Environmental impacts of the regulation of the Shinano River, Niigata prefecture, Japan

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Abstract

The coastal zone of Niigata Prefecture is severely affected by erosion. This study was developed to investigate the relationships between river regulation and changes to the coastal zone. Regulation of the Shinano River began during the Meiji Period with the construction of a long jetty. The jetty was built to avoid the silting of the river mouth, and allow the significant maritime trade to continue with inland transport via the Shinano River. Additional regulation involved the dredging of two channels southward from the mouth of the Shinano River, the Sekiya and the Ohkozu, for the purpose of flood mitigation in the Niigata Plain. To evaluate changes to the coastline, several approaches were used. Firstly, six sets of aerial photographs were examined. Then, the sediments grain-size parameters and mineral variation were analyzed to find the correspondence with shoreline changes. As a third approach, field surveys were conducted and historical data on the coastal process was assessed. The coast in the vicinity of the artificial channels accreted and there was erosion on the down-drift side of the river mouth.
Keywords: Shinano River, jetty-Ohkozu channel, Sekiya channel, erosion.

1 Introduction

In Japan, coastal erosion affects most of the shoreline along the Sea of Japan, though seldom along the Pacific coast. The most significant changes are observed along the coast of Niigata Prefecture especially from the mouth of the Shinano River to the district of Joetsu. Erosion is due to several factors, mainly

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the reduction in river sediment supply to the coast caused by the construction of diversion channels such as the Ohkozu and Sekiya channels. Changes to the shoreline have also occurred from the interference of coastal protective structures with the natural longshore transport, causing a sand deficit on their down-drift side. Indeed, Niigata is the biggest port along the Sea of Japan and it prospered in the feudal age by transporting rice from the Echigo Plain. The city was also an important place for maritime trade and inland transport via the Shinano River. In those days, the mouth of the Shinano River was so frequently filled with sediment carried by the river that the port's business was often hampered. Following the river reform on the Niigata Plain in the latter part of the nineteenth century, a jetty was constructed on the west side of the river mouth in 1906 to move the sandbar further seaward to maintain a deeper channel for navigation. This resulted in a larger volume of sand being retained that is more difficult for sediments to move down the shoreline. This inhibition of sand movement continued further along the coast. The beaches between the welding of the bar and the river entrance suffer great erosion. With respect to Ohkozu and Sekiya channels, their main purpose was to mitigate the flooding that affected the low lands in Niigata Prefecture.

This was widely discussed by Isobe [5], Tanaka [14], Takeyama [13], Tsuchiya et al. [9] and Yoshikawa et al. [15]. Several investigators also believe that a series of tectonic disturbances in the geological past, together with the natural geomorphology of the coastal zone, led to the coastline being vulnerable to hazards. This is based on indications of a high subsidence rate Nakano and Takehisa [7], the low topography, the geomorphologic units consisting of mainly low resistant materials such as natural levees, sand dunes and swamps Urban Kubota [1], and exceptional winter tidal waves. However, there has been little investigation on the effect of river regulation on changes to the coastal environment, especially the drop in river sediment supplied to the coast, as shown by the sorting pattern of heavy minerals and textures of beaches sand.

2 The study area

The study area (Figure 1) is located in a very sensitive coastline stretching between the mouth of the Shinano River and the Ohkozu channel, Niigata Prefecture, Japan. It has a well- developed social and economic infrastructure. The coastal plain in the region has large-scale irrigation schemes where crops such as rice and vegetables are grown. The study area was formed by both fluvial and marine deposits in the Quaternary age. It has been affected by worldwide sea- level changes as well as local tectonic movements. It consists mostly of alluvial lowland, less than 5 m high, with a few, very scattered remnants of terraces Yoshikawa et al. [15]. Geomorphologic units consist mainly of Late Quaternary units such as coastal sand dunes (III- II 600- 500 years BP) Urban Kubota [1]. These units are backed by alluvial depression of the Niigata Plain and natural levees. Beach types found along the Japanese coast show the occurrence of multi- bar beaches which also occur along the study area Mogi [6].

