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ANALYSIS OF RIVER MOUTH BEHAVIOR CHANGE BY USING AERIAL PHOTOGRAPHS

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The morphology change of the Nanakita River mouth is monitored by the utilization of aerial photographs colleted since 1990 to 2002. The method for detecting land and water area in the photos is investigated by the application of image analysis in order to reduce time consuming for manual digitization. From the color information in the aerial photo, hue and lightness are appropriately used to detect land and water area. The criterion can be acquired by normal distribution function. The photo analysis results show that the Nanakita River mouth behavior trends to stabilize and has less development of the left sand bar in the recent years. In this study, the influence from seaside is examined. Breaking of wave is calculated from the wave ray model then longshore sediment transport near the river mouth can be computed from CERC formula. The computed results show the decreasing of longshore sediment transport corresponding to the river mouth behavior. For this reason changing of longshore sediment is supposed to be one of the significant factors for stabilization and diminishing of left sand bar in the recent year.

Key Words: *river mouth morphology, Nanakita River, image analysis, longshore sediment transport*

1. INTRODUCTION

River mouth morphology change has a significant impact to an estuary where freshwater from river flow and saline water coming across. Generally, estuaries are essential for the survival of many species such as fish, bird and shellfish. Besides, the wetlands that fringe many estuaries also perform other valuable functions to protect the land from storm and flood damages, and as water draining from the uplands carries sediments, nutrients and other pollutants when the water flows through fresh and salt marshes, much of the sediments and pollutants are filtered out. Moreover, it is inevitable to do the study of estuaries in order to support the public infrastructure, serving as harbors and ports vital for shipping, transportation, and industry.

In the present study, the river mouth morphology change is focused. Generally, the history of a river mouth demonstrates a continuous change in its geometry by the width of the channel, its configuration and the cross-sectional area. The traditional approach to attain this information is to carry out continuous field observation. However, this method consumes a lot of time and human works as well as being impractical to cover a large area. Therefore, aerial photograph is an alternative and economical means for studying the evolution of river mouth geomorphology. Conventionally, the analysis of aerial photographs is carried out by the manual digitization for tracing the river mouth feature (plan view). Nevertheless, it is not suitable for analysis a large number of photos. In this study, the image analysis based on color information in the photographs is selected and applied to determine the river mouth features. The purposes of the study are to be able to describe the designation of the waterline used for representing of river mouth feature by mathematical expression, to evaluate the change pattern of the Nanakita River mouth morphology and the factor affecting to the change in the last decade. The available aerial photographs since 1990 to 2001 taken every one or two months are examined.

2. STUDY AREA

The Nanakita River originates at the northern part of Sendai City in Miyagi Prefecture and pours into the Sendai Bay as seen in **Fig.1**. The catchment area and the length of this river are 229 km^2 and 45 km respectively. Tidal range at the Nanakita River estuary is about 1.5 m at spring tide, while the flood discharge of the 100-year return period is 1,650 m^3/s and the typically river discharge is 10 m^3/s. There is a jetty on the left-hand side of the river mouth, which limits the migration of the mouth to

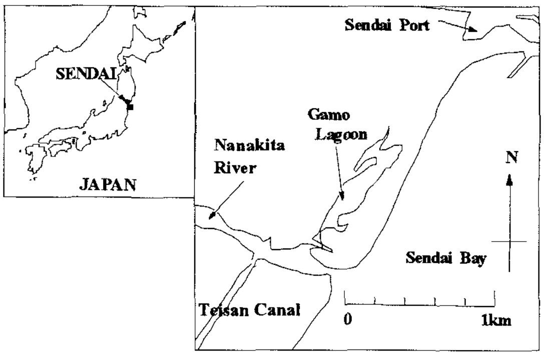

Fig.1 Location of the Nanakita River mouth

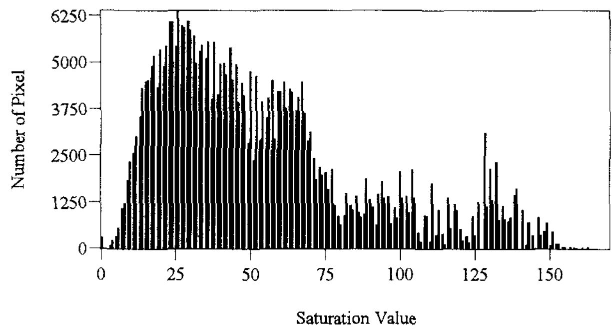

Fig.2 Histogram of saturation value for the Nanakita River mouth photo on 10 Jul 00

