Journal of Hydroscience and Hudraulic Engineering
Vol. 4, No. 2, November, 1986, pp.11-19.

OBSERVATIONS OF BED TOPOGRAPHY DURING THE 1981-FLOOD IN THE ISHIKARI RIVER

by

Tadaoki Itakura
Hajime Yamaguchi
Yasuyuki Shimizu

Civil Engineering Research Institute, Hokkaido Development Bureau
Sapporo, Hokkaido, 062, Japan

Tsutomu Kishi
Mikio Kuroki

Department of Civil Engineering, Faculty of Engineering
Hokkaido University, Sapporo, Hokkaido, 060, Japan

SYNOPSIS

Observations of the bed topography were performed in the Ishikari River during a flood in August 1981. Bed configuration of the river channel altered depending upon the hydraulic properties of the flow. Sand waves on the river bed decayed and hence the hydraulic roughness decreased at greater flow rates. Analyses of the geometrical properties of the sand waves formed on the river bed were performed. It was revealed that the relationships for the shape of the sand waves which had been previously reported could well be extrapolated beyond the range of the previous data. Investigations of the meso-scale bed configurations were carried out to find out that a theoretical analysis of a diagram of regime criteria was well confirmed by the present field data. Measurements of suspended sediment transport rate were performed during the flood. The field data agreed well with a theory of suspended sediment on sand waves by the authors with some modifications on the hiding factor for the non-uniform mixture of size of the bed material.

INTRODUCTION

In alluvial streams it is well known that the channel geometrical characteristics and hence also the hydraulic roughness depend on the depth, velocity and sediment transport rate of the flow, but these flow properties are in turn strongly dependent on the channel configuration and its hydraulic roughness. This phenomenon has been demonstrated often in laboratory flumes but a few field data have been reported. In August 1981, the Ishikari River had the greatest flood since the gauging stations had been operated. The flow rate was 12,500 m^3/sec at its maximum and was more than the design flood discharge at that time. Observations of the bed configuration were performed during the flood using an echo sounder as a part of the flood observations. In this paper, some results of the observations and the geometrical characteristics of sand waves are described.

GENERAL DESCRIPTION

The observations of the bed configuration were carried out during August 7 to 11, 1981 in a reach of the Ishikari River from the river mouth to 15 km upstream. In this section, some examples of the observations performed between the

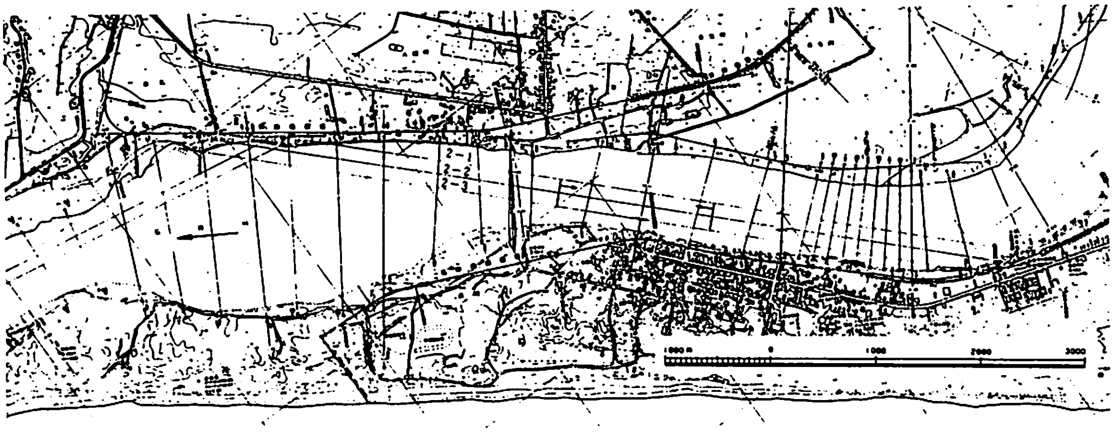


Fig. 1 Plan view of the Ishikari River

stations 1.5 km and 4 km from the river mouth are described.