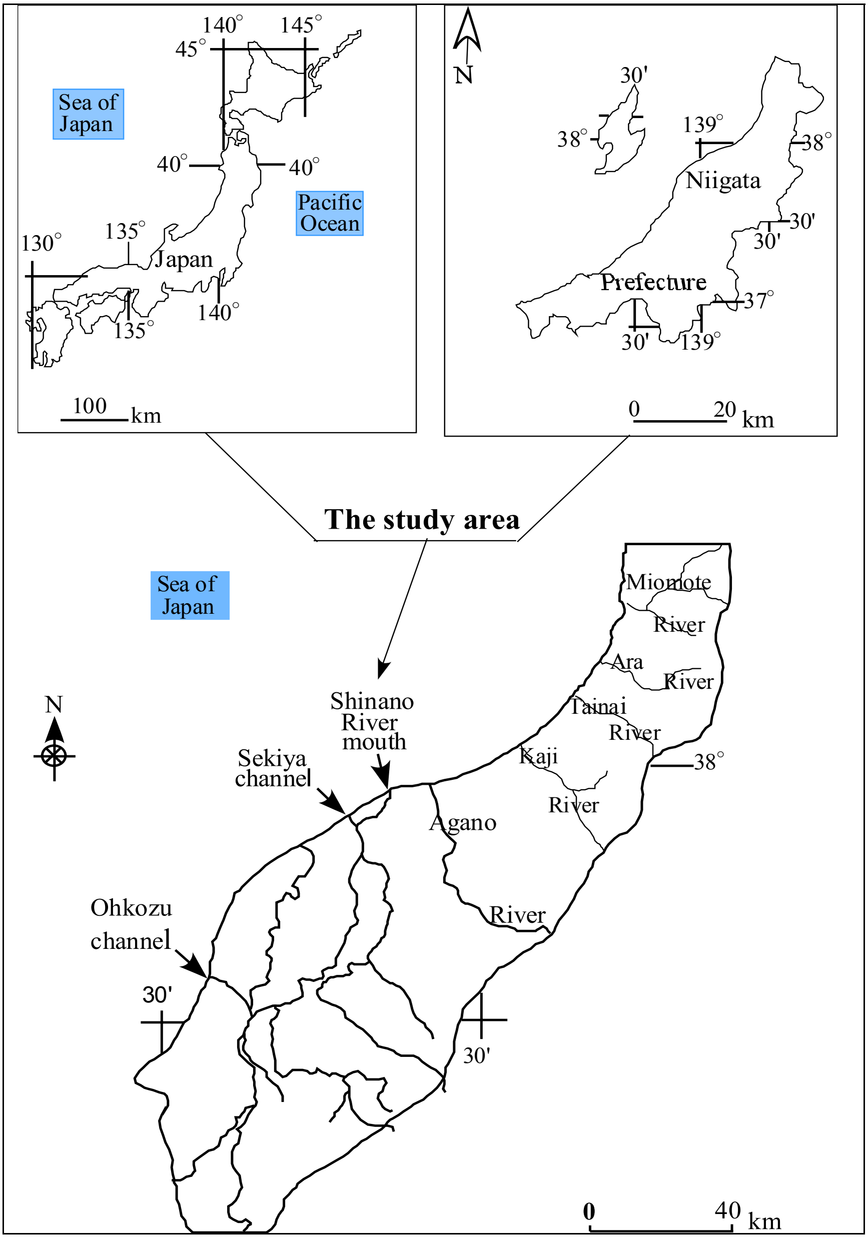

Figure 1: Location map of the study area.

3 Data collection

In this study, a survey was carried out to examine the impacts of river regulation on a portion of the Niigata shoreline from the mouth of the Shinano River to the beaches along Teradomari. Several approaches were use to evaluate the changes to the shoreline.