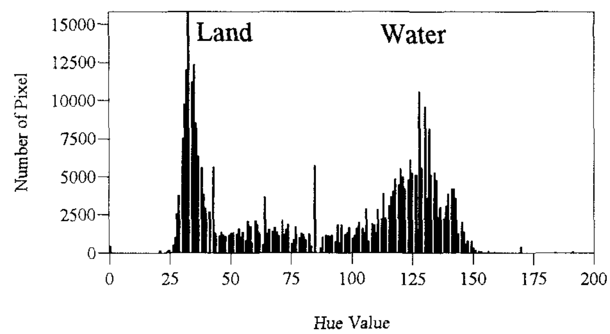

Fig.3 Histogram of hue value for the Nanakita River mouth photo on 10 Jul 00

the north direction, whereas the movement in the south is not limited. During winter season, the river mouth often closes due to small river discharge. The complete closures of the river mouth were observed in 1988 and 1994. According to the remarkable river mouth topographical changes, it effects flooding problems, salinity intrusion in the low land area and the environment in the Gamo Lagoon, an area well known for wild birds, the Teisan Canal and many precious historic waterfront area.

3. METHODOLOGY OF WATERLINE DETERMINATION BY IMAGE ANALYSIS

Color information in the aerial photograph of the Nanakita River mouth is used to identify the waterline similar to the previous study, which determined waterline by using ARGUS video image for monitoring intertidal beach morphodynamics by Aarninkhof and Roelvink[1] and discrimination of the waterline of video image shorelines and nearshore processes by Alport et al.[2] Generally, an image pixel stores its color information in channels. The channels can be defined as the "RGB" color space, in which pixel color is the composition of red, green and blue. However, in this study, pixel color is analyzed based on the use of the "HSL" color space, in which pixel color is defined as the mixture of hue or color, saturation and lightness value because the "HSL" color space is more intuitive approach and corresponds to human perception of color. The three components are measured on a scale from 0 to 255. Hue distinguishes the various colors such as green and blue. The hues are arranged around the color wheel and assigned values from 0-255. At the top is red at 0 and then moving counter-clockwise, (yellow = 43), (green = 85), (cyan = 128), (blue =170) and (magenta =212). Saturation is the strength of a hue, or the amount of grey it contains. A vivid color usually has a high saturation level and contains less grey. As the saturation decreases, the amount of grey increases and the color becomes less vivid. Lightness or luminance means the perception of amount or intensity of light. A lightness value of 0 on the scale is total darkness, or black. A value of 255 on the scale is total lightness. By following the HSL color space; hue, saturation and lightness composition contributes the specific value for water and land area. The demarcation criterion will be used for detecting land and water area and tracing the waterline following the checking of the color information of all pixels in the photo. At the beginning stage of analysis, according to the discrepancy in scale and location of each photograph, the aerial photographs are rectified by linear transformation equation and resampled by nearest neighbor method to standardize and select the area of interest in the photos. After that, the rectified images are separated to "HSL" channels. Then histogram of each channel, hue, saturation and lightness, which are shown in **Fig.2** to **Fig.4**, can be plotted. It can be investigated that hue and lightness values obviously divide into two groups and effectively indicate the water and land pixel. The land pixel is located in the low range of hue value and high range of lightness value and vice versa for water pixel.

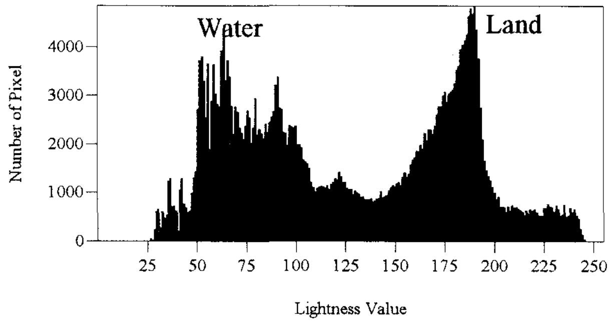

Fig.4 Histogram of lightness value for the Nanakita River mouth photo on 10 Jul 00

