Experimental Study of Bed Variation Around Spur-Dikes

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Abstract

In general, rapid rivers transport much sediment often causing degradation of river beds and scour of river banks.This leads to deterioration of low-flow channels and dike damage. To prevent these, spur-dikes are used since they are very effective in containing river channels. Spur-dikes are river structures with multiple functions, including flow channel establishment, prevention of scour near dikes and revetments, and causing sedimentation to change the flow direction away from river banks to the river center. Spur-dikes may also be used to reduce flow velocities.However, much is yet to be learned about the influence and effects of spur-dikes during floods.

Introduction

In Hokkaido, many steep-flowing rivers remain in their natural states, characterized by dish-shaped cross sections, multiple currents criss-crossing each other, and alignments changing year by year. River improvement work is being carried out on the Satsunai River, as is typical of such rivers, including installation of concrete-block spur dikes to prevent scouring and erosion of the banks, and to blend the present multi-current flow into a single, stable course.

Spur dikes are structures to control the local hydraulic action of currents. The two major hydraulic functions of spur dikes are to regulate the velocity of flow (reduce the speed), and to control the course of currents (keep them away from the river banks). At times of flooding, however, much about the influence and effect of spur dikes is still unknown.

This report examines the river-bed evolution at the spur-dike heads under design-flood-discharge flow conditions, based on experiments using a large-scale hydraulic model.

Outline of Experiment

The experiment was conducted using a scale model of the Satsunai River which is one of the three well known large and steep rivers in Hokkaido. Figur −1 shows the placement of the spur-dikes in this scale model.

The spur dikes were arranged in such a way as to almost completely satisfy the following conditions, which were established from experiments conducted the year before: The ratio(L/B) of the length of the spur dike length(L) to the river width(B) was more than 0.2: and the ratio (D/L) of distance between spur dikes (D) to the spur dike length (L) was less than 4.

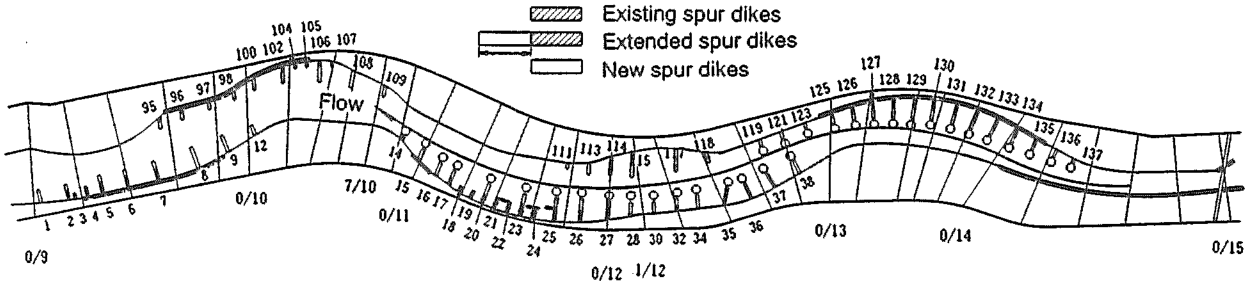

Figure - 1 Long-Term-Plan For Improving River Channel

Experimental Method

(1) Adjusting the minor bed to the design-river-bed height⟹ (2) Installing spur dikes according to the current plan ⟹ (3) Flowing water for 48 hours⟹ (4) Installing spur dikes according to the 20-year long-term plan ⟹(5) Flowing water for 48 hours⟹ (6) Flowing water according to the design-flood-discharge hydrograph.

The two 48−hour water flows were undertaken to create the initial conditions of the river channel, based on the fact that river-bed evolution under actual conditions is determined primarily by snow melt the exception being times of flooding. A snow-melt discharge rate equivalent to $400m^3/s$ ($23\ell/s$ in the model) was maintained for the equivalent of two weeks (48 hours in the model test) to prepare an initial river channel. Next, the design hydrograph shown in Figure −2 was used in the experiment($149.7\ell/s$ in the model).

