# Topographic and Geological Features Involved in Water Leakage at Levee Foundations and in Levee Body Deformation by Piping on the Kakehashi River

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## INTRODUCTION

The authors investigated on the Kakehashi River (Ishikawa Pref., Hokuriku District, Japan) and found water leakage at the levee foundation were observed near the former river channel. However, such water leakage does not always occur at a place where a levee and a former river channel cross, so it is critical to accurately predict vulnerable places in a levee so that monitoring can focus on these places. The present study compares the data from these model experiments to data on observed soil properties and soil compositions of the levee where deformation occurred on the Kakehashi River in order to improve the accuracy of a method for identifying vulnerable locations in a levee.

## METHOD

Aerial photos taken by the U.S. military (Geospatial Information Authority of Japan, 1946&1947) were chiefly used for identifying the former river channels of the Kakehashi River by using a stereoscope (magnification x3; field of view: 70mm).

Based on the map of the former river channels and a longitudinal geological profile, the relationship between the locations of water leakage (Figure 2) and their foundation ground soil properties was summarized.

Thus, for each cross-sectional surface where boring survey was conducted, the soil properties and the thickness of the surface layer up to 3m thick near the toe were investigated(Figure 5.)

Thus, for each cross-sectional surface where boring survey was conducted, the soil properties and the thickness of the surface layer up to 3m thick near the toe were investigated. These and the permeability coefficient (hereinafter: "k") of the underlying gravel bed (the permeable layer) are summarized in a schematic. (Figure 5.) Locations of water leakage were analyzed in relation to the thickness of the surface layer and k of the permeable layer. The particle size composition of the surface layer was also analyzed toward understanding its association with types of water leakage(Figure 11.)

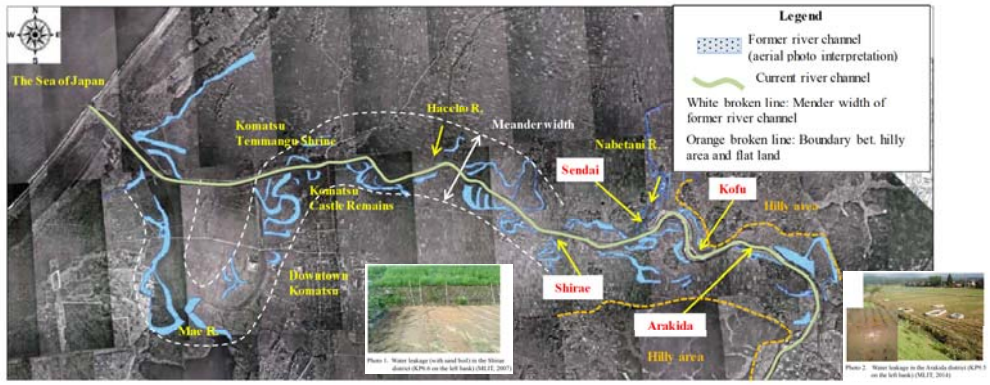


Figure 1. The former river channels of the Kakehashi River identified in U.S. military aerial photos, and places of water leakage (MLIT, 2008)

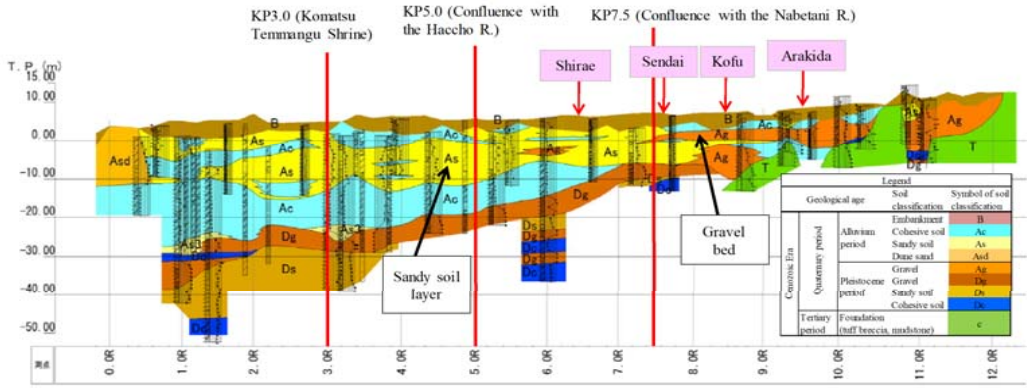


Figure 2. Longitudinal geological profile along the levee on the right bank of the Kakehashi River (MLIT, 2014)

## RESULTS

Water leakage took place on the river section upstream of the Haccho River. On that section, a bed of highly permeable gravel is distributed in the foundation layer(Figure 1,2.)

