it needs rectification process to conform to another coordinate system, conform to each other images and get accurate result (Anonim, 2005). The rectification process in this study conform the image to the local coordinate system in Japan (JGD2000/Japan Plane Rectangular CS X). This local coordinate system is expressed in meter distance, such as UTM system, so the extracting data will be more easy and accurate. The rectification process use 10 Ground Control Points (GCP) from Japan Map and give total RMS error about 12 pixels x 0.51 m = 6.12 meter. At last the rectified image has Japan local coordinate system and the beach line oriented around 212^0 clockwise from North.

Shoreline Detection and Delineation

The method of shoreline detection and its reliability has been discussed in many papers (Camfield and Morang 1996, Boak and Turner 2005). The shoreline delineation around the Nanakita River mouth was being processed by automatic delineation using BeachTools extension in GIS program from CIRP Project of US Army Coastal Engineering Center. The tool also can generate the baseline and transect for measuring shoreline position automatically. It can remove the tedium and subjectivity of extracting data by hand and allowing for much greater precision of such measurement (Hoeke et al., 2001). An example of shoreline delineation by this tool is shown in Figure 2(a) below.

Then the image is corrected toward tidal and wave setup phenomena for getting same water level. But only tidal correction had been made in every image, since the error caused by wave set-up is much smaller than the one caused by tidal level. All shoreline in image was being corrected to the same level i.e. mean water level at Tokyo Port (TP-0 m level). The tidal correction use data from tidal measuring station at Sendai Port and Ayukawa Port. According to these data, the tidal level at the time image can be determined. So the correction value was got by using calculation from tidal data and average beach slope (i.e. 0.11) from Kurosawa and Tanaka (2001).

Total shoreline length which analyze in this study is 1,600 m. Cross section or transect had been set up with 20 m interval. Every cross section is approximately perpendicular to the shoreline. The generation of baseline, cross section and measuring the distance between baseline and shoreline had done by the tool automatically. Figure 2(b) show the position of baseline and cross section.

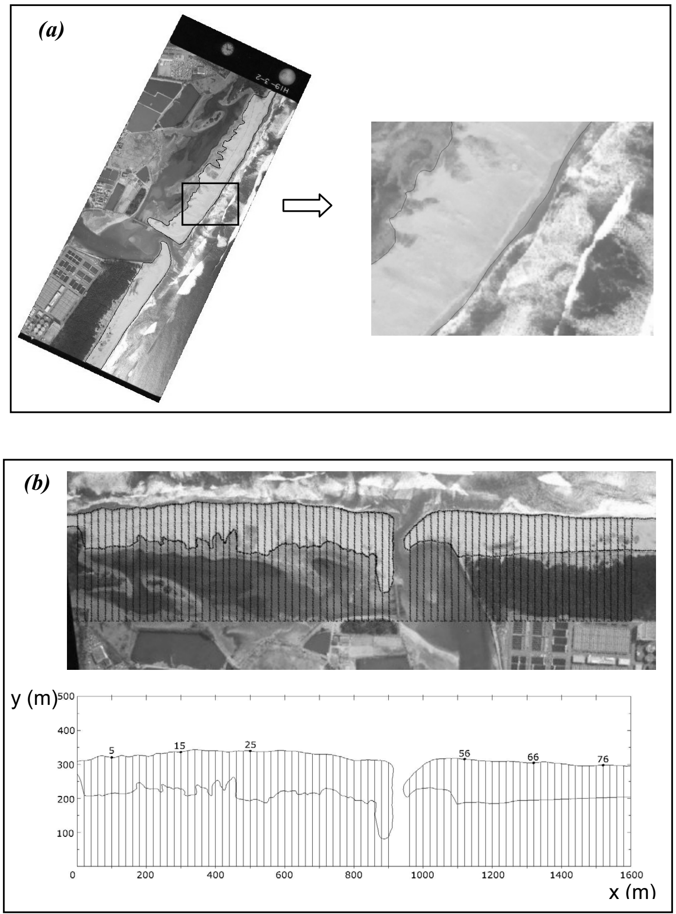

Figure 2: *(a) Shoreline delineation, (b) Baseline and cross section position*

3. RESULTS AND DISCUSSIONS

In order to analyze shoreline change in spatial term, it calculate the mean of shoreline position ($\overline{y}$) and standard deviation (σ) in every section as follows :

$$\overline{y}(x) = \frac{1}{n}\sum_{t=1}^{n} y(x,t) \qquad (1)$$

$$\sigma(x) = \sqrt{\frac{\sum (y-\overline{y})^2}{n-1}} \qquad (2)$$

where y denotes the position of shoreline at distance x and time t. Figure 3 shows the results of statistical analysis on left and right side of river mouth. The shoreline is seen to be retreat if it refers to shoreline position on May 1990 and September 2009. Fortunately due to a lot of data, the behavior of shoreline change can be examined carefully during 19 years. Both on left and right side, the mean position show steady line alongshore. The mean position is more advance near river mouth due to the effect of blockage from river discharge flow.