The bed topography around a single spur dike is very different than the topography around a spur dike in a row of spur dikes. Not only is the scour depth different but also the configuration of the bed. It was not possible to measure the scour depth throughout the experiment.

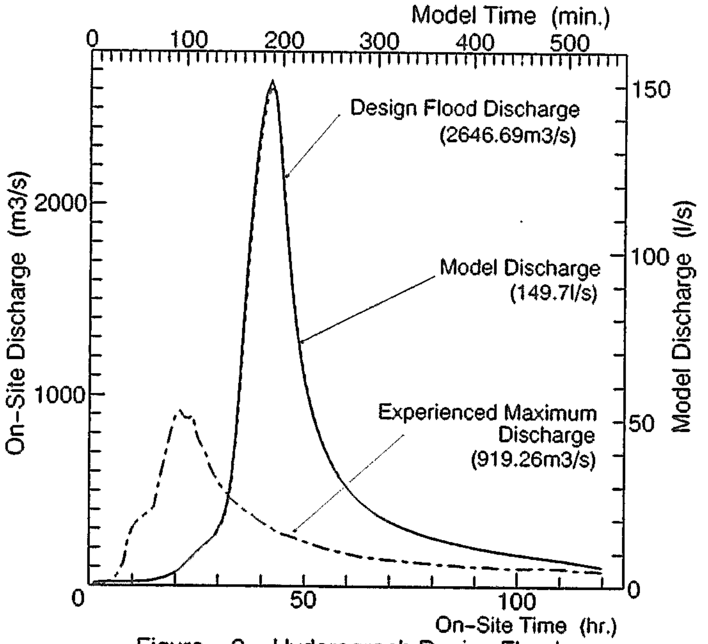

Figure - 2 Hydorograph Design Flood Discharge of Satunai River

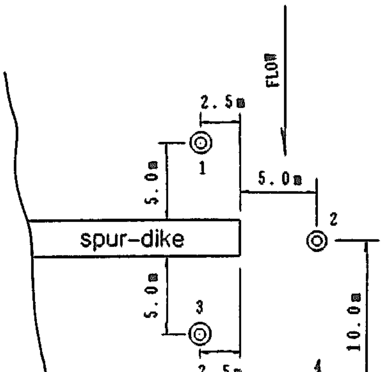

Figure - 3 Plane View of Scour-Obuservation Areas

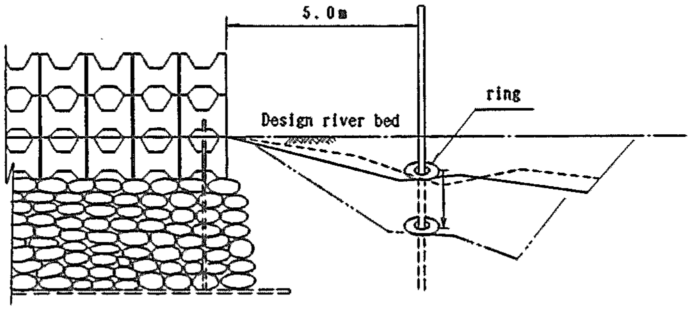

Figure - 4 Cross Section of Scour-Observation Areas

Therefore, we installed erosion depth measurement guages shown in Figures −3 and −4 to measure scour during the flood.

In this method, rings settled as the areas beneath them at the spur- dike heads were scoured by the flowing water; when sedimentation began in the area, sand accumulated on the rings. After the test, sediment was removed down to the rings to measure the maximum scour depth.

Spur dike arrangement and River-Bed Evolution at Spur-dike Heads

Using the experimental results shown in Figure −3, from the spur dikes number 1 to 4. The relationship depth of water(h) and erosion dipth (Zs), the relationship between the ratio of distance between spur dikes to the length of spur dikes(D/L) and the depth of erosion(Zs), and the relation between the length of the spur dikes to river width(L/B) and the erosion depth(Zs) was investigated.