The plan view of the reach and the longitudinal and cross sectional observation lines are shown in Fig. 1. Fig. 2 shows the hydrograph of the 1981-flood in which the notations a～e indicate the time when the observations of the bed configuration were performed. Flow data are summarized in Table 1 in which Q= flow rate; h= depth of flow; I= slope of energy gradient; U= areal average velocity; U_*= shear velocity(=$\sqrt{(ghI)}$); τ_*= dimensionless shear stress(=hI/sd); s= specific weight of bed material in water; ks= size of equivalent sand roughness; n= Manning's roughness coefficient; Δ, L= average wave height and average wave length of sand waves respectively as calculated by a spectral analysis. For more details of the observations, Takagi et al. (5) could be referenced.

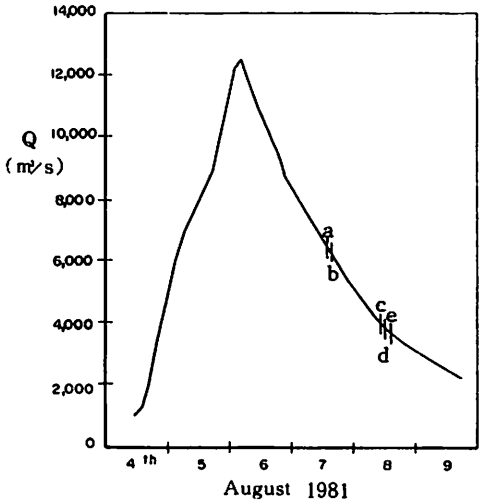


Fig. 2 Hydrograph of the 1981-flood

Table 1 Summary of flow data

	Date, Time Aug. 1981	Q (m³/s)	h (m)	I (×10⁴)	U (m/s)	U_* (m/s)	τ_*	ks (m)	n	Δ (m)	L (m)
a	7th 14:30	6,200	8.45	3.01	2.45	0.157	5.93	0.118	0.029	2.0	330
b	15:30	6,100	8.43	2.97	2.41	0.157	5.84	0.130	0.030		
c	8th 10:30	3,900	8.07	2.33	1.61	0.136	4.38	0.592	0.038	2.0	70
d	11:15	3,800	8.06	2.31	1.57	0.135	4.34	0.658	0.039		
e	14:05	3,600	8.05	2.29	1.49	0.134	4.30	0.860	0.041		

The profiles of the channel bed along the logitudinal line denoted 2-2 in Fig. 1 are shown in Fig. 3 in which notations a～e are to be referred to the same notations in Fig. 2 and Table 1.

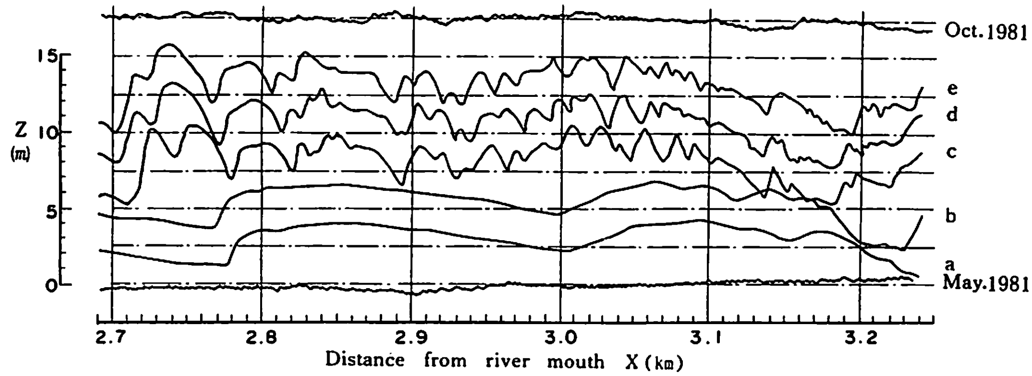


Fig. 3 Profiles of bed surface

In Fig. 3, longitudinal profiles before and after the flood in May and October 1981 were also depicted at the bottom and at the top respectively. Before the flood, the bed was flat with small ripples. It altered to dune during the flood at the flow rate of 4,000～6,000 m³/sec and the migration velocity of the sand waves was 2 mm/sec. It turned back again to flat bed after the flood had receded.

Relationship between τ_* and the grain shear stress τ_*' is shown in Fig. 4 and it is found that the bed configuration is in a category of dune II or transition.

Fig. 5 shows the relationship between Manning's roughness coefficient and the flow rate. The dimensionless shear stress was more than 10 at the maximum flow rate and the sand waves were supposed to be washed away to form a flat bed and consequently the roughness coefficient decreased with increasing flow rate at this reach.