The maximum and minimum (max-min) position on left side also show same trend line with the mean line. On right side there is some variation in max-min position near river mouth. It is caused by the movement of river mouth path which ever strongly deviate to the right. The range of max-min position is about 70 m on both sides.

The standard deviation of left side is 14.5 m and right side is 13.5 m on average. The left side has bigger movement than right side. It means the left side get more external force (i.e. wave force) than right side which is due to wave reflection from port breakwater. The magnitude of σ value (+14 m ~ -14 m) is about ½ of the range of max-min position. This condition implies that the shoreline move dynamically within the range during the time.

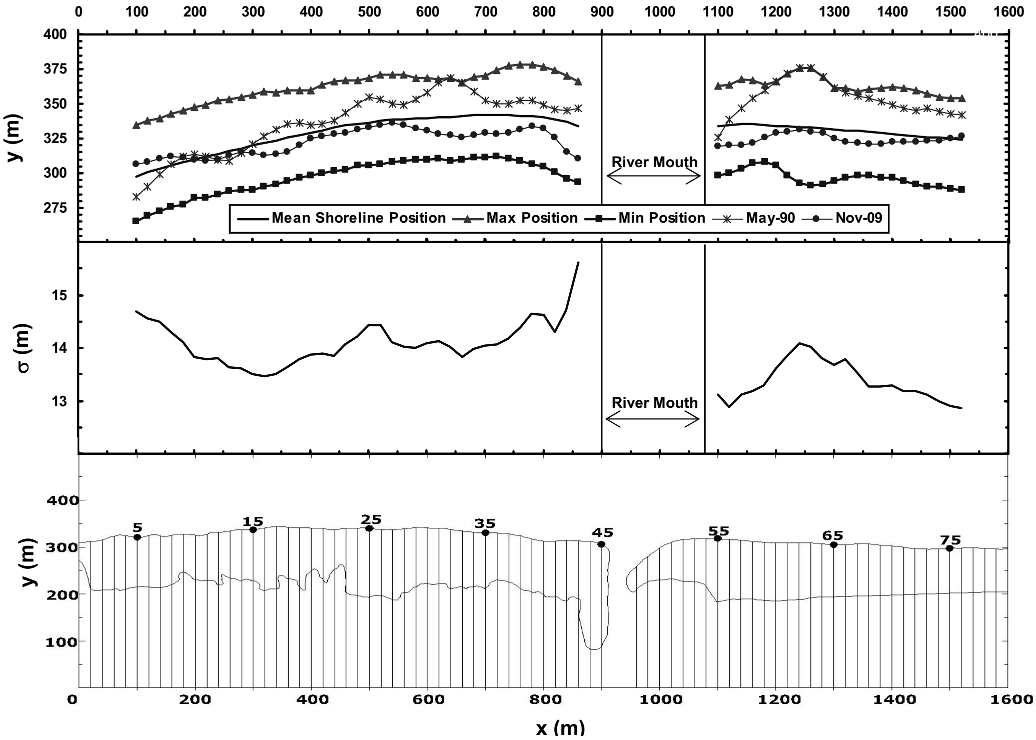

Figure 3: *Max-min position, mean position, and standard deviation*

In temporal term, the position movement of some shoreline section can be seen in Figure 4. All side show seasonal fluctuation every year. The shoreline was moving dynamically in respond to seasonal condition. In long term, the left side also show changing trend of movement. The trend of movement go down from 1990 until 1999, change to up from 2000~2005 and go down again from 2006~2009. The right side also show same trend but with less magnitude. The changing trend on right side will be more clearly seen from calculation of change rate in those periods. Some zero or small data on sections very near with river mouth are due to influence of river mouth movement. And the zero data on beginning and last sections are due to the limitation of image.

The change rate calculation will show the trend of movement, i.e. advance or retreat. The change rate (*a*) is calculated by linear regression from relationship as follows :