Figures −5 and −6 show the relationship between the flow depth(h) and the erostion depth(Zs) when the hydrograph was that of the snowmelt flood and the design water discharge respectively. In figures −5 and −6, the symbols denote the location of the measurement as shown in Figure −3. The differnce in flow depth between Figures −5 and −6 is large, but the erosion depth(Zs) is similar. As the depth of the flow increases, the scour depth increases also, but only by a small amount, For the snowmelt discharge experiment the erosion depth in front of spur dikes number 1 and 2 is almost the same. However, for the design high water flood (Figure −6) the erosion near spur dike 1 is much larger than erosion at the other spur dikes.

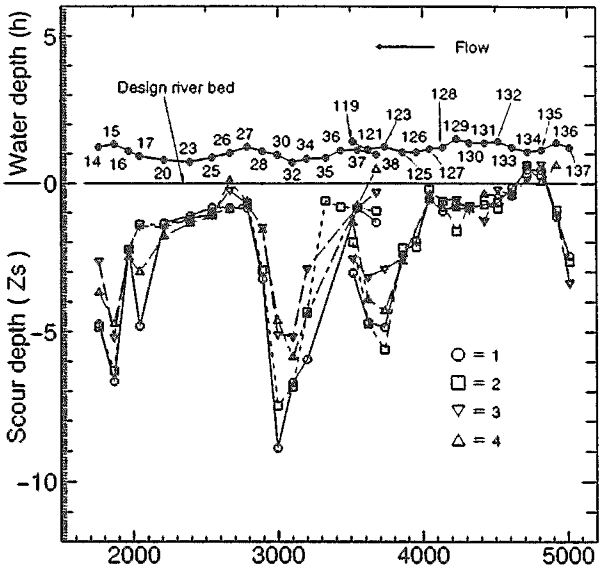

Figure - 5 Relationship between Water depth(h) and Scour depth(Zs)(400m3/s)

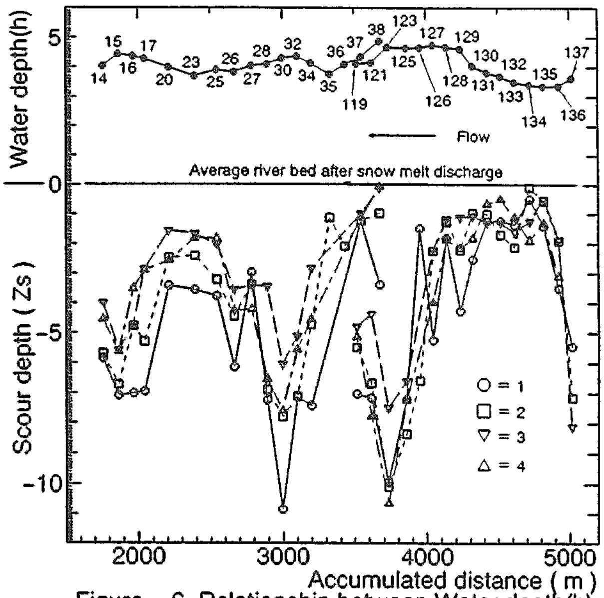

Figure - 6 Relationship between Water depth(h) and Scour depth(Zs)(2646.7m3/s)

Suzuki[1)] presented an example of a spur dike experiment (shown in Figure −7) where there is substantial erosion around the first spur dike and little erosion around the others. Suzuki also showed that when the ratio D/L becomes large, the scour around a spur dike in a train of spur dikes becomes the same as that of a singular spur dike.

In order to check this suggestion made by Suzuki, the relationship between D/L and scour depth Zs is plotted in Figures −8 and −9 for two groups of spur dikes, $No.14 \sim 38$ and $No.119 \sim 137$, as shown in Figure −1. From these two figures, when D/L is smaller and approaches 1, the erosion depth becomes much smaller, When D/L becomes large ($D/L = 2 \sim 3$) the erosion depth becomes large, and is especially large near a meander bend. Therefore, by reducing the ratio D/L in natural rivers it may be possible to reduce the erosion depth.

