Channel Response to an Extreme Flood Event in the Tokachi River Basin

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INTRODUCTION

In August 2016, three typhoons struck Hokkaido within two weeks, and the fourth Typhoon Lionrock caused heavy precipitation in the Tokachi River Basin from August 29 to 31, inducing landslides and debris flows in the headwaters of the Hidaka Mountains. Sediment discharge from hillslopes triggered morphological changes throughout the basin, causing bed aggradation and channel widening. Due to flooding and bank erosion, residences, roads, and farmlands were severely damaged in some areas, while only small local changes could be observed in some other adjacent rivers. River banks were a major sediment source in this event, which implies the necessity to consider longitudinal and lateral sediment connectivity in understanding catchment scale sediment delivery process. In this study, morphological changes of six tributaries in the Tokachi River Basin were compared to elucidate major conditions (geomorphology, discharge, geology, channel works) affecting channel response and sediment connectivity at catchment scale.

STUDY SITE & METHODS

Figure 1 shows the geological features of six tributaries in the western part of the Tokachi River Basin (Zorin, Kyusan, Pekerebetsu, Memuro, Bisei, and Tottabetsu). The headwaters of the Zorin, Kyusan, Pekerebetsu, and Memuro Rivers are underlain by weathered granite, and periglacial slope deposits (includes weathered granite rocks and sand) form rather low gradient slopes (2-10 degrees). The Hidaka Super-Group which consists of sedimentary rocks is, distributed in the headwaters of Bisei, and gabbro lies in the upper reach of Tottabetsu. Also channel work distribution varies in the six tributaries as shown in **Figure 1**.

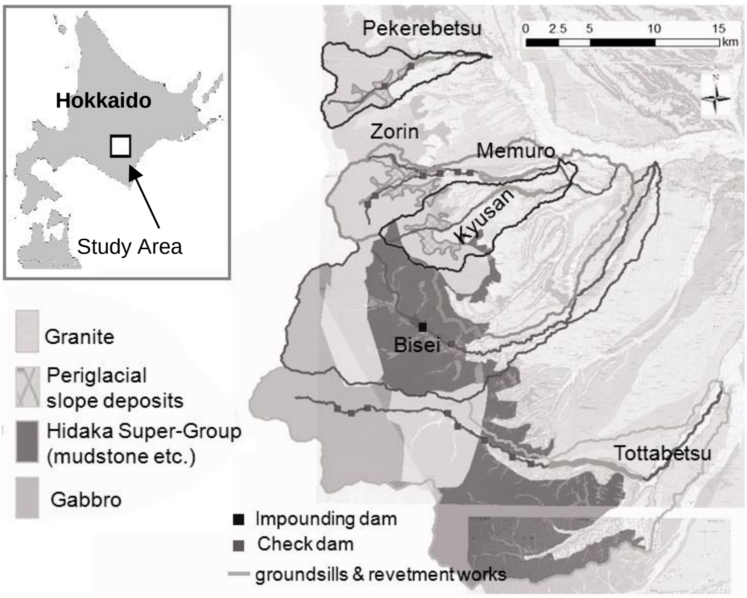

Figure 1 Geological features and channel work location in study site. Adapted from "Geologic Map of the Central Part of the Tokachi Plain" "Geologic Map of the Southern Part of the Tokachi Plain", Tokachi Subprefectural Office of Hokkaido, 2001.

This region is usually dry in summer, but 531 mm of precipitation was recorded the Tottabetsu gauge station during the 72-hour event, accounting for a half of the average annual precipitation. Aerial photos and LiDAR data were combined with field surveys to understand the sediment delivery process during the event. Channel width changes in the six tributaries were compared to determine how morphology, discharge, geology, and channel works affected the responses. Active channel widths were measured every 100 m along the river courses from aerial photos taken in 2014 (before the event) and in October 2016. Widening caused by lateral erosion and by deposition upstream of check dams were distinguished by bed elevation change estimated from LiDAR data. Generally, channel width and discharge are assumed to follow the regime theory, as expressed by Eq. 1,

$$W = aQ^b \tag{1}$$

where W is the channel width, Q is discharge, and a, b are coefficients.
By replacing the discharge by the catchment area, it can also be expressed as Eq. 2,

$$W = cA^d \tag{2}$$

where A is the catchment area, and c, d are coefficients. If the rivers follow the regime theory, channel width is assumed to correspond to discharge, and if not, other conditions such as geological features or channel work distribution are expected to control channel width. The relationship between catchment area and channel width every 500 m along the course were observed to elucidate the factors affecting channel response.

CHANNEL WIDTH CHANGE

Four tributaries with granite and periglacial deposits upstream (Zorin, Kyusan, Pekerebetsu, and Memuro) showed significant widening throughout the catchment, while relatively small local changes were observed along the Bisei and Tottabetsu. At one part of the Pekerebetsu, channel width was 10 m prior to the event, and the flood expanded it to 230 m. In the four rivers, debris flows were produced from weathered granite in the headwaters, bed aggradation occurred in the "debris-flow deposition zone" (bed slope: 2-10 degrees), and channels were widened by lateral erosion of periglacial deposits, which supplied sediment downstream. The increased sediment input also caused aggradation and widening in the lower reaches, producing sediment from the floodplain. This process was considered to have been repeated downstream, causing channel widening throughout the catchment. In contrast, not much change was noted in the "deposition zones" for the Bisei and Tottabetsu, although several debris flows were confirmed. Since the Hidaka Super- Group and gabbro are less erodible than periglacial deposits, relatively small amounts of sediment were yielded from the banks of these two rivers. All six rivers roughly followed the regime theory prior to the event, but only the Bisei and Tottabetsu matched the relationship after the event. Channel changes in the other four rivers seemed to be controlled by variable geological conditions and channel work distribution. The channel was forced to narrow downstream of check dams, in reaches with revetment works, and in areas where the bedrock was exposed, while widening occurred at the exit of contraction reaches and upstream of check dams. No significant bed change was observed in the confined reaches, which implies the function of transporting sediment to the lower reaches, retaining longitudinal connectivity in the catchment. In contrast, the check dams became a longitudinal "disconnectivity", impeding downstream sediment delivery and scaling down the repeated process of widening, which mitigated the impact on the lower reaches.

CONCLUSION

The sequence of aggradation and lateral erosion processes resulted in widening of the whole catchment. Variable geological features and channel work distribution controlled longitudinal and lateral sediment connectivity, which affected catchment-scale channel width change.

Keywords: Channel response, Widening, Sediment connectivity