# Evaluation of Micro-Topographies in Riverside Areas to Estimate High Flood Disaster Potential by Using DEM Data

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**Abstract**

In this study, the Mikasa River in Fukuoka City and the Ooyodo River in Miyazaki City are selected in flood plains. We want to show variable background of flood disasters in drainage areas of both rivers by using free downloadable geographic information of Japan. We made relief maps by GIS using 5m DEM and classified several micro-topographies concern to overflow and/or inundation. The topographies are dike, slope of dike, river side, water area, lowland, natural levee and others. Average elevation of the topography is calculated in each section of the river. Relative elevation to a referenced topography was calculated and longitudinal profiles on each of the topography were made by Excel. We confirmed the areal relation between the convex curves of the longitudinal profiles and the river conditions of existence some barriers such as weirs, bridges, confluence of tributaries, flection of the rivers and bottleneck sections. We also confirmed the relation between the convex curves of the profiles and previous flood conditions, where overflow points and/or inner water flooding areas existed. Consequently, we clarified that it is easy to recognize the vulnerable section or area for natural disaster of inundation from the analysis of geomorphic quantities on micro-topographies.

**Keywords**: micro-topography, 5m DEM, longitudinal profile, the Mikasa River, the Ooyodo River

## 1. Introduction

In Japan of the humid monsoon region, the disasters by flood and storm surge induced by rainy season and typhoons are likely to occur every year. Residential and cultivation areas are damaged by the flood that develop micro-topographies such as natural levee and back marsh by the overflowed sediments. Newer residential area has developed at the back marsh with lower grand elevation by urbanization in Japan. Such area is often to suffer damage induced by inundation in flooding.

Because it is believed that we can predict the characteristics of flood damage from the distribution and topography of micro-topography, researchers tried to classify the topographies qualitatively using by aerial photographs (Ohkura et al., 1989) or satellite images (Oya, 1975). The classification on micro-topography is used in making disaster maps. Usually there is a damage size difference in the same topography areas because of the ground elevation difference. In this study, we evaluated each topography class quantitatively by GIS analysis using 5m DEM. We clarified the characteristics of the elevation change on each of the topography in the longitudinal profile and yielded factors of the change at where the flood damage is likely to occur. Then we discussed the evaluation method to define weak areas for natural disaster such as overflow or inundation by flood using the characteristics of the change.

## 2. Research Methods

### 2.1 Case Study Areas

We selected the Mikasa River as a small example and the Ooyodo River as a large example of Japanese river (Fig.1).

The Mikasa River is a class B river flowing through the northern part of Fukuoka Prefecture. Its stream length is approximately 21km and its catchment area is approximately 90km$^2$. Approximately 12km length upstream from the river mouth is selected as our study area. We set 119 analysis sections for the river. Each size is approximately 150m wide and 100m length. Large areas were inundated by the river water and a large amount of sediment was deposited in the Mikasa River basin by the flood induced by the heavy rain of rainy season in July 2003 (Kuroki et al., 2012). Mountains and hills of granite are distributed upper stream area of the river.

The Ooyodo River is a class A river flowing through the southern part of Miyazaki Prefecture. Its stream length is approximately 107km and its catchment area is approximately 2,230km$^2$. Approximately 29km length upstream from the river mouth is selected as our study area. We set 116 analysis sections for the river. Each size is approximately 1,000m wide and 250m length. Large areas were inundated inside the levee and a large amount of sediment was deposited in the downstream of the Ooyodo River basin by the flood induced by the heavy rain due to the typhoon no.0514 in September 2005 (Iso et al., 2006). The Ooyodo River is flowing through the valley bottom plain or coastal plain. They are surrounded by the mountains and hills consisting of Neogene and pyroclastic flow plateau consisting of Ito pyroclastic flow.

