Study of channel morphodynamics and bank failure risk in the Shogawa River under extreme flood scenarios

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Background

The Sho River in Toyama Prefecture is one of the steepest rivers in the country and has historically suffered from large-scale channel morphodynamics and dike breaches. In order to ensure the safety of flood control, various measures have been implemented on the Sho River over the years.

Overflow of the Sho River(1934)

Damage to Sho River revetment(2004)

Reference
国土交通省：庄川のまな災害 https://www.mlit.go.jp/river/toukei_chousa/kasen/jiten/nihon_kawa/0412_shogawa/0412_shogawa_02.html

In recent years, as changes in rainfall patterns in many areas of Japan have led to the frequent occurrence of floods exceeding historical maximum levels , consideration of future rainfall disaster risks has also become essential in Toyama Prefecture.

Issue

In steep-gradient rivers, large-scale floods can cause rapid changes in channel formation, resulting in temporal and spatial shifts of the points of the outer bank areas inside the low-flow channel.

Estimating high risk embankment erosion is difficult.

Objectives

1. Understand the channel morphodynamics and the location of bank failure risk following future changes in rainfall characteristics in the Sho River.
2. Comparing the hazard areas calculated using the latest ALB topography with those classified by the government as Category A (most hazardous) for floods.

Analysis Method

I. Numerical analysis accuracy

1. Reproduce calculations for the historical flood in 2004 (Case 1)
2. Comparison of water surface elevation between the 2004 trace water level and Case 1

II. Examination of each flood scenario

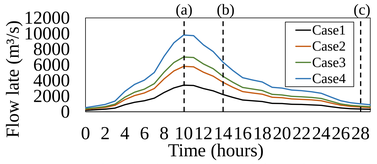


Fig.1 Flow hydrograph used for calculations

Case1: Historical flood in 2004 (peak flow rate: 3,400m³/s)

Case2: Planned high water flood (peak flow rate: 5,800m³/s)

Case3: Excessive flood (peak flow rate: 7,000m³/s)

Case4: Potential maximum flood (peak flow rate: 9,800m³/s)

III. Estimation of disaster risk

1. Identify locations with high levee erosion risk
2. Comparing of the risk map drawn up by the government (Red part in Table.1)

Scope of study and model overview

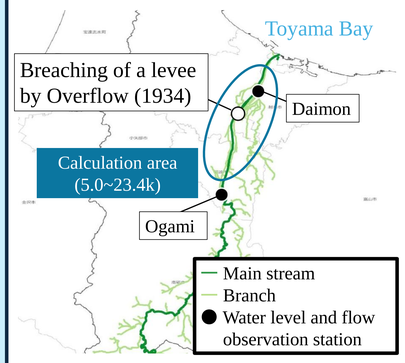
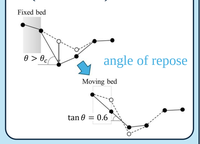


Fig.2 Calculation domain

The calculation software
→iRIC Nays2DH

Data
・Initial topography
→ALB data (2021)
・Average diameter of the bed material
→Upstream areas:50 mm
→Midstream and Downstream areas:75 mm

How to estimate bank (fixed bed) erosion



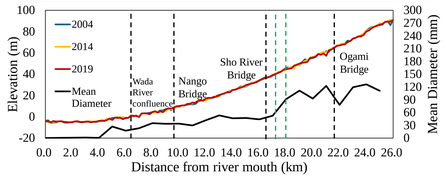


Fig.3 Gradient of riverbed and mean diameter

Results

I. Numerical analysis accuracy

Differences between calculated and trace levels are less than 50 cm at most locations.

*Ignored areas where the location of bank edge line has been changed

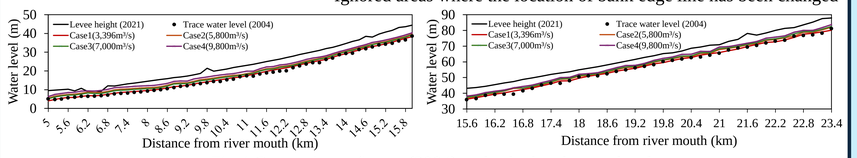


Fig.4 Comparison of trace (2004) and calculated water level
Left) Midstream and Downstream Right) upstream