Firstly, six aerial photographs from 1914, 1928, 1958, 1972-1974, 1981 and 1991-1995 were assessed. These images were rectified to the same scale, registered, and superimposed. The registration was based on control points of fixed geographic features such as the mouth of the Shinano River and the mouth of the Ohkozu channel. The Department of Geology and the Faculty of Engineering, Niigata University, provided data on geological aspects and historical coastal processes.

Field surveys were also carried out. Up to 100 samples of beach sediments were collected at 5m intervals along Teradomari coast and the beaches to the west of the mouth of the Shinano River.

Grain size analyses were made using the method of Drop, which consists of introducing 10 grams of sediment into the analyzer bottle containing 155 cm of volume of water, and deposited on a slide of Aluminum. The analyzer bottle was connected to a computer. At the end of the timing (10 to tens of seconds), grain-size parameters (grain-size, kurtosis, skewness, standard deviation) are translated directly to the computer.

Heavy mineral grains were separated from light sediments by using bromoform with polytungstate (density 2.82g), weighed and converted into percentages. The heavy minerals were mounted on slides (28mm×48mm and 1.3-1.4 mm thick) and fixed using Petropoxy (10 parts Resin hardener). The slides were put on digital Hot Plates adjusted at 75°to let the resin set. The heavy minerals were polished with carbon 1500 grains to reduce their thickness. The slides containing the heavy minerals were then heated and recovered by finer slides (24mm×32mm and 0.12-0.17mm thick) using Canada Balsam. The slides have been cleaned by Ethanol to remove the carbon. For each sample, two hundred grains were analyzed. The identification accounted standard petrographic criteria (color, specific gravity, etc.) and optic microscope.

4 Results and discussion

4.1 Sediment patterns

Sediments parameters accounted grain size distribution and heavy mineral contents (figure 2).

4.1.1 Mineralogical variations

The heavy mineral fractions in all the samples ranged 0.1%-0.2% for beaches situated along the west side of the river mouth and 8%-10% along Teradomari beaches. Several mineral species have been identified and classified into minerals of high specific gravity and minerals of low specific gravity. The mineral procession is dominated by three of the most stable heavy minerals such as apatite, rutile and tourmaline. The grouping of the heavy minerals in minerals of low specific gravity and minerals of high specific gravity made it possible to identify the portions of strong agitation and low agitation.

The high percentage of minerals with high specific gravity (83%) such as rutile and tourmaline along the beaches to the west of the river mouth suggests a portion with strong agitation, which is not favorable for the accumulation of sands. Heavy minerals of lower densities are selectively entrained and transported offshore by the swash of waves on the beach face, tending to leave as a lag the minerals that have higher densities Li and Komar [4]. Similar results were obtained by Frihy and Lofty [2] and Idrissi et al [3] in their analyses along the northern Sinai coast of Egypt and on the coastal zone of Casablanca, Morocco.

Conversely, beaches along Teradomari coast tend to have heavy minerals with lower specific gravity dominated by opaques (magnetites and ilmenites), which constitute 88% with smaller concentrations of apatite and tourmaline. The increase in the proportion of minerals with lower specific gravity suggests a portion of shoreline with weak agitation that is favorable for the accretion of sediments.

