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Successful disaster management of the July 2020 Shaziba landslide triggered by heavy rainfall in Mazhe Village, Enshi City, Hubei Province, China

Introduction

From June to July 2020, southern China suffered from continuous rainfalls far heavier than those of previous years (Wei et al. 2020). The heavy rains resulted in natural disasters such as floods and landslides in many places. According to the monitoring data supplied by the Hubei Provincial Bureau of Hydrology and Water Resources, between 8 June and 19 July 2020 (the so-called Plum Rain Season), the average rainfall in this period reached 692 mm in Hubei Province, which is 2.45 times that of the same period in the last 10 years (282 mm)—the heaviest rainfall recorded in this region since 1961. Enshi City, located in the southwest region of Hubei Province, also experienced extremely heavy rainfall (Fig. 1a). The accumulated rainfall from 8 June to 19 July 2020 was 823.8 mm, and the maximum daily rainfall was 81.9 mm (17 July 2020). The accumulated rainfall from 16 July to 18 July was 165.5 mm overall (Fig. 1b).

These heavy rainfalls have increased the risk of landslides in Hubei Province. The largest to occur as a result was the Shaziba landslide in Mazhe Village, Enshi City. The landslide is located at the upper reaches of the Qingjiang River, a tributary of the Yangtze River, with coordinates of 30.36° N and 109.30° E (Fig. 2).

Landslide characteristics and failure process

The Shaziba landslide is located on the left bank slope of the Qingjiang River, with the Yunlonghe and Dalongtan dams located upstream and downstream, respectively. The average slope angle of the landslide area is 10 to 15°, with nearly vertical cliffs at the front toe of the landslide, and the main slide direction is 195°. The length of the landslide is about 1500 m, the maximum transverse width is 320 m, and the volume is estimated to be 1.0 × 10^7 m^3 (Fig. 3). The bedrock surrounding the landslide area is composed of medium-thick limestone and a medium-thin layer of Middle and Upper Permian (P2–P3) marl, with a small amount of locally distributed thin coal seam (Hubei Geological Bureau 1984). The bedrock dip azimuth in this vicinity was measured between 197° and 220° with a dip angle of 10° to 15°. The landslide area is mainly composed of Quaternary silty clay with a small number of boulders, which are the weathered colluvium of limestone. This site was recognized previously as an old landslide and has been patrolled daily by residents due to the increased reactivation risk. The patrol was organized according to the Chinese policy of Mass Observation and Mass Preparedness for geo-disaster prevention, which directs all locals to participate in the observation of and preparation for geohazards.

On 17 July 2020, the first fresh crack in the Shaziba landslide was found and reported to the local government through WeChat, a smartphone social media application. After the occurrence and development of the initial landslide, local administration offices related to national land management and emergency management, as well as the Hubei provincial government, formed a systematic emergency plan and took actions to reduce the landslide risk. The deformation zone is located under a motorway and is formed by subsidence in the zone head, fissures in the ground, and cracks in houses. The azimuth of the general sliding direction of the landslide is 195°, which coincides with the dip direction of the bedrock. Little sliding mass entered Qingjiang River until 18 July; however, on 19 July, about 3 × 10^5 m^3 of debris on the west side slipped into the gully along a slope of about 270°. Some of the sliding mass entered the Qingjiang River in the form of debris brought by the water flow into the gully. On 20 July, the deformation scope expanded, and about 2.5 × 10^6 m^3 of debris in the west side slipped into the gully. At about 5:30 am on 21 July, more debris in the west gully slipped into the Qingjiang River. On 21 July, by 6:00 am, the volume of mass that flowed into the Qingjiang River reached about 1.5 × 10^6 m^3.

We conducted the first site investigation of the landslide on 23 and 24 July 2020 and the second investigation on 29 and 30 July 2020. During these investigations, we mainly carried out aerial photography with UAV and surface deformation investigation. Figure 3 shows images from before and after the July 2020 Shaziba landslide occurrence. In Fig. 3b, a gully is easily identifiable on the west side of the landslide area, and the landslide itself can be separated into two parts by the zoning line. The east part moved a short distance and shows good integrity, while, in the west part, a large volume of the sliding mass moved out, forming a large main scarp and high flank. It was observed that the water flow in the gully was rapid and large. According to the residents, the gully collected not only the surface rainfall but also concentrated water flow from drainage channels on the west side of the landslide. We judged that a large amount of concentrated surface water flow from the main scarp combined with the heavy rainfall in this area initiated the landslide. Surface runoff then formed in the gullies, and this led to the loose sliding mass there turning into debris flow and running into the Qingjiang River channel. The final, but temporary, result was a landslide dam, which dammed the Qingjiang River.