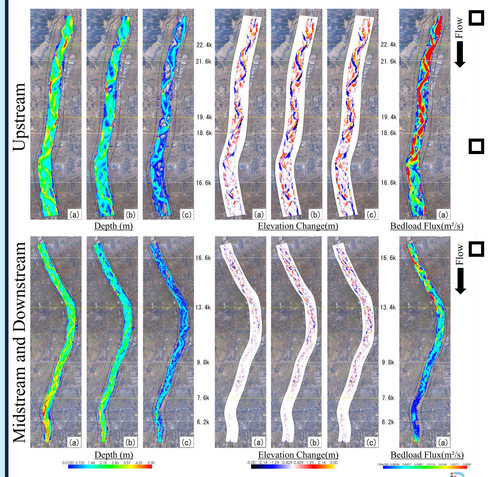


Fig.5 Contour map (Case1)
Left) Depth Middle) Elevation change Right) Bedload flux

- The rate of elevation change is small in the downstream area from 7.6 km. This is due to a gradual slope transition between 4.0 and 5.0 km.
- Upstream from 13.0 km, active channel migration is confirmed under the multi-thread flow.
- In the upstream sections, the meandering shape of the channel and the cut bank (outer bank) are clearly defined compared to the middle and downstream sections. Locations such as left bank 19.4 km and left bank 22.4-22.8 km, where the cut bank was formed before the flood, resulted in embankment damage due to riverbed deepening.

II. Examination of each flood scenario

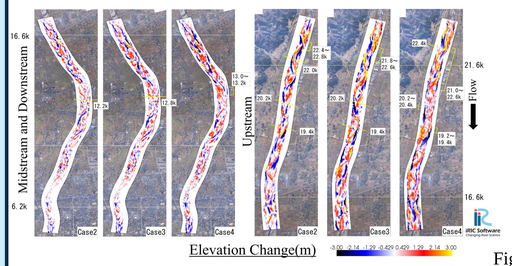


Fig.6 Elevation change (Case2~Case4)

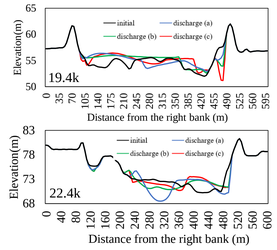


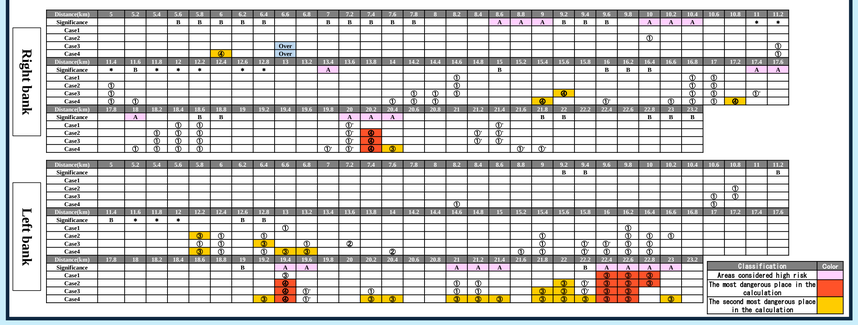
Fig.7 Temporal changes in the cross-sectional diagram at the disaster areas (Case4)

- In Case 2, partial embankment damage was confirmed at 19.4 km on the left bank, 22.4-22.8 km on the left bank and 20.2 km on the right bank, where the water collided before reaching peak flow.
- In Case3 and Case4, the risk of embankment failure due to overtopping was confirmed near the confluence with the Wada River on the right bank at 6.6 km. In addition, the increased flow rates resulted in more areas where the channel flowed along the embankment, increasing the risk of erosion. In specific, calculations showed that the embankment was damaged along the longitudinal direction for approximately 2 kilometers around the left bank at 22.4 km.

III. Estimation of disaster risk

Table.1 Comparison of government risk map (2023) and calculation results (5.0 to 23.2k)

① Damage to low-water bank protection due to deep riverbed erosion
② Damage to low-water bank protection due to high-water channel erosion
③ Damage to levee bank protection due to deep riverbed erosion (including channel migration)
④ Damage to levee bank protection due to high-water channel erosion



Conclusion

- In all cases, levee breach was not confirmed. However, levee bank erosion was observed in several areas. In addition, the location of bank erosion are shifted as increasing flow rate.
- In steep-gradient rivers, significant changes in channel location occur with each major flood event. It is therefore essential to update the information by obtaining new riverbed elevation data. In addition, accuracy of the calculations must be updated for each subsequent major flood.