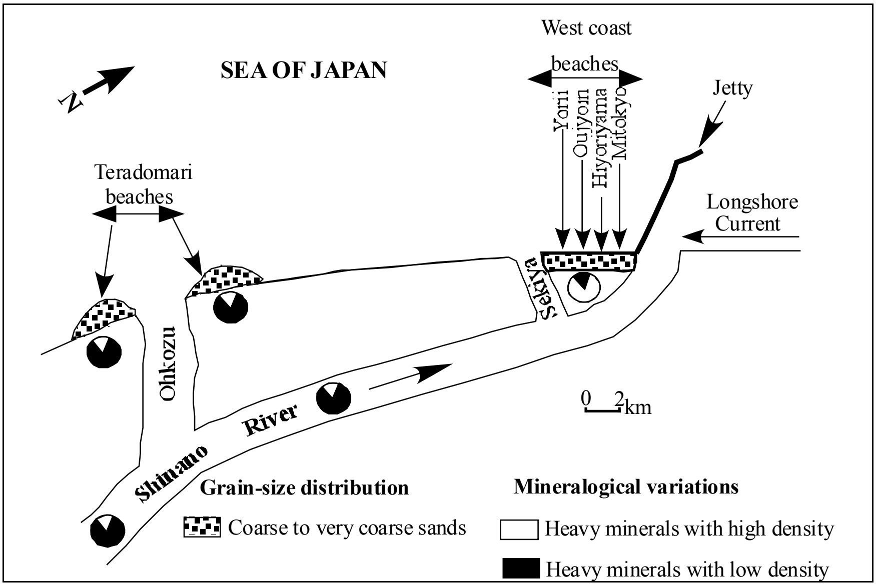

Figure 2: Grain-size and mineralogic distribution of sediments.

4.1.2 Grain-size distribution

The granulometric analysis of the sands taken along the beaches of Teradomari shows a generally coarse fraction dominated by sediments ranging 0.5mm-1mm (94.415% of the samples), classified as very well sorted (So=0.21) and strongly coarse-skewed (Sk= -1.50 in average). The granulometric analysis of the sands taken in the Ohkozu channel and further upstream of the Shinano River shows the same pattern since 93.476% of sediments range 0.5mm-0.25mm, very well sorted (So=0.22) and strongly coarse-skewed with terms for skewness averaging -1.5. The resemblance between the granulometric characteristics of sediments of

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the beaches along Teradomari coast and those of the main channel of the Shinano River indicates significant river sediment supply to the beaches along Teradomari coast.

In the other hand, grain-size distribution along the coast to the west of the mouth of the Shinano River shows a slight distinctive pattern with a more important fraction of coarser grains since 74.532% of the sediments range 1mm-1.25mm. The beaches of his section are separated from the river mouth by the protruding jetty, which prevents sediment supply to this section and indicates that river sediment supply to the coast has become inexistent or negligible. This is confirmed by the difference between the granulometric characteristics of the channel sediments and beaches of this section. The lack of river sediment supply and the absence of longshore sediment transport have amplified the erosive trend observed along this portion by reducing the sedimentary input necessary for the balance of the beaches.

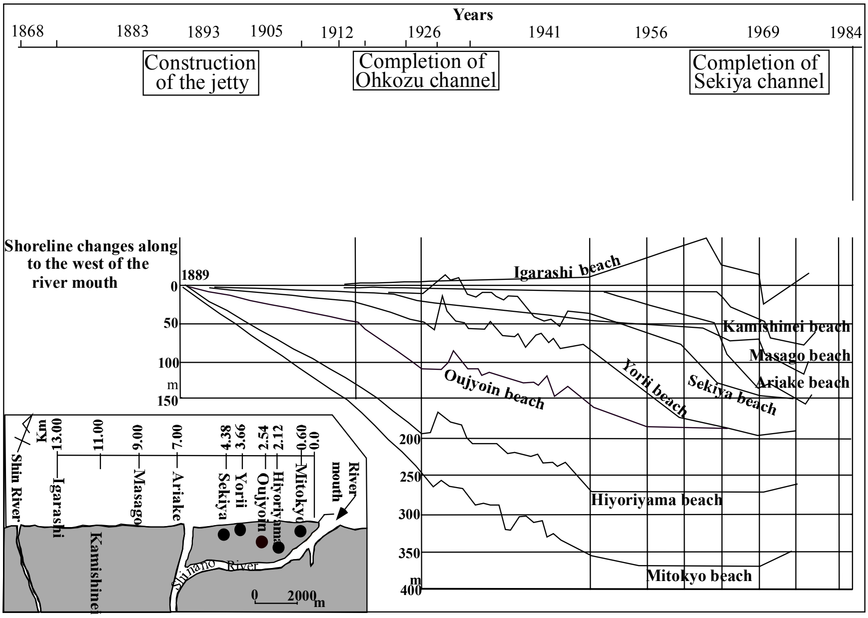

Figure 3: Changes to the shoreline along the west side of the river mouth following the regulation of the Shinano River, Urban Kubota (1). The bold circles indicate the sampling sites along this portion.