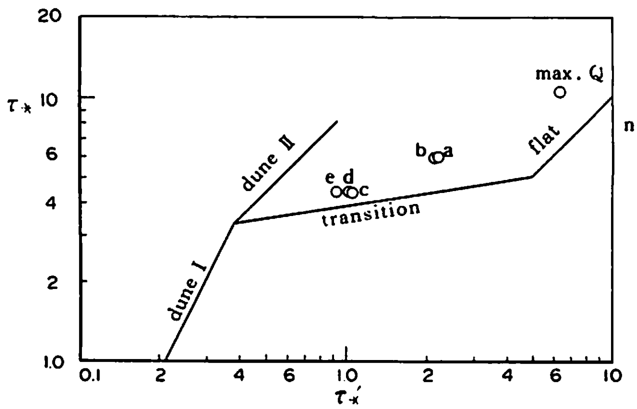


Fig. 4 Relationship between τ_* and τ_*'

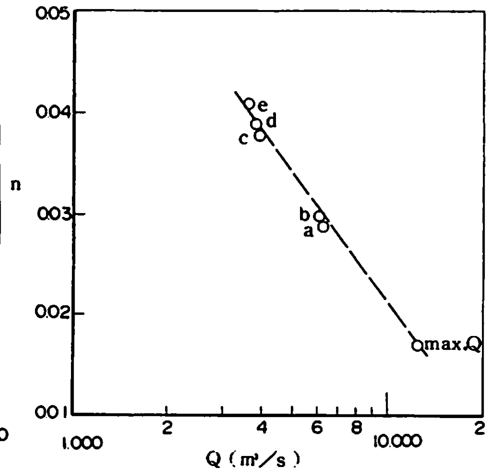


Fig. 5 Manning's roughness coefficient

GEOMETRICAL PROPERTIES OF SAND WAVES

The bed material of this reach is composed of very fine sand particles with a mean diameter of dm = 0.26 mm as shown later in Fig. 15. Consequently the dimensionless shear stress is very great and the value of the critical shear stress is very small. An analysis of the geometrical properties of sand waves was made applying some relationships which had been deduced from flume experiments and field observations. Present field data of the Ishikari River are plotted with double circle in the following 4 figures.

Fig. 6 shows the average length of sand waves. A straight line in Fig. 6 was proposed by Yalin (7) as:

$$L = 5h \tag{1}$$

Although the present field data fall within the scatter of the previous ones, it is recongnized that the present sand waves have longer wave lengths.

Heights of sand waves are plotted in Fig. 7 in a non-dimensional form with respect to the depth of flow. Curves in Fig. 7 were proposed by Yalin(7) as:

$$\frac{\Delta}{h} = \frac{1}{6}\left(1 - \frac{\tau_{*c}}{\tau_*}\right) \tag{2}$$

The multiplier in brackets on the right side of Eq. 2 implies the dimensionless excess of tractive force. As for the proportional constant in Eq. 2, Tsubaki(6) suggested that 0.3 fitted better than 1/6. The present field data are just between them at very great values of dimensionless tractive force beyond that of