Figure 4 shows the situation at the head of the landslide area. The fresh cliff in the west flank was formed by this event and reaches a maximum height of 71 m; several minor scarps are identified near the detached white line, which indicates a road winding over the western part of the landslide mass. From the cracks between the minor scarps, the moving direction of the landslide, which is the compound of main sliding direction to the south and the local sliding direction to the west, was measured between 248° and 261°. At the central part and west part of the

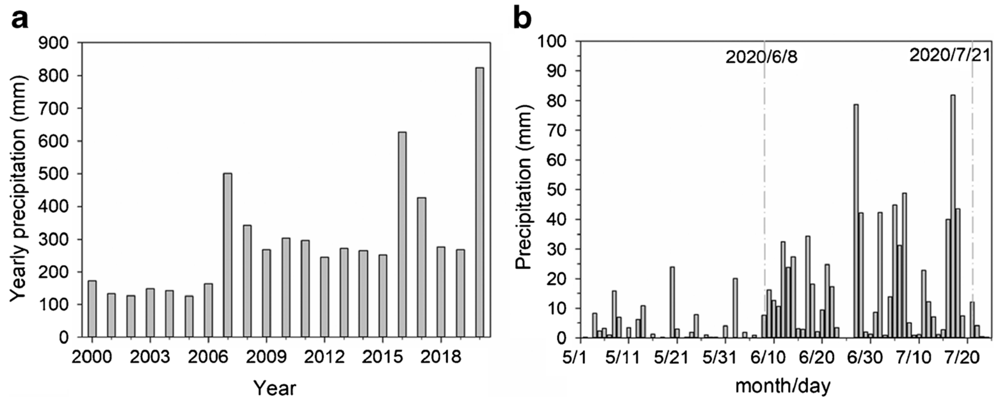

Fig. 1 Rainfall data for Enshi City, Hubei Province. **a** Accumulative precipitation from 8 June to 21 July in the last 20 years. **b** Daily precipitation from May to July 2020 (data resource: Hubei Provincial Bureau of Hydrology and Water Resources)

main scarp, there are two concentrated water flows, which resulted from the surface water flow during the heavy rainfall.

In the early morning of 21 July, the Qingjiang River was blocked by the sliding mass, and a landslide dam was formed. If the landslide dam continued to increase its height, the upstream water level would have risen further; if the dam were to break, it would possibly affect Enshi City, located downstream. Considering that the landslide is located between the Dalongtan and Yunlonghe dams (Fig. 1), a disaster management plan was adopted to decrease the landslide risk. The plan involved two primary precautions: emptying the storage capacity of the downstream Dalongtan reservoir to avoid the flood threat to the downstream Enshi City if the landslide dam broke, and using strong runoff to flush the landslide dam to stop the increase of the landslide dam height by increasing the discharge of the upstream Yunlonghe reservoir. At 10:15 am on 21 July, the Yunlonghe reservoir increased its discharge, broke through the top of the landslide dam, and formed a spillway for flood discharge (Fig. 5). The water level gradually decreased and alleviated the danger of the landslide dam breaking instantly. This operation successfully reduced the potential threat of disasters caused by the landslide; details of this success were reported by China Daily (2020).