4.2 Eroded beaches

Beaches along the west side of the river mouth have undergone a significant and almost continuous retreat since the construction of the long jetty on the river mouth in 1906. The construction of the jetty disturbed the North-South oriented littoral sediment transport, causing erosion of the beaches to the west of the river mouth, located downdrift. The completion of the Ohkozu and Sekiya channels then aggravated the sedimentation imbalance and accelerated the regressive evolution of the beaches along this portion. The lack of longshore and river sediment supply led this portion being exposed to the erosive action of the swell that is particularly strong during winter. The retreat of the shoreline to the west of the river mouth is estimated at 400m during the eighty years considered for this study, that is to say a rate of erosion of 5m/year. Except for the Igarashi beach, which shows localized sediment deposition, the beaches of this portion (Mitokyo, Hyoriyama, Oujyoin and Yori) underwent significant erosion (Figure 3). This led the decision maker to undertake a vast program to mitigate the erosion by a large scale of coastal hardening involving engineering structures such as detached breakwaters and artificial reefs.

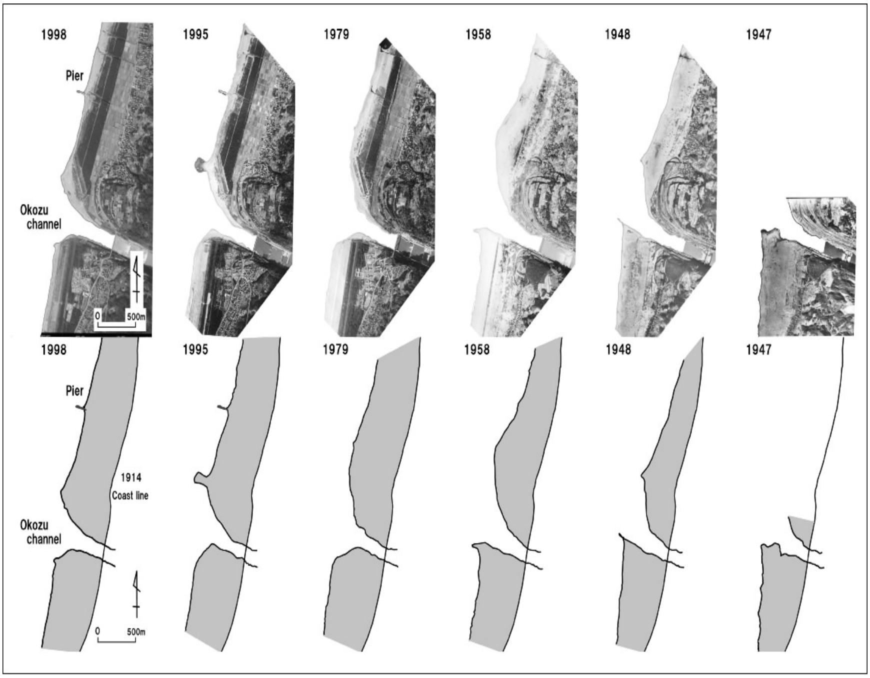

Figure 4: Changes to the shoreline along Teradomari following the completion of the Ohkozu channel, Yamagishi et al [11].