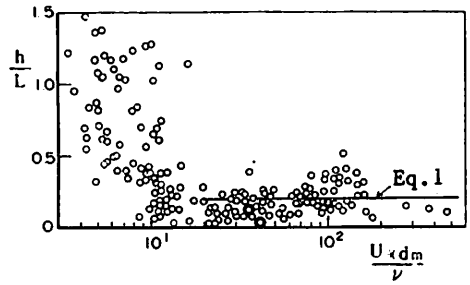


Fig. 6 Wave length of sand wave

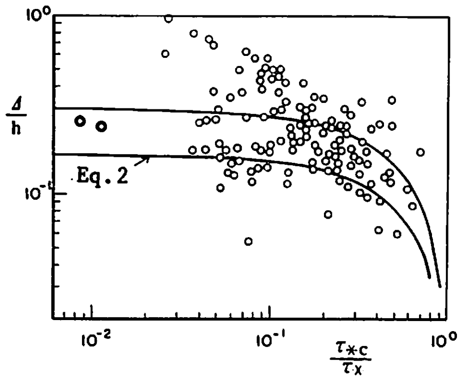


Fig. 7 Height of sand wave

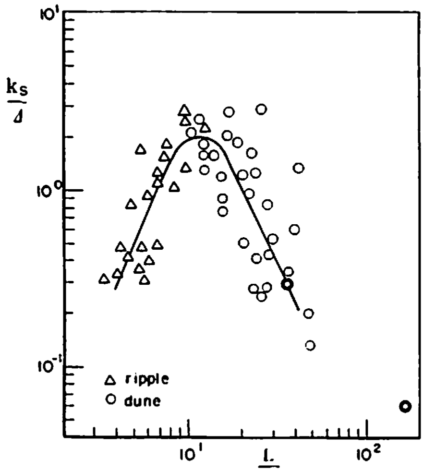


Fig. 8 Equivalent sand roughness

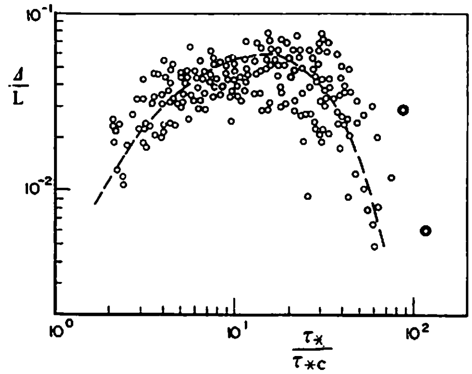


Fig. 9 Steepness of sand wave

the previous data.

A relationship between the equivalent roughness and the wave length of sand waves are shown in Fig. 8 with a curve proposed by Tsubaki(6). Fig. 9 shows the steepness of sand waves and a curve proposed by Yalin and Karahan(8). It is recognized in these figures that both of the proposed relationships can be extrapolated beyond the range of the previous data taking into account the considerable scatter.

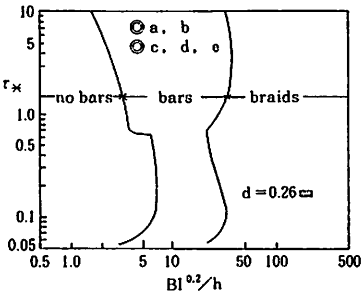
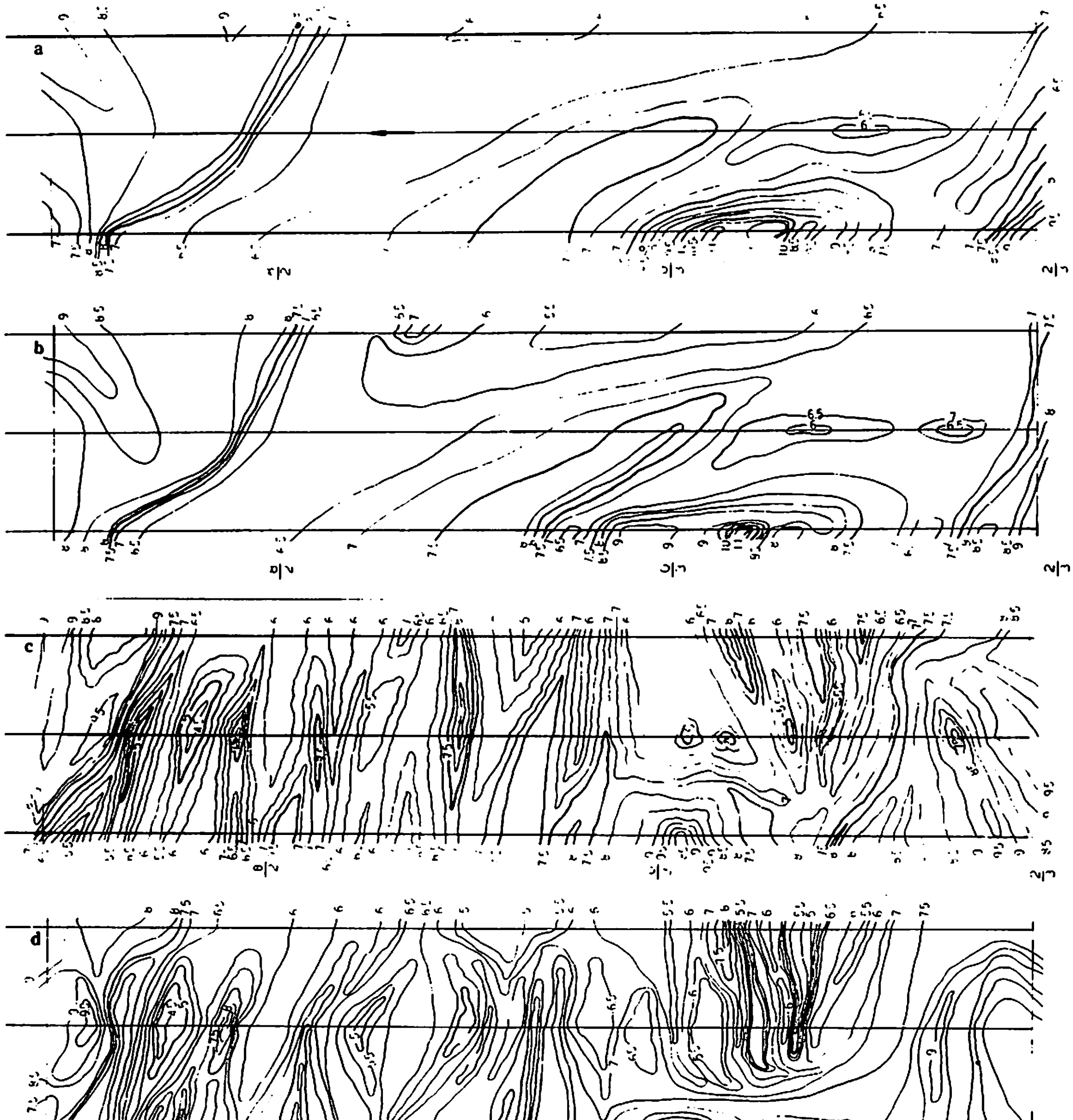


