Landslide dams caused by the M7.8 Kaikoura Earthquake

Yosuke YAMAKAWA[1*], Daizo TSUTSUMI[2], Toru SHIMADA[3],
Brenda ROSSER[4], Sally DELLOW[4], Chris MASSEY[4],
Wataru SAKURAI[5] Syoki TAKAYAMA[6], Kazuki KITO[6] and Tomomi MARUTANI[7]

[1] Graduate School of Life and Environmental Sciences, University of Tsukuba, Japan
[2] Disaster Prevention Research Institute, Kyoto University, Japan
[3] Kokusai Kogyo, Co., Ltd., Japan
[4] Institute of Geological and Nuclear Science, New Zealand
[5] National Institute for Land and Infrastructure Management, MLIT, Japan
[6] Graduate school of Science and Engineering, Ritsumeikan University, Japan
[7] Graduate School of Agriculture, Hokkaido University, Japan
* Corresponding author. E-mail: yamakawa.yosuke.ga@u.tsukuba.ac.jp

INTRODUCTION

The M7.8 Kaikoura Earthquake on November 14, 2016 triggered more than 200 landslide dams in the mountainous area of Northern Canterbury. Four of them, the landslide dams on the Hapuku, Linton, Towy, and Leader River, had the greatest potential risk downstream if the dams were to breach. Institute of Geological and Nuclear Science (GNS Science), Environment Canterbury (ECan), New Zealand Transport Agency (NZTA), and the Kaikoura District Council installed monitoring sensors and cameras at each river, and instituted an early warning system to prevent a flood disaster if a landslide dam broke. Understanding the natural process of sediment transport, including landslide dam formation and outburst floods, can be very important for preparing an evacuation system and countermeasures. We plan to compare the differences and similarities between the landslide dams caused by the Kaikoura Earthquake and the ones in Japan. As a preliminary study, a team from the Japan Society of Erosion Control Engineering conducted field investigations in Northern Canterbury from 7 to 12 April 2017 with support from GNS Science, ECan, and the Kaikoura District Council. Here, we present an outline of the disaster caused by the magnitude 7.8 Kaikoura Earthquake, describe several landslide dams in detail, and compare the natural conditions leading to the formation of or overtopping/breach of landslide dams in Kaikoura.

1. Hapuku (42°14.636'S, 173°40.192'E)

The landslide dam on the Hapuku River (Fig. 1) was the highest (about 150 m high) of the dams triggered by the M7.8 Kaikoura earthquake and covered an estimated 656,430 m^2, with 12,000,000 m^3 of collapsed rock (Rosser, 2017). The landslide was a rock avalanche. The bedrock geology of the watershed is dominated by greywacke (a variety of sandstone). Numerous shallow landslides also occurred along the Hapuku River. The main dam crest, which was monitored by a live camera installed by Kaikoura District Council, overtopped on 6 April 2017, after which the water level of the lake behind the dam decreased rapidly, although it did not empty. Rapid increases in flow depth due to the overtopping were observed about 11 km downstream from the dam, at State Highway 1, on a water level recorder installed and operated by NZTA.

Fig. 1 Landslide dam on the Hapuku River

2. Linton (42°20.866'S, 173°27.933'E)

The landslide avalanches caused a landslide dam in the upstream reaches of the Linton River. GNS Science estimated the source area at 95,000 m^2 and the source volume at 851,027 m^2. The source was composed of greywacke (Rosser, 2017). Overtopping had already occurred before our visit on 11 April 2017. A significant decrease in the water level of the lake from April 1 to 7 suggested an outbreak due to overtopping (Environment Canterbury, 2017). On 11 April, we observed an eroded channel on the dam cause by the overtopping.

3. Towy (42°26.727'S, 173°13.216'E)

A large landslide caused a landslide dam on the Towy River, a tributary of the Conway River. The landslide had an estimated area of 62,000 m^2 and 508,827 m^3 of collapsed rock. The bedrock geology of the watershed is dominated by greywacke (Rosser, 2017). According to Environment Canterbury (2017), the reservoir water level increased rapidly from 16 to 18 November; the highest risk of overtopping was on 18 November. Water seepage was found on the downstream slope of the dam on 21 November. Partial erosion and collapse of the dam body due to water seepage and headward erosionwas confirmed on 23 November. The dam was eroded by overtopping flow from 28 November to 5 December. We observed water in the Towy dam lake on 11 April. However, the risk of flood caused by a dam breach was considered to be low because the dam height was already low.

4. Leader (42°35.215'S, 173°13.070'E)

The Leader dam was caused by a large landslide that occurred at the left bank of the Leader River, located near Waiau, the suspected epicenter of the Kaikoura Earthquake. According to GNS Science, there was 2–3 million m^3 of collapsed soil, a landslide area of 190,000 m^2, 1,000 m runout of the collapsed soil, a dam lake of 0.1 km^2, and a 20-m-high dam at the site (Rosser, 2017). Overflowing occurred on Feb. 13–14; the total estimated water discharge was 400,000 m^3, at a rate of 15 m^3/s, and the water level decreased by 4 m (Archibald & Della-Pasqua in prep). In the field survey, we estimated that the water depth overflow was around 50 cm. The overflow water flowed in a cascade from the existing terrace, and not over the collapsed soil, because the collapsed soil deposited on the original river bed diverted its course towards the right bank. The erosion at the overflow point likely did not occur quickly because the water was flowing over hard bed rock.

CONCLUSION

The M7.8 Kaikoura Earthquake caused many large landslide dams with risks for breach and the landslide dam on the Hapuku River was actually eroded by overtopping flow. In future studies, we plan to collect additional information on landslide dams and compare the natural conditions of the landslide dams in Kaikoura with those in Japan, to prepare for the next potential disaster.

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