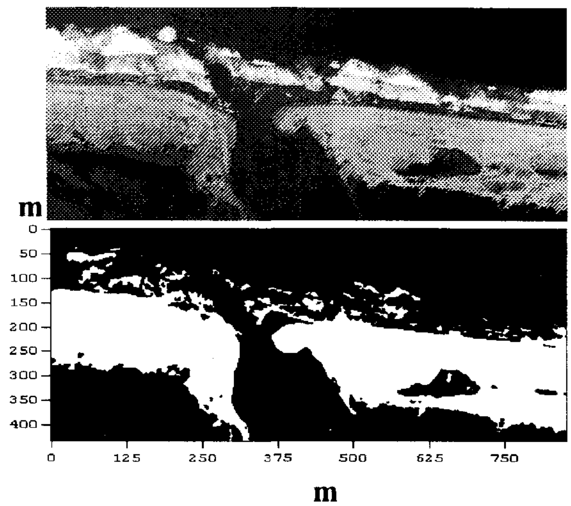

Fig.5 Results of middle point criterion on 10 Jul 00

The first trial method to determine a discrimination criterion for separating land and water pixel clusters in the photo is the middle point of land and water groups in hue and lightness histograms. However, the results are not satisfactory because the wave breaking is often included in the land area due to its white color.When the color of wave breaking is examined, it is located in the medium range of the hue histogram and high range of the lightness histogram as shows in **Fig 6.** Therefore, the appropriated criterion has been selected thoroughly to avoid error from wave breaking.

In order to find the proper discrimination criterion and prevent error from wave breaking, the criterion is evaluated by color information of land area group. The land and water pixel groups in the hue and lightness histograms are assumed to be normal distribution. Normal distribution function $f(x)$ is shown in Eq.(1).

$$f(x) = \frac{1}{\sqrt{2\pi}\,\sigma} e^{-(x-\mu)^2/2\sigma^2} \qquad (1)$$

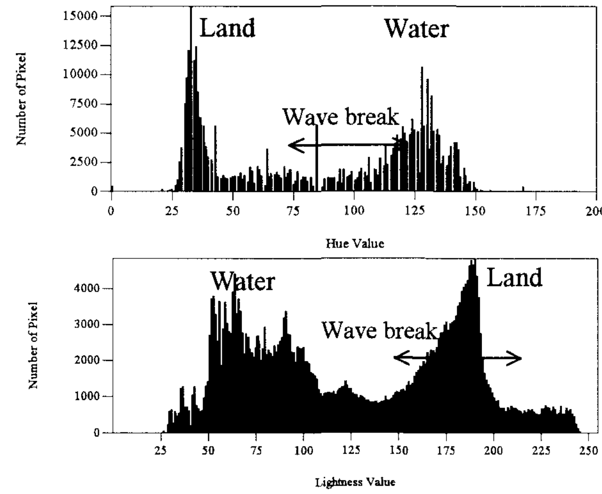

Fig.6 Location of wave breaking pixel in hue and lightness histogram

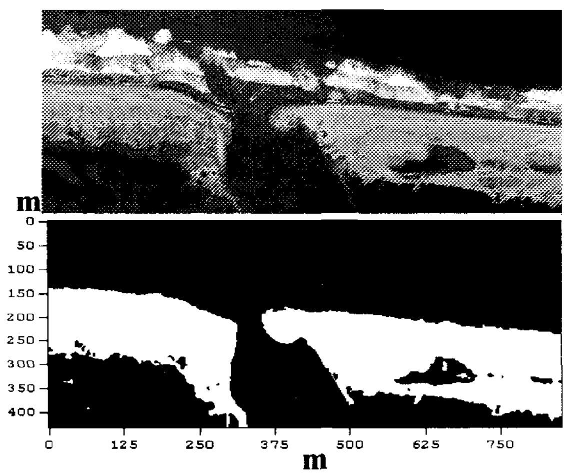

Fig.7 Results of normal distribution criterion on 10 Jul 00

when μ is the mean value and σ is the standard deviation. The upper limit of land area in the hue histogram and lower limit of land area in lightness histogram are defined as the land-water demarcation criterion. The position calculated from normal distribution function is located at 3σ or at the 5.5 % of maximum gradient. By applying this method, the wave breaking can be exclued from the land area as a consequence of the waterline resonable tracing.

4. MONITORING OF RIVER MOUTH MORPHOLOGY CHANGE

Once the land and water area of the river mouth can be extracted from the aerial photographs, the river mouth morphological change can be assessed.