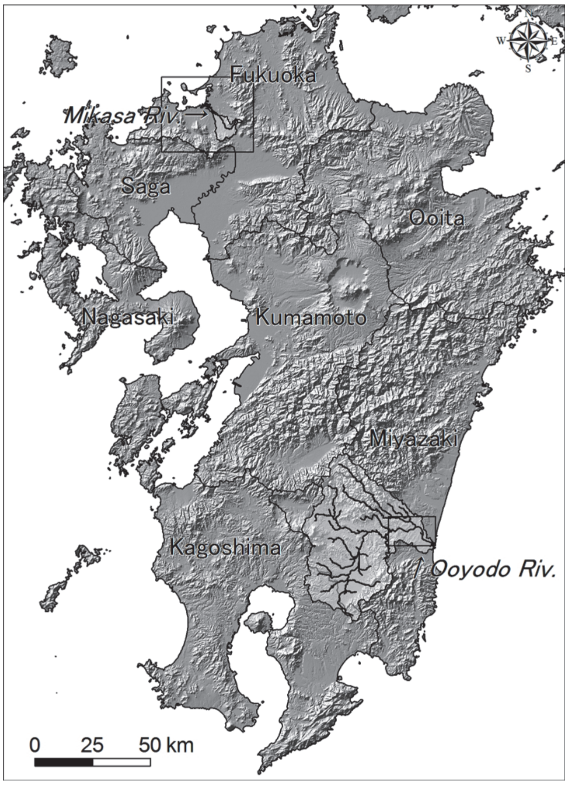


Fig.1 Study areas and Rivers in Kyushu Island

### 2.2 Classification and Calculation on Topography

The micro-topographies are dike, slope of dike, river side, water area, lowland, natural levee and others (Fig.2). We made two kinds of relief maps by GIS calculation using 5m DEM and classified these topographies by using the maps. Average elevation of the topography is calculated in each section of the river. Then relative elevation on the basis of the lowland or water area was calculated and longitudinal profile by the elevation on each of the topography was made by Excel. On the Mikasa River, we confirmed the areal relation between the existence of weirs and bridges and the forms of longitudinal profiles, and between the forms and overflow sections. On the Ooyodo River, we confirmed the areal relation between the river conditions such as confluence of tributaries, flection of the rivers and bottleneck sections and the forms of longitudinal profiles, and between the forms and inundated sections inside the levee. Then we discussed how vulnerable sections to the inundation should be clarified from the longitudinal profiles made by the ground elevation data on micro-topographies.

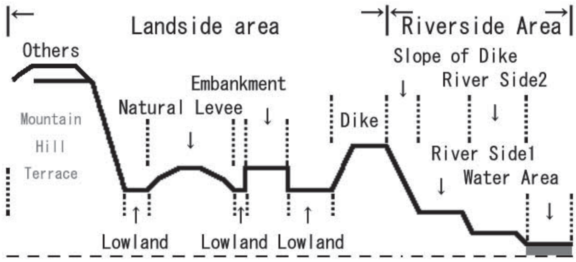


Fig.2 Topography classification of the Ooyodo River

## 3. Result and Discussion

### 3.1 The Mikasa River

In the longitudinal profiles on relative elevation on each of the topography, we can identify some convex curves caused by increasing of the elevation toward the downstream. Convex curves constituting multiple sections are clear in the profiles on relative elevation to lowland (Fig.3). In the lower part of Fig.3, a table on analysis sections with the weirs and bridges, and the overflowing was attached.

On the relative elevation of riverside, the minimum value is -4.76m and the maximum one is 0.07m. Each convex curve was constituted by over 10 sections. In a convex curve, relative elevation gradually increases and rapidly decreases toward the downstream. There are convex curve a (from section 117 to 101), convex curve b (from section 100 to 65), convex curve c (from section 64 to 46) and convex curve d (from section45 to 01). Weir 3, 6 and 7 are located at the downstream ends of the each convex curves a, b and c, and the sea is located at the downstream end of the convex curve d. This means that the speed of moving fluid decreases and the sediment accumulates affected by the weir and sea at the downstream end of the convex curves. In Fig.3, many small convex curves constituting approximately 500m long of about 5 sections can be also identified. The extreme value of the curve is easily recognized in the section with a bridge. Section 96, 80, 42 and 33 having extreme values show clear correspondence with the bridges and do not close to the weirs. This fact means that speed of moving fluid decreases and sediment accumulates affected by the bridges.