Water leakage occurred at places where cohesive soil is distributed near the ground surface, the surface layer is 1~3m thick, and the k of the permeable layer is at least 10-4m/s(Figure 5.)

At KP8.4 on the right bank, the minimum safety factor is 1.046, which is higher than 1; thus, sliding failure did not occur (Figure 8.) A portable cone penetration test conducted after the levee failure. indicates that part of the sand layer in the foundation ground is relatively weak. Because the location, shape and the dimensions of the weak part are consistent with those of the calculated circular sliding surface, it is possible that the sliding failure was due to a decrease in the effective stress caused by an increase in hydrostatic pressure(Figure 9.)

At KP8.6 on the right bank, even when the strength of the sand layer decreases because of failure due to piping (on the assumption that the angle of shear resistance $\phi$=0 ), the safety factor is 1.149. A safety factor higher than 1 means that sliding failure does not occur(Figure10.)

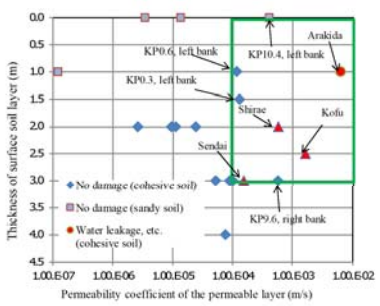


Figure 5. Relationship between the permeability coefficient of the permeable layer and the thickness of the surface layer

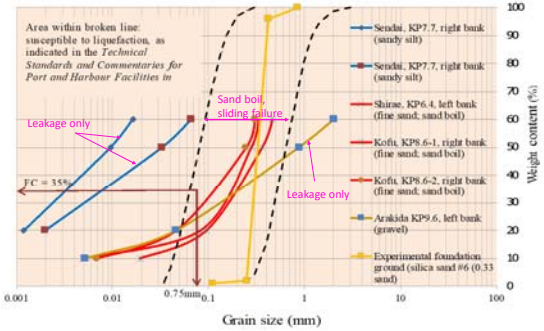


Figure 11. Grading curves for the soil of sand boil sites

Photo 3. Site of sliding failure near KP8.4 on the right bank (MLIT, 2014)

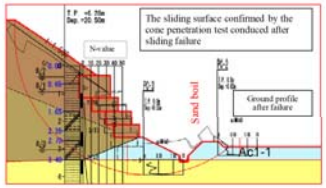


Figure 9. Portable cone test results for KP8.4 on the right bank (MLIT, 2014)

Photo 4. Sand boils near KP8.6 on the right bank (MLIT, 2007)

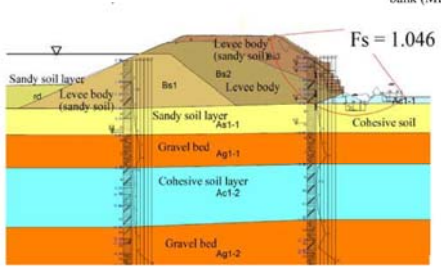


Figure 8. Geological profile at KP8.4 on the right bank (MLIT, 2014)

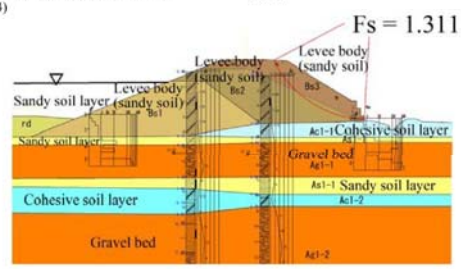


Figure 10. Geological profile at KP8.6 on the right bank (MLIT, 2014)

## CONCLUSIONS

1. Judging from the configuration of the former river channels identified in aerial photos, water leakage at the levee foundation took place at the boundaries between meander channels on floodplains and braided channels on alluvial fans or valley bottom plains(Figure1,2.)
2. The particle size composition of soil susceptible to sand boils is in the range of particle sizes associated with liquefaction. Water leakage alone took place in soil consisting of particle sizes outside that range(Figuer11.)
3. Regarding the levee body deformation at KP8.4, it is likely that the circular failure occurred due to a decrease in shear resistance caused by soil particle movement in the sand layer of the foundation ground(Figure8,10.)