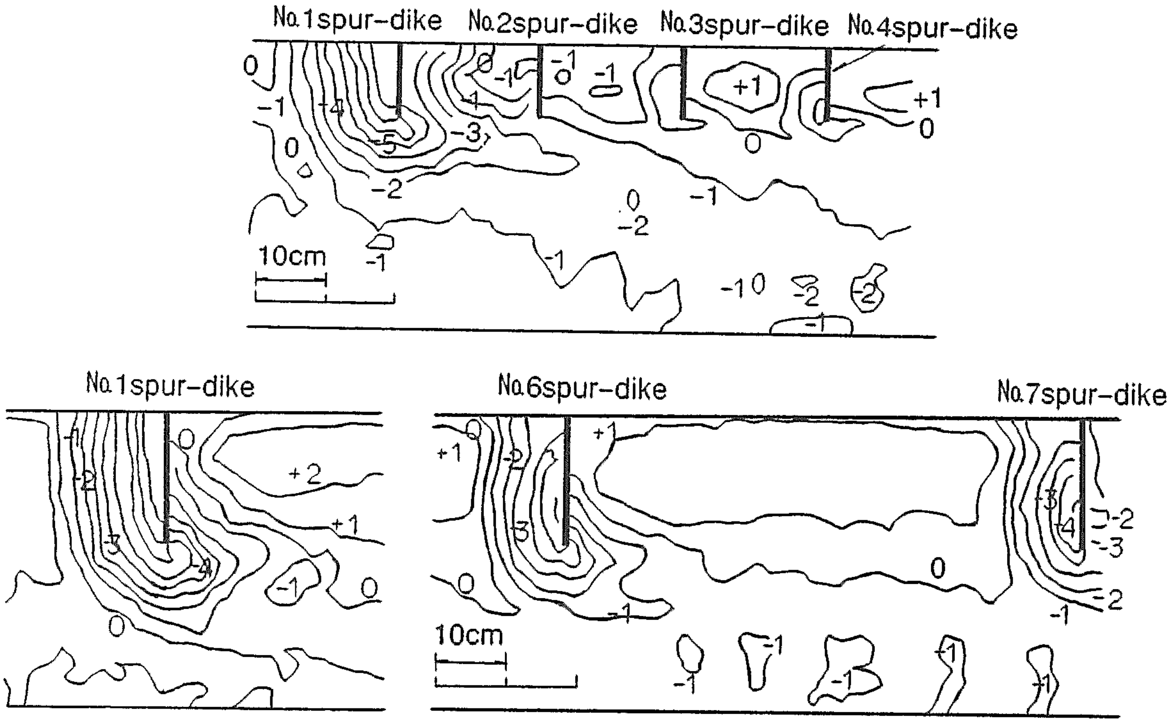

Figure - 7 Bed topography near spur dikes

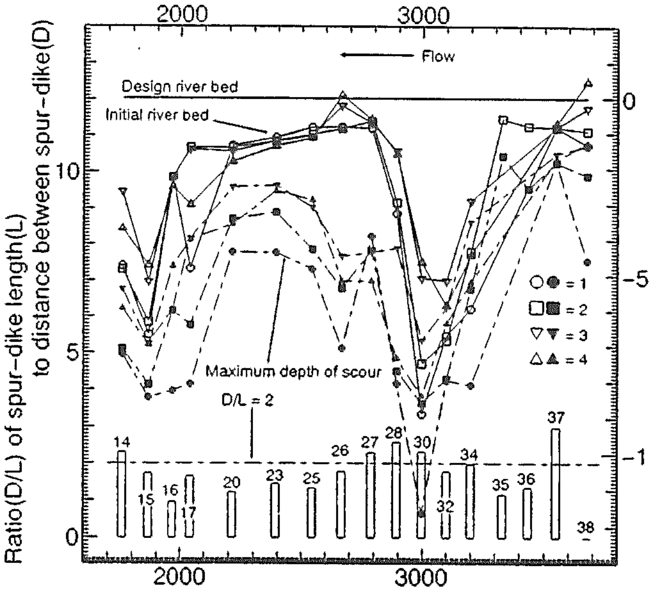

Figure - 8 Relationship between D / L and Scour depth (Left Bank)