Overflowing sections can be identified area 1 (from section 102 to 101), area 2 (from section 92 to 63) in upstream, and area 3 (from section 36 to 15) in downstream. Each area is located at the sections with higher relative elevation in convex curves a, b and c. Overflow occurred at a lot of small areas including one section and two sections too. In the upstream of the section 60, we can confirm clear correspondence of the overflowing area 1 to weir 3, and the overflowing area 2 to weir 4, 5 and 6. In the downstream of the section 60, we can confirm clear correspondence of the overflowing sections to bridge 18, 19, 20 and 26. These facts mean that weirs, sea, bridges disturbed river flow, speed of moving fluid decreased, flood level increased, and finally overflow was induced.

Therefore, we can identify the depositional condition outside of the dike by the longitudinal profiles on relative elevation of river side and estimate the location with easy overflowing.

In Fig.4, convex curves A to G can be identified. In each convex curve, the relative elevation increases and then decreases towards the downstream. The amplitude of the convex curve is the maximum about 10m and its wavelength is longer than 2.5km of 10 sections. The convex curve A indicates that the sediment deposit easily there by the confluence of the river to the sea. Since tributaries do not always concentrated near the sections with extreme values of other curves, the reason of the development of the convex curves is not the confluence of tributaries here. Considering the topography setting, because flection and bottleneck part of the river are close to the sections with extreme values of the curves, they seem to be the forming factors of the profiles. The higher topography's extreme value of the curve is larger. The difference value of relative elevations between the topographies maximizes near the center and minimizes near the both ends in an extent of the each curve. The sections with extreme values of the topographies outside of the dike are located approximately 5 sections downstream than those of

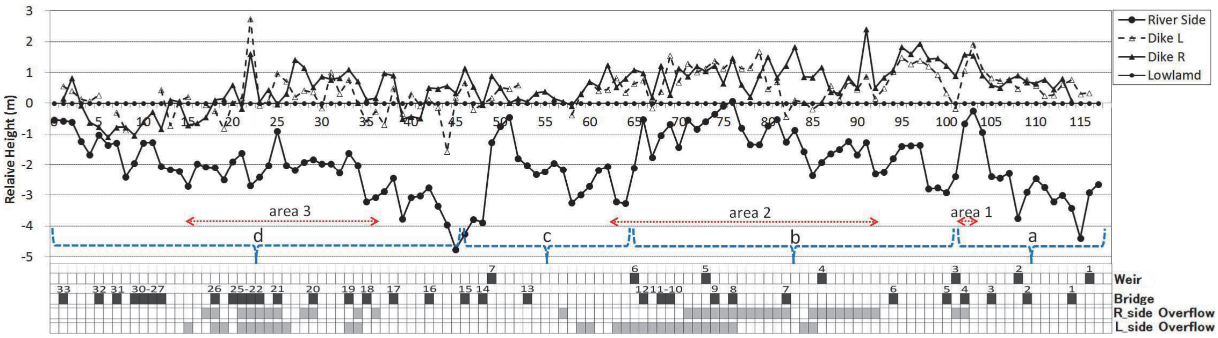


Fig.3 Longitudinal profiles of the Mikasa River and river conditions relating overflow

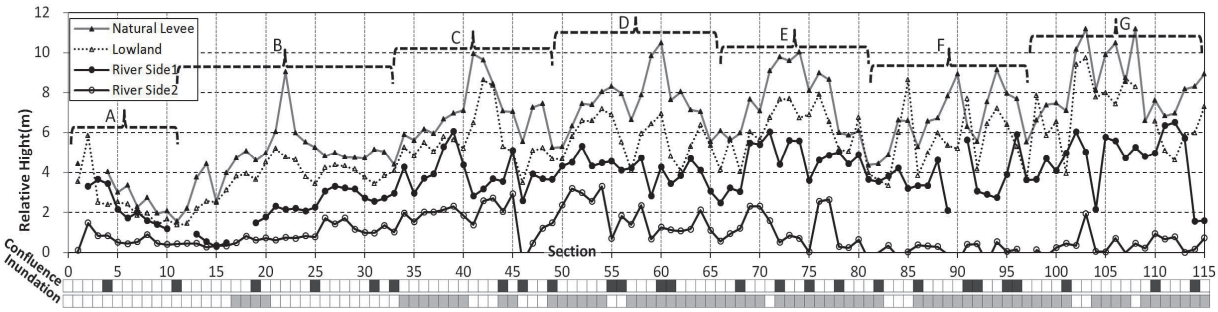


Fig.4 Longitudinal profiles of the Ooyodo River and river conditions relating inundation

the topographies inside of the dike.