In this study, the yearly river mouth behavior will be considered. However, the photos had been taken every month from 1990-1993 and every two

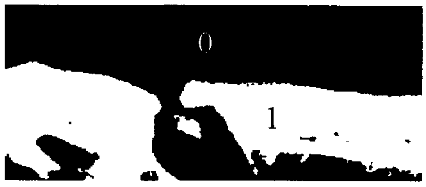

Fig.8 Assigned value a of land and water area

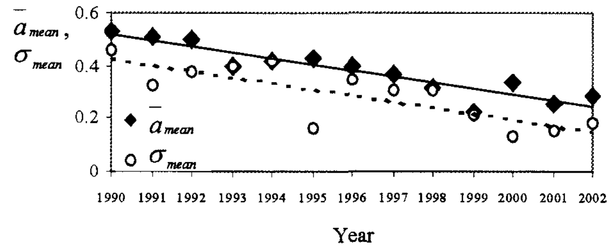

Fig.10 Average and standard deviation of land area for the river mouth opening

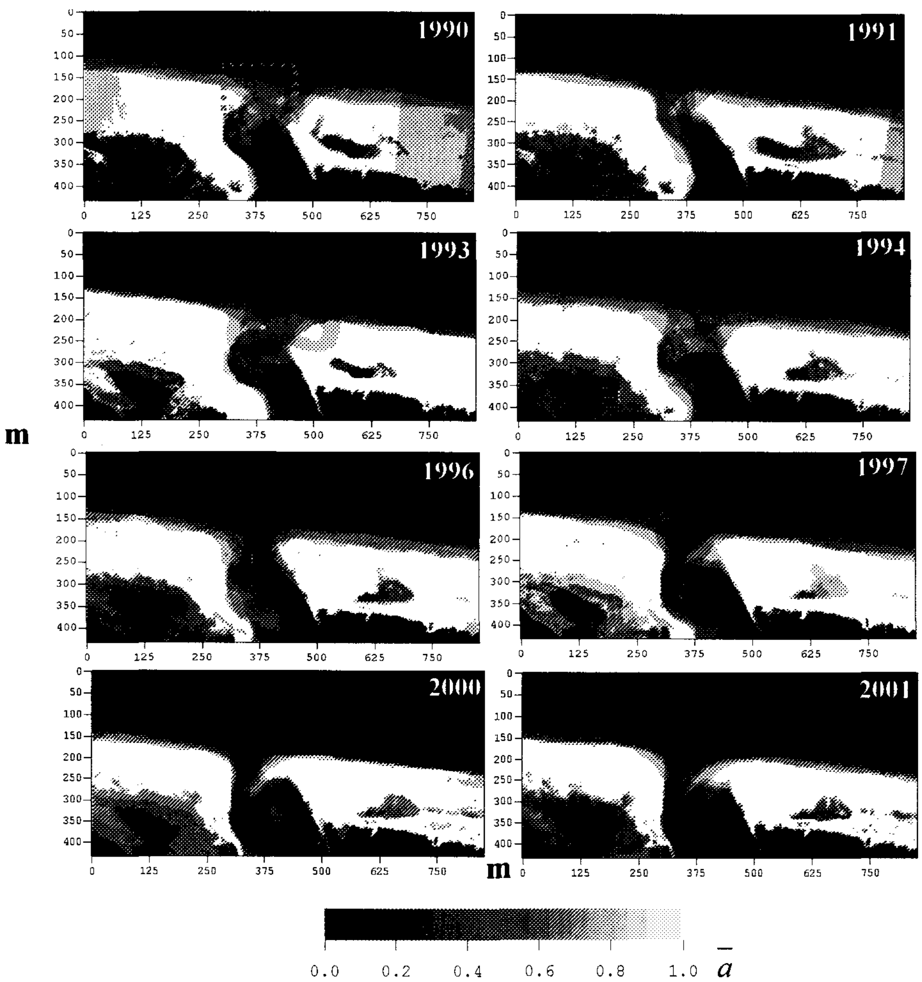

Fig.9 Yearly morphological change of the Nanakita River mouth from 1990-2001

months, which are odd number from 1994-2002. Hence, the photos in January, March, May, July, September and November are considered to keep the same number of photos for each year. The change of the river mouth is presented by the average probability of land area at the river mouth within one year to neglect the effect of seasonal change and compared with another year. The land area is assigned $a = 1.0$ when water area is assigned $a = 0.0$ as shown in **Fig.8**. Every pixel in each year **(Fig.9)** is calculated $\bar{a}$ from averaging 6 photos with value either 0.0 or 1.0 in that pixel for each month. The yearly analysis results are shown in **Fig.9** and the results show that the river mouth behavior has been more stable from the past to recent year. In 1990-1995, the sand bar developed from both sides, right and left, within a year whereas, in 1996-2002, the results show the decreasing development of left sand bar. Moreover, the area of interest supposed to be river mouth opening is established at the river mouth as shown by dotted frame and the average value of probability of land area at the river mouth opening ($\bar{a}_{mean}$) is calculated together with standard deviation (σ_{mean}). The results are plotted in **Fig.10**.