Fig. 10 Regime criteria of meso-scale bed cofiguration



Figs. 11-a ~ 11-d 3-dimensional properties of sand waves

3-DIMENSIONAL PROPERTIES OF SAND WAVE

A theoretical investigation of meso-scale bed configuration was performed by Kuroki and Kishi(4) to obtain a diagram of regime criteria as shown in Fig. 10. Double circles in Fig. 10 show the present field data and are classified to be bars of the meso-scale bed configuration.

Figs. 11-a to 11-d show the plan view of the bed topography and were drawn using the longitudinal bed profiles obtained on 3 observation lines denoted 2-1, 2-2 and 2-3 in Fig. 1. Each figure denoted 11-a ~ 11-d coinsides with the data described with the same notations in Fig. 2, Table 1, etc. Figs. 11-a~11-d show the bed topography of the left half of the main channel. Numbers in the figures indicate the distance from the water surface in m. It is observed in the figures that the bed configurations of 11-a and 11-b are typical bars, on the other hand 11-c and 11-d are more remarkably 2-dimensional.

OBSERVATIONS USNING A SIDE SCANNING SONAR

A set of detailed longitudinal and cross sectional depth soundings is necessary to observe the 3-dimensional property of the bed configuration and very often it is difficult to carry out a simultaneous measurement during a flood. A side scanning sonar is a type of equipment which is useful in measuring the areal topography under a deeper water. An attempt was made to apply this equipment to the observation of the bed configuration in river channel. The measurement was conducted on August 11, 1981 at the reach 7 km up-stream from the stations described in the preseding section. It was almost at the end of the flood and the flow rate was 1,500 m^3/sec and average depth of flow was 8 m. The river channel is alomost straight as illustrated in Fig. 12.

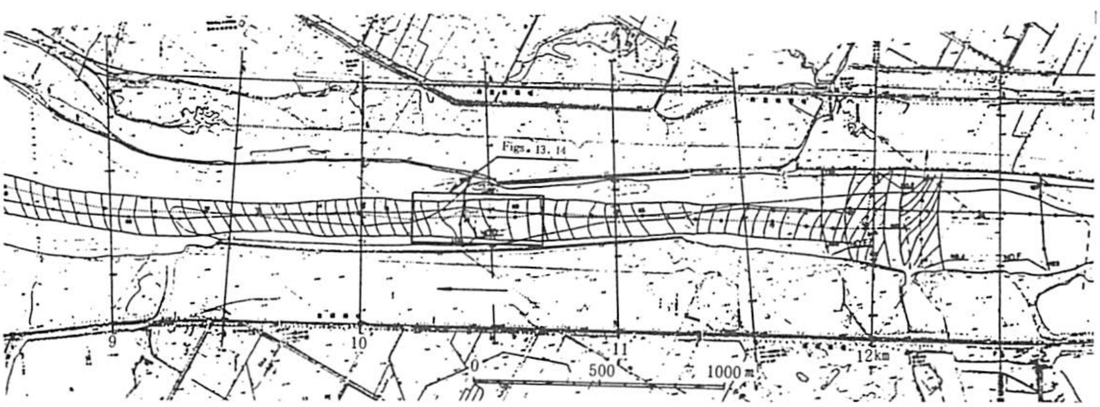


Fig. 12 Plan view of the Ishikari River

An example of the recorder chart is shown in Fig. 13. Lighter parts in the picture are at higher elevations and the crest lines are illustrated in Fig. 14. A sand wave can be observed which has a wave length of 60 ~ 100 m. At both sides