Additionally, many small convex curves with approximately 1 km length by 4 sections can be identified. The extreme value of the small curve tends to appear on the section with the confluence of tributary. This fact means that sediment remarkable accumulates near the section with the confluence of tributary. On the small curve, the sections with extreme values of the topographies outside of the dike are located 1 or 2 sections downstream the topographies inside of the dike.

### 3.2 The Ooyodo River

In the longitudinal profiles on relative elevation on each of the topography, we can identify some convex curves caused by increasing of the elevation toward the downstream. The curves constituting the analysis sections are clear in the profiles on relative elevation to water area (Fig.4). In the lower part of Fig.4, a table on analysis sections with the confluence of tributaries and the inundation by overland flood was attached.

We discussed the estimating method for inundated sections by using the waveform shift in the profiles on relative elevation of the topographies. Fig.5 shows an analyzed result on the Honjo River of the Ooyodo River tributary. The difference values of relative elevation between river side1 and river side2, lowland and river side1, and natural levee and lowland are shown in it. In the graph on lowland and river side1, concave curves appear close to the inundated analysis sections 4 and 20. In other graphs, concave curves do not appear close to them clearly.

Therefore, in the graph on the difference values of relative elevation between lowland and river side1, we can estimate the inundated sections inside the levee from the concave curves and not inundated sections from the convex curves exactly.

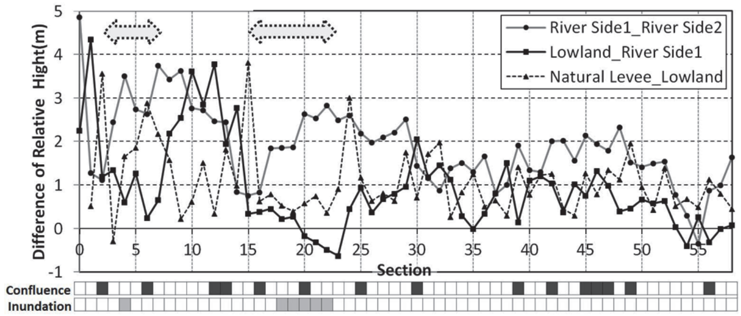


Fig.5 Difference values of relative elevation of the Honjo River

## 4. Conclusion

Consequently, we clarified that it is easy to recognize the vulnerable section and area for natural disaster induced by flood from the analysis of geomorphic quantities on micro-topographies.

Results of analysis using the longitudinal profile made by the relative elevation of riverside of the Mikasa River are as follows.

1) In the profile, convex curves of over 1km long and small convex curves of approximately 500m long can be identified.

2) Sea and weirs are located at the downstream end of the former curves and bridges are located at the sections of the latter curves. These facts indicate that the relative elevation rise by the sediment deposition due to decreasing the speed of moving fluid.

3) Overflows occurred at the downstream sections of the former curves and at the sections of the latter curves. Therefore, we can estimate the overflowing sections easy by the longitudinal profiles on relative elevation.

Results of analysis using the longitudinal profile made by the relative elevation of riverside of the Ooyodo River are as follows.

1) In the profile, convex curves of over 2.5km long and small convex curves of approximately 1km long can be identified.

2) Flection and bottleneck part of the river and sea are located at the center sections of the former curves and the confluences of tributaries are located at the sections of the latter curves. These facts indicate that the relative elevation rise by the sediment deposition due to decreasing the speed of moving fluid.

3) On the curves and the small curves, the sections with extreme values of the topographies outside of the dike tend to be located a little downstream from those of the topographies inside of the dike.

4) In the graph on the difference values of relative elevation between lowland and river side1, it is easy to estimate the inundated sections inside the levee from the concave curves and not inundated sections from the convex curves.


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