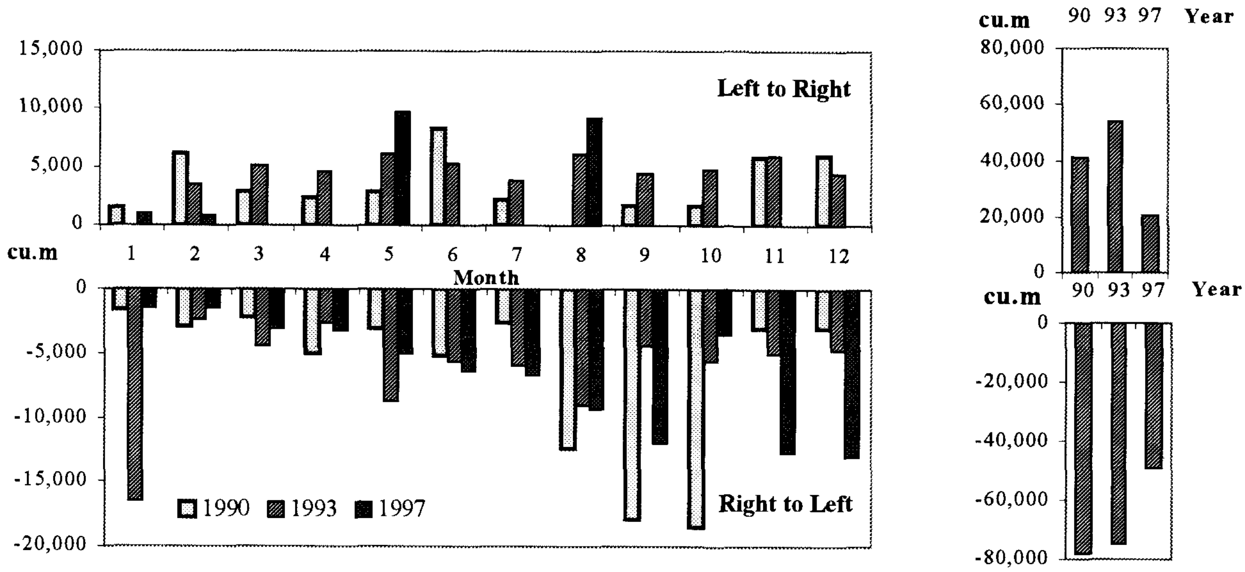

Fig.11 Calculated longshore sediment transport in the Nanakita River mouth area

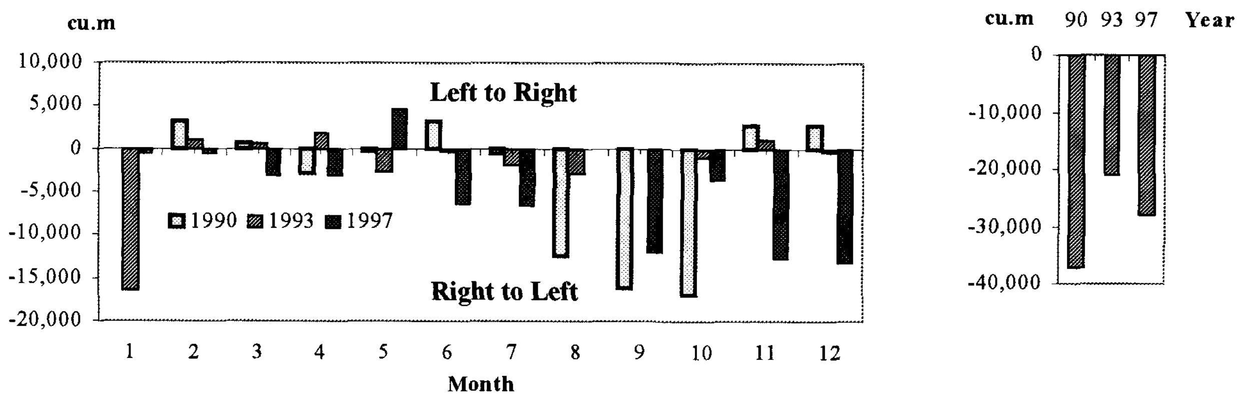

Fig.12 Calculated net longshore sediment transport in the river mouth area

The average of probability of land area in the area of interest can be used to explain the ratio of sand bar developing into river mouth opening within one year and the average of standard deviation implies the fluctuation magnitude of sand bar development into the river mouth opening.