$$y(x,t) = a(x)t + b(x) \tag{3}$$

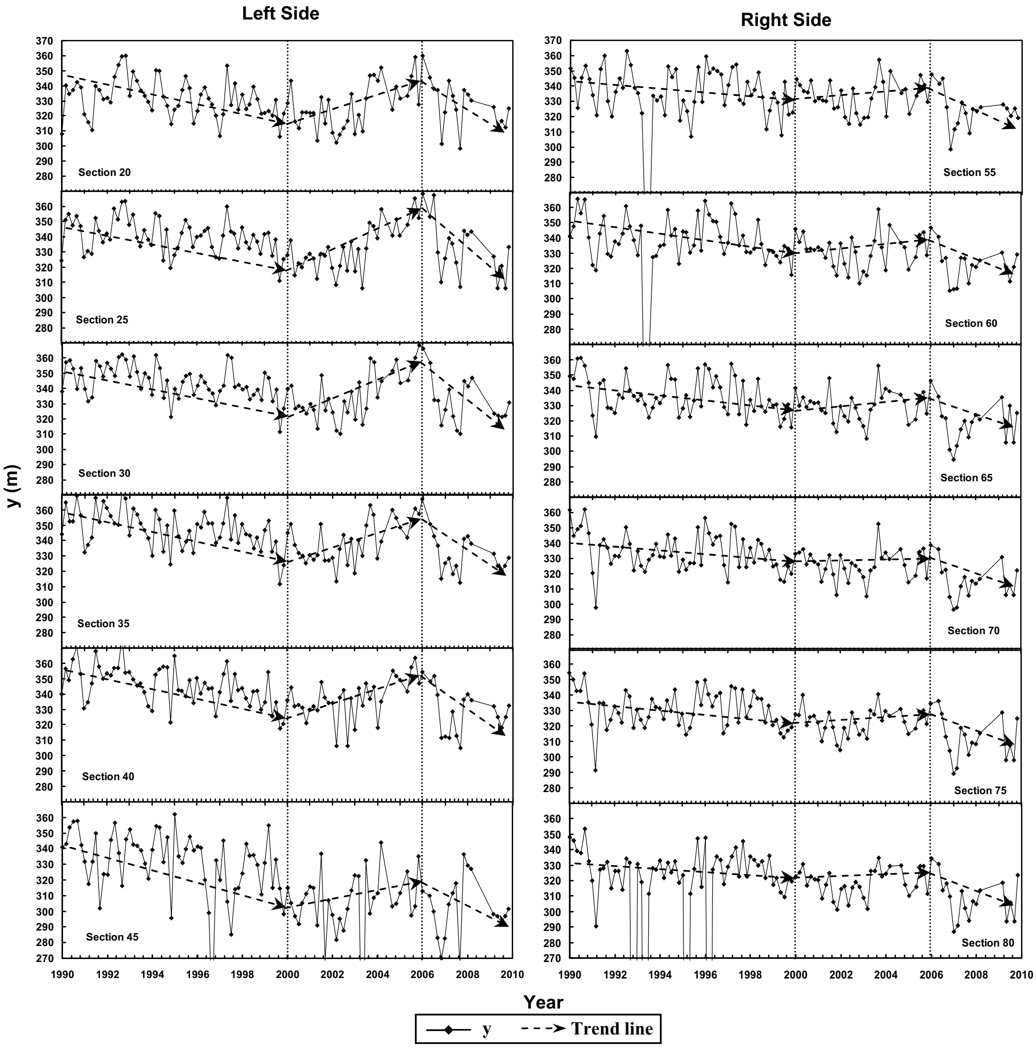

Figure 4: *Movement of shoreline position from 1990~2009*

The change rate is calculated in 3 different periods, i.e. 1990~1999, 2000~2005 and 2006~2009. Figure 5 shows the left side retreat during 1990~1999, change to advance in 2000~2005 and retreat again in 2006~2009. The right side show same trend but with smaller magnitude as mentioned before. The changing trend of movement reflect to the condition of longshore sediment transport which influenced by river mouth. River mouth might act like jetty which interrupt the longshore sediment transport by means of flow pattern or sand terrace forming in front of river mouth. The different magnitude between left and right side also depicts that the left side get more wave force than right side as effect of the port breakwater.

Moreover, there is no indication of net significant advance or retreat movement in this area. This situation depicts the decreasing function of river mouth as sediment supplier to the beach. The shoreline is moving advance or retreat in respond to wave action with little sediment supply from river mouth as main source component in that area. In addition, there is no exist significance sink component which can decrease the sediment. Therefore, the condition of shoreline around the Nanakita River mouth can be said in “dynamic stable”.

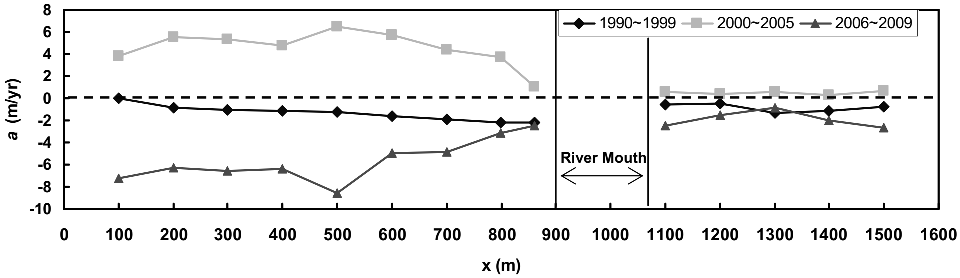

Figure 5: *Trend of shoreline change*

4. CONCLUSIONS

In general, the conclusions are follow :

- The utilization of aerial photograph in shoreline change analysis has presented. The frequent taken images have given comprehensive results for understanding the shoreline behavior in that area.
- In general the shoreline around the Nanakita River mouth is moving dynamically during the time with constant maximum-minimum range (about 70 m) and standard deviation (about ± 14 m).
- The trend of shoreline change was fluctuated in long term. The trend was retreat from 1990~1999, change to advance in 2000~2005 and back to retreat again in 2006~2009.
- The left side has different behavior with right side as effect of port breakwater.
- The condition of shoreline around the Nanakita River mouth is in "dynamic stable".

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