4.3 Prograding beaches

The beaches of Teradomari prograded substantially following the completion of the Ohkozu channel. The sedimentary contributions accumulated along this portion come essentially from the Shinano River by way of the excavated channel. The coast to the west of the river mouth was deprived of almost 90% of volumes of sediment that are diverted towards the beaches of Teradomari. Indeed, prior to its regulation, the Shinano River discharged to the coast a total volume of sediments estimated at 1,000,000 m^3/y. After the completion of the Ohkozu channel in 1932 and the Sekiya channel in 1972, up to 900,000m^3/y of volume of sediments was diverted mainly towards the Ohkozu channel (oral communication, 2004). As a result, the coastal zone surrounding the Ohkozu channel shows sedimentary progradation of more than 700 meters as shown in figure 4.

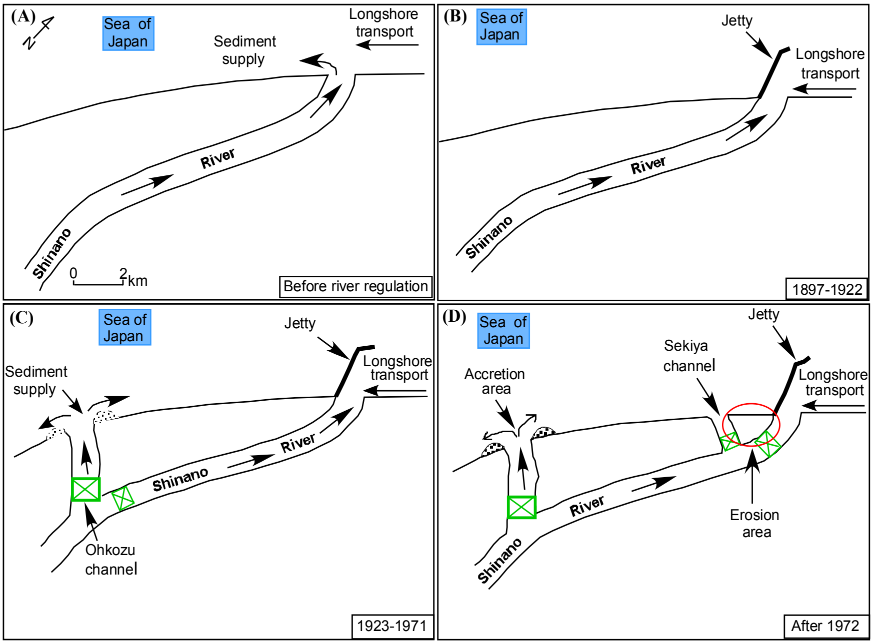

Figure 5: Schematic illustration of the impacts of river regulation. (A): Configuration of the shoreline before the regulation of the Shinano River. (B): Drop in longshore sediment transport downdrift side following the construction of the long jetty. (C): Exacerbation of the erosive trend with the construction of the Ohkozu channel, which discharges 90% in volume of sediments towards the beaches Teradomari. (D): The beaches of Teradomari accreted more than 700m of sediments to the detriment of those to the west of the river mouth, which undergone significant erosion averaging 400m.

5 Conclusion

We attempted to understand the relationship between river regulation and changes in the coastal area along a portion of the Niigata Prefecture shoreline over an eighty-year period. The geomorphology showed a predominance of low topography and low resistant units, with significant ground subsidence and influence from strong tidal waves in winter. Before river regulation, fluctuations in the shoreline were due to typical seasonal changes such as the retreat of the beaches due to the increase of the swell energy in winter with rough-seas and accretion again when the seas were calm. Seasonal surveying made it possible to determine the variations of height on the beaches along the study area. This natural erosion and accretion process had been altered by engineering works. With construction of a long jetty on the western side of the mouth of the Shinano River, there was a significant reduction in sediment delivery by the longshore current and a drop in sediment supply to the coast leading to impoverishment of the majority of the beaches to the west of the river mouth and resulting in rapid erosion.

Construction of the Ohkozu and Sekiya channels further reduced the sediment discharge to the coast by more than 90% (Yamagishi [16]). The coast to the vicinity of the mouth of the Ohkozu channel accreted more than 700 meters of sediment since 1912, and the coast to the west of the mouth of the Shinano River eroded significantly, averaging 400 m. A schematic illustration depicting the regulation of the Shinano River and induced impacts is given below (figure 5).