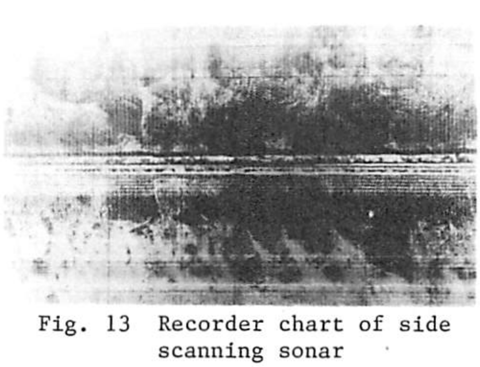


Fig. 13 Recorder chart of side scanning sonar

of the center line of the chart, there are records of the measurements just below the instrument which correspond to the longitudinal profiles. In this case, it is difficult to get precise qualitative information about the height of the bed configuration, although a better device has been developed recently. Recognizable wave crests of the sand wave are drawn in Fig. 12. It is recognized in Fig. 12 that the inclination of wave crests referred to the center line of the river channel alternates periodically for each 1.5 km distance. The flood flow itself was supposed to meander even in the straight channel during the flood.

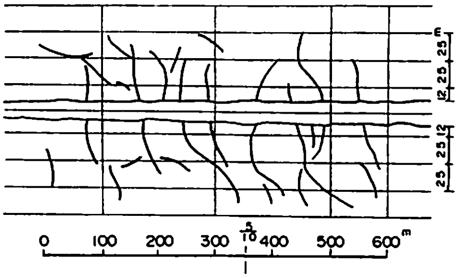


Fig. 14 Location of wave crests

OBSERVATIONS OF SUSPENDED SEDIMENTS

The bed material at the reach studied is composed of fine sand particles. Fig. 15 shows the distribution of size of the bed material. The dimensionless shear stress is great as shown in Fig. 4. According to a criteria diagram for types of transportation of the bed material load given by Shinohara and Tsubaki(6), the present condition is classified into the category of sediment transport where the suspended sediment predominates.

Fig. 16 shows the observed trasport rates of suspended sediment load. The curve shown in Fig. 16 was calculated from the theory of suspended sediment on sand waves proposed by Itakura and Kishi(2). In the proposed equation, the pick-up rate of suspended sediment from the bed was modified to take into account the hiding factor which occurs in beds composed of non-uniform sized material. The parameter B* in the equation was modified as follows.

$$B_* = \xi_i \cdot B_{*0} \quad (3)$$

$$B_{*0} = 0.143 \quad (4)$$

$$\xi_i = \left[\frac{\log 23}{\log(21\frac{d_i}{d_m} + 2)}\right]^2 \quad (5)$$

in which dm= mean diameter of the bed material. Eq. 5 is based on Asada's(1) analysis of the grain shear stress for each fraction of a mixture of bed particles and subscript i signifies the value corresponding to the percentage i of the grain size distribution in the non-uniform mixture of sediment. There is good agreement between the observations and the theory as shown in Fig. 16.

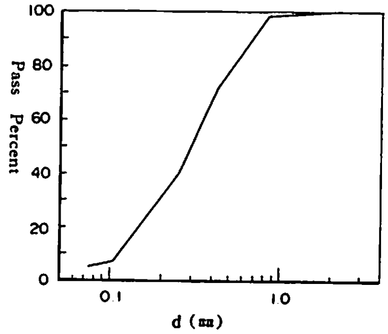


Fig. 15 Distribution of size of bed material

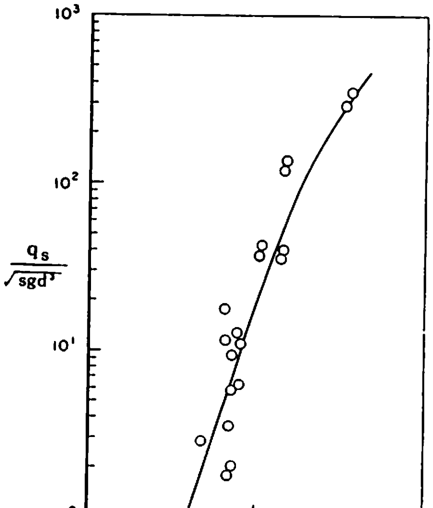


Fig. 16 Transport rate of suspended sediment

CONCLUDING REMARKS

Detailed observations of the bed topography were performed in the Ishikari River during a flood. The results of the observations are summarized as follows:

The bed configuration was supposed to be altered during the flood depening upon the hydraulic properties of flow as; flat→dune→transition→flat (at the maximum flow rate)→transition → dune→flat.

The roughness coefficient of the river bed decreased with increasing flow rate at this particular reach.

Geometrical properties of the present sand waves revealed that the relationships for the shape of the sand waves which had been reported could well be extrapolated beyond the range of the previous data.

A theoretical analysis of the regime criteria of the meso-scale bed configurations was confirmed by the present filed data.

The field data of suspended sediment transport rate agreed well with theory, providing the equation of pick-up rate of sediment from the bed was modified to account for the hiding factor.

Studies of the bed configuration and its deformation in alluvial channels are necessary and very important on managing river channels. But less field data has been reported compared to the flume experiments. It is usally too expensive and dangerous to carry out the field observations during the flood and very often it is difficult to obtain useful data. The Hokkaido Development Bureau will continue to perform observations of the bed topography of river channels during floods. An analysis of the bed configuration made by Kikkawa(3) was referred in the section of 2-dimensional bed configuration and is greatly acknowledged.

REFERENCES

1. Asada, H.: Study on the sediment discharge in mountain river and the process of sedimentation in reservoir, Technical Report Civil Engineering Laboratory, Research Institute of Electric Power Industry, No.2, 1976.
2. Itakura, T. and T. Kishi: Open channel flow with suspended sediments on sand waves, Proc. of the 3rd International Symposium on Stochastic Hydraulics, Tokyo, pp.589-598, 1980.
3. Kikkawa, H.: Study of flow at contraction at river mouth of the Ishikari River, Part 3, Report of River Hydraulics and Hydrology Laboratory, Civil Engineering Research Institute, Hokkaido Development Bureau, 1982.
4. Kuroki, M. and T. Kishi: Theoretical study on regime criteria for river morphology using three-dimensioneal shear flow model, Proc. of the 28th Japanese Conference on Hydraulics, pp.769-774, 1984.
5. Takagi, J., S. Makino, S. Takemoto and Y. Morita: Field study of flood flow and bed evolution in the lower Ishikari River, Proc. of the 26th Japanese Conference on Hydraulics, pp.57-62, 1982.
6. Tsubaki, T.: Sediment transport and deformation of river bed, Chapter 14, Hydraulics II, Morikita-shuppan, Japan, pp.216-243, 1974.
7. Yalin, M. S.: Geometrical properties of sand wave, Proc. of ASCE, Vol. 90, No.HY5, pp.105-119, 1964.
8. Yalin, M. S. and E. Karahan: Steepness of sedimentary dunes, Proc. of ASCE, Vol.105, No.HY4, pp.381-392, 1979.

APPENDIX - NOTATIONS

The following symbols are used in this paper:

- B = width of river channel;
- B_* = parameter in equation of pick-up rate of suspended sediment from bed of uniform particle size (Ref.2);
- B_{*0} = 0.143, parameter in Eq. 4;
- d = particle size of sediment;
- dm = mean diameter of sediment;
- h = depth of flow;
- I = slope of energy gradient;
- ks = height of equivalent sand roughness;
- L = wave length of sand wave;
- n = Manning's roughness coefficient;
- Q = flow rate;
- s = specific weight of sediment in water;
- U = areal average velocity of flow;
- U_* = $\sqrt{(ghI)}$, shear velocity;
- Δ = wave height of sand wave;
- ξ = hiding factor for mixture of size of sediment particles in Eq. 5;
- τ_* = hI/sd, dimensionless shear stress;
- τ_{*c} = critical dimensionless shear stress; and
- τ_*' = grain shear stress.

Subscript i signifies the value corresponding to percentage i of a non-uniform mixture of sediment represented by a special diameter of material.