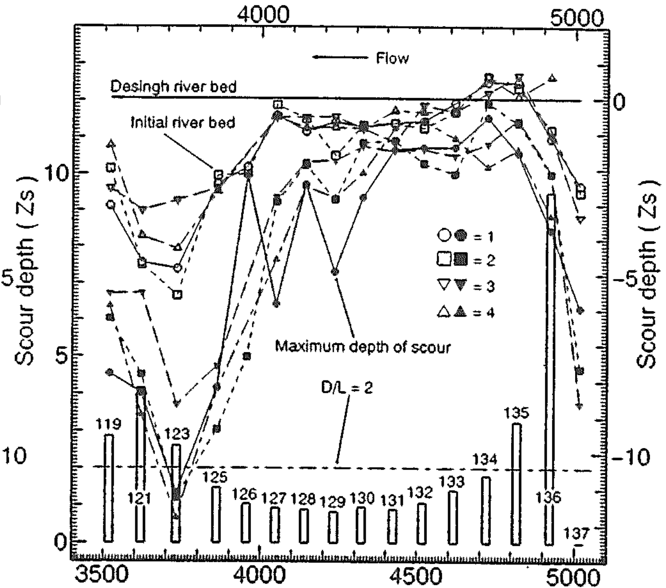

Figure - 9 Relationship between D / L and Scour depth (Right Bank)

The relationship between the ratio of spur dike length to river width L/B and erosion depth are shown in Figures −10 and −11. According to these two figures, when L/B becomes greater than 0.2, the scour depth becomes very small. Also, when L/B becomes less than or close to 0.2, the erosion depth becomes the maximum value. The erosion of the spur dikes is much larger at the inflection points of the meander curve (Figure −1). Except at the inflection points, the erosion depth can be reduced by correctly choosing the characteristics of the spur dikes.

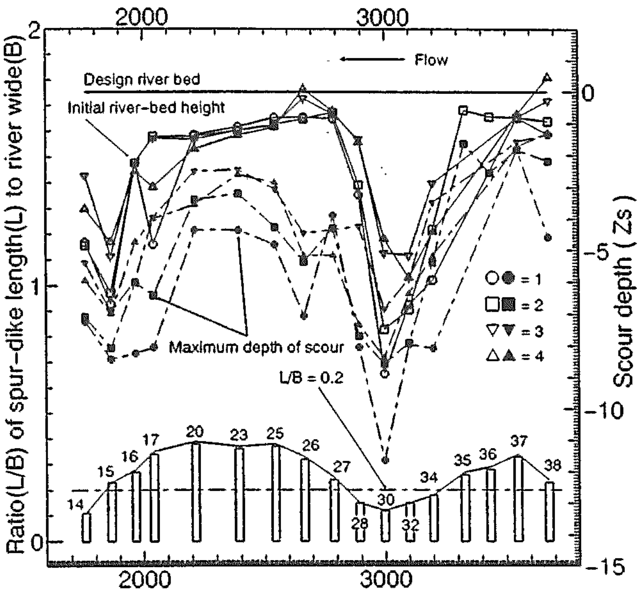

Figure - 10 Relationship between L / B and Scour depth (Left Bank)

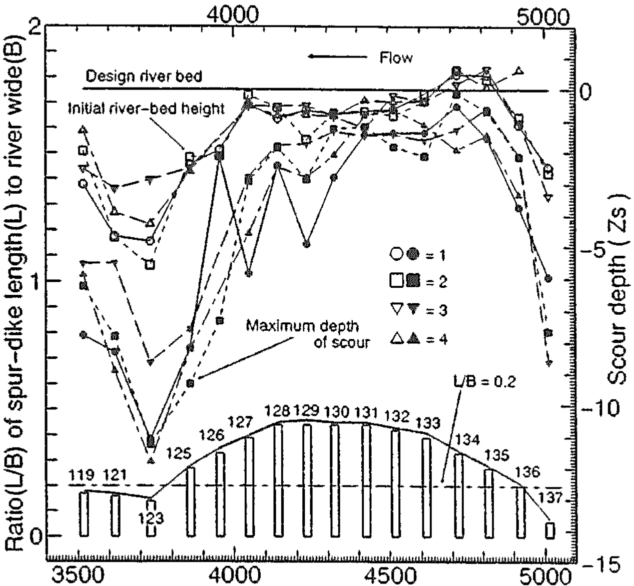

Figure - 11 Relationship between L / B and Scour depth (Right Bank)