Considering river regulation has affected the coastal landscape, we encourage efficient mitigation of coastal degradation by both engineering methods and with integrated management. For successful and sustainable management actions in the coastal zones, the management action must be technologically feasible, economically viable, socially desirable, legislatively permissible administratively achievable, also environmentally sustainable Elliot and de Jonge [12]. Environmentally sustainable management action is highly welcomed for the coastal zone of Niigata Prefecture in particular since it has suffered so far major damages and has been threatened by several hazards such as flooding and high waves, while at the same time coastal erosion has worsened.

References

[1] Urban, K., *Geomorphology of Niigata Prefecture*. Niigata University, Graduate School of Science and Technology, Faculty of Sciences, pp 10-47, 1979.

[2] Frihy, O.E. & Lofty, M.F., *Shoreline changes and beach-sand sorting along the northern Sinai coast of Egypt.* Springer-Verlaag:Geo-Marine Letters (17), pp 140-146, 1997.

[3] Idrissi, M., Ait Laamel, M., Hourimeche, M., Chadgali, M., *Impacts of the swell on the current morphological and sedimentary evolution of the coastal zone of Casablanca-Mohammedia (Morocco).* Elsevier: Journal of African Earth Sciences (39), pp 541-548, 2004.

[4] Li, Z. & Komar, P.D, *Longshore grain sorting and beach placer formation adjacent to the Colombia River*. Journal of Sedimentary Petrology (62), pp 429-441, 1992.

[5] Isobe, M., *A theory of integrated coastal zone management in Japan*. Department of Civil Engineering, University of Tokyo, p 18, 2001.

[6] Mogi, A., *On the shore types of the coasts of Japanese Islands*. Geogr. Rev. Japan, 36, 245-266 (J+E), 1963.
[7] Nakano, T., and Takehisa, Y., *Ground subsidence in the Niigata Plain*. Geogr. Rev. Japan, 33, 1-9. (J+E), 1960.
[8] Sakaguchi, Y., *Notes on the problems of the paleogeography of the Echigo Plain, Niigata Prefecture*. Quat. Res (Japan), 3, 284-289. (J), 1964a.
[9] Tsuchiya, Y., Shibano, T., and Nakanishi, T., *Long- term shoreline change of the Naoetsu harbor*. Coastal Eng. In Japan 19: 109-20, 1976.
[10] Uda, T. Shoichi, K., and Torao, T., *Beach changes caused by the construction of coastal structure on the Ichibouri Coast in Niigata Prefecture*. J Japanese Geomorphological Union, Vol 9, No 1, Jan 1988.
[11] Yamagishi H., Takashi, I., Ayalew, L.& Ota, Y., *Environmental geology of the Kakuda-Yahiko Range- geomorphic sequence and landslide susceptibility*- Department of Environmental Science, Faculty of Science, Niigata University, Japan, pp. 57-59, 2003
[12] Elliot, M., and de Jonge, V.N., *Responses of estuaries to natural and anthropogenic changes: perspectives and a global view*. ECSA 37 ERF 2004 conference Ballina (Australia) June 20-24, Proceedings. P: 21, 2004.
[13] Takeyama, S., *Changes of river bed in the middle reaches of "Tones" River.* Geogr. Rev. Japan, 31, 486-495. (J+E), 1958.
[14] Tanaka, M., *Rate of erosion in the Tanzawa Mountains, central Japan.* Geogr. Ann., 3, Ser. A, 155-163, 1976.
[15] Yoshikawa, T. Kaizuka, S. & Ota, Y., *The landform of Japan*. University of Tokyo Press, 222 p, 1981.
[16] Yamagishi, T. *Personal communication*, 15th July 2004, Consultant, Kitac. Co. Ltd, Niigata city, Japan.