As the area of interest was established, the trend in **Fig.10** can be explained that the river mouth opening becomes wider in the recent year as the result from no development of left sand bar. The lower standard deviation also explains the more stability of river mouth feature in the recent years. By the analysis of aerial photographs, the results of tracing waterline are the location at only the time taking photos, however the effect of tidal level and wave setup are also included in the actual condition. Therefore, the available 12-points field survey data in January 1996 describing the location of shoreline at TP.0 are compared with the waterline location computed from image analysis. From adjustment of +0.58m-tidal level, the total Root Mean Square Error equals to 5.77 m. When including the adjustment of wave setup, which is computed from 0.44 m-incident wave height with 10.9 sec-period measured at water depth 20 m offshore by CERC[3), total Root Mean Square Error becomes 5.76 m, which is the error, contributed by this image analysis method.

5. ESTIMATION OF LONGSHORE SEDIMENT TRANSPORT

The morphological change at the river mouth is the result from the combination effect from riverside and seaside. However, in this study, the influence from seaside is mainly examined. According to the gradual change behavior of the Nanakita River mouth is observed in the period of a decade classified as a long-term changing time scale. Therefore, the shore parallel sediment transport has the significant role to contribute this kind of change and longshore sediment transport is evaluated in this section by Eq.(2) from CERC.

$$Q = K(\frac{1}{8}\rho g H_B{}^2)(\sqrt{gh_B})\sin\alpha_B\cos\alpha_B \qquad (2)$$

where Q is longshore sediment transport volume, ρ is the density of sea water, ρ_s is the density of sediment, g is the gravitational acceleration, H_B is the breaking wave height, h_B is the depth at the breaking point, α_B is the breaking wave angle to the shoreline. In this study K, which is an empirical coefficient, is 0.05 following the previous determination by Tanaka and Shuto[4] through a comparison between the measured shoreline change in the northern part of Sendai Coast and a numerical simulation using one-line model. The wave characteristics and location of breaking wave in Eq.(2) are computed by the use of wave ray method associate with Goda's wave breaking criterion[5]. The bathymetry data in 1990, 1993 and 1997 surveyed from Sendai Port to the Nanakita River mouth with grid size 50×10 m in longshore and offshore direction respectively uses together with monthly average of incident wave height, wave period and wave direction measured at 20m-depth offshore are inputted to the wave ray model. Subsequently, the volumes of longshore sediment transport in the vicinity area of the river mouth are shown in **Fig.11** and **Fig.12**.

According to the missing of wave data, the wave characteristics in Sep 90 and Dec 90 are substituted to the absence in Oct 90 and Nov 90, respectively. Wave data in Nov 97 is also substituted in Dec 97. The computation is carried out to determine the average longshore sediment transport volume in the area 500 m covering the Nanakita River mouth. The average shoreline direction at the river mouth is calculated from the bathymetry data in each year. **Fig.11** shows that the sediment transport from right to left direction of the Nanakita River mouth in 1990, 1993 and 1997 are predominant, which can be seen from yearly volume of sediment transport. However, the magnitude noticeably decreases in 1997 for both directions. Especially, the sediment transport from left to right direction shows the zero value for 8 months within one year, while sediment transport from right to left direction still exists in every month. This result conforms to the phenomena investigated by aerial photographs analysis that behavior of the river mouth in the recent year has a trend to keep more stable and no development of left sand bar because of much lesser sediment supply in the left direction. The contrary can be observed from the analysis results in 1990 and 1993 when the magnitudes of sediment transport in the river mouth area are rather high.

6. CONCLUSIONS

The "HSL" color information in the aerial photograph is utilized to trace the waterline in this study and normal distribution assumption is suitable to locate the land-water demarcation criterion. As the land and water area can be extracted from aerial photographs, the temporal change of the river mouth can be monitored. The morphological change from 1990-2002 is observed that river mouth behavior in the recent year is more stable and the left sand bar rarely develops when compared to the past. Therefore, the longshore sediment transport in the river mouth area is estimated by the use of available bathymetry data in 1990, 1993 and 1997. The analysis result proves that longshore sediment transport in the vicinity area of the Nanakita River mouth has significantly decreased in 1997, especially, in the left side of the river mouth. The calculation results show that the changing of longshore sediment transport has a correlation to the actual changing behavior, which river mouth is stabilized and left sand bar is diminished.

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