The characteristics of deposition were also investigated. Location nunber 2 shown in Figure −3 is expected to be the position where strong flow is diverted from the banks. However, at location, water is diverted from the central current and the erosion depth becomes larger as already shwon in Figures −5 and −6, In this case, when the bed is eroded near the spur dikes, the spur dikes collapse at the end. Thus it is important to stabilize this portion of the spur dikes. Figure −12 shows the characteristics of erosion before the hydrograph, wring the hydrograph, and after the hydrograph.

The erosion depth during the at hydrogragh $No.14 \sim 38$ is $1.05m$ and $3.25m$ and the maximum scour depth is 4.50 and $5.00m$ before and after the hydrograph, For the spur dikes $No.119 \sim 137$ the erosion is 0.5 and $2.75m$ before and after the hydrograph which is much smaller than $No.14 \sim 38$. A few points are eroded 4.25 and $7.15m$ before and after the flood. Most of the places have deposition during the folling limb of the hydrograph, According to the results of an on-site survey near groundsills, using a device to record scouring by Yamashita$^{3)}$ et al., the evolved river bed returns to its original condition. In this experiment using a large-scale model, the same phenomenon was observed near the spur dikes. This was because the river bed was scoured to the maximum at the time of the design-flood dis charge,But, as the velocity was reduced, tractive force diminished, too, and material transported from upstream began accumulating.

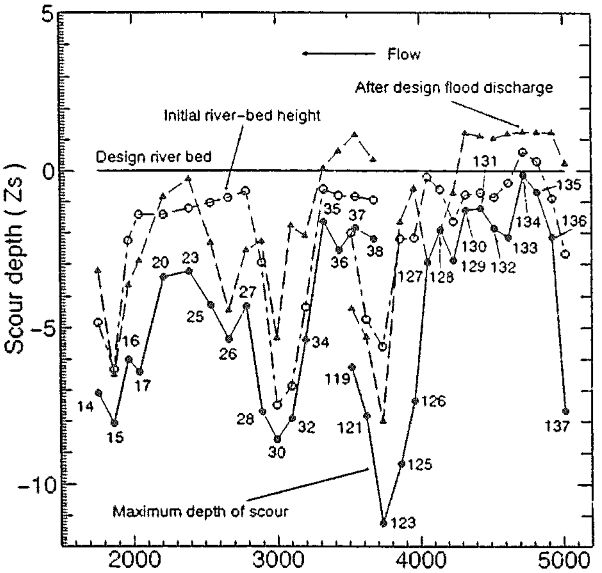

Figure - 12 Rivir-Bed Evolution at Spur-Dike Head Areas

Closing Remarks

In this experiment,it was shown that the maximum scour depth at heads of spur dikes became greater when the discharge was larger, such as at flooding and other times, but the river bed returned almost its original condition after the flooding. It was shown in the experiments that the largest scour occuhred at the inflertion points of the meander curve.

Reference Materials

1) Kouiti SUZUKI,Functions and problems of Hydraulic Structures
2) Suzuki,K.,Michiue,M.and Hinokidani,O.,Local bed from around a series of spur-dikes in alluvial channels,Proc.22nd Congress IAHR,1987
3) Shoji YAMASHITA, Yasuyuki SHIMIZU and Yasuharu WATANABE, River-Bed Evolution near Groundsils in Steep Rivers, Collection of Hydraulic Technology Studies, Vol.36, February, 1992, *pp*.35 ~ 42
4) Hideo KITUKAWA, Revised River Engineering 17, Asakura Shoten, December, 1978
5) Hisashi AKIGUSA, Hideo KITUKAWA, Yoshijiro SAKAGAMI, Kazuo ASHIDA, and Akira TSUCHIYA, Study on Spur Dikes, Report from Civil Engineering Research Institute, Ministry of Construction, October, 1960, *pp*.61 ~ 153