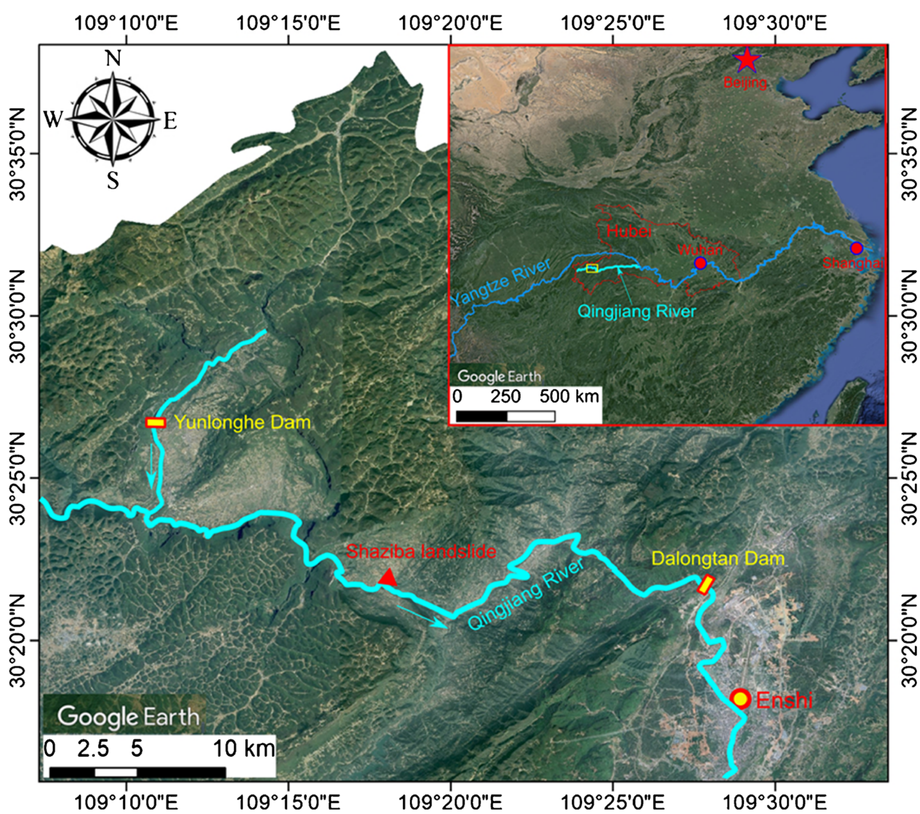

Fig. 2 Location map of the Shaziba landslide

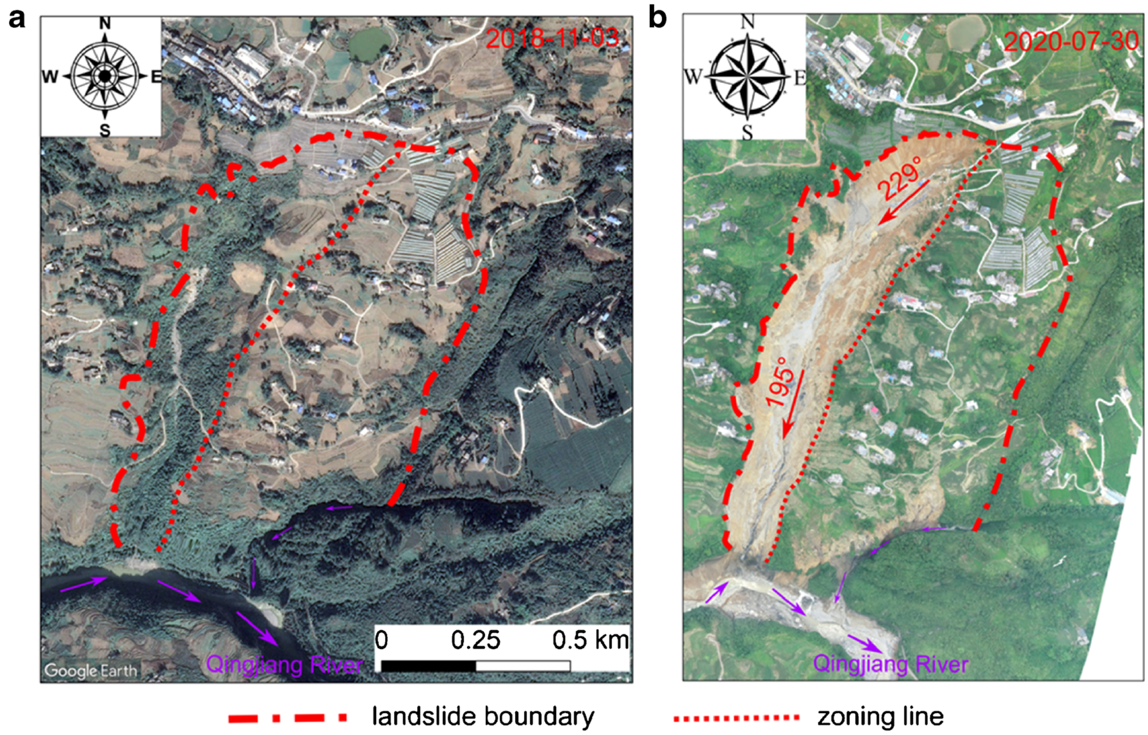

Fig. 3 Images before and after the July 2020 Shaziba landslide occurrence. **a** Google Earth image around the landslide site, taken on 3 November 2018. **b** UAV image of the landslide, taken on 30 July 2020

Evacuation of people who may be affected by the landslide was conducted in order. At 5:00 pm on 17 July, according to the suggestion of engineering geologists, the first group of 19 households with more than 100 people living near the landslide were evacuated; at 8:29 am on 18 July, the second group of 32 households with more than 100 persons were evacuated. All evacuations were completed before 6:00 pm on 18 July: all in all, 261 persons from 51 households were evacuated in these first two rounds. Then, in order to minimize the possible risk to locals by the landslide itself and the landslide dam, the local government

Fig. 4 Minor scarps at the head, showing the displacement of the sliding mass to the gully on the west side

Fig. 5 Spillway formed on the top of the landslide dam

evacuated all remaining residents in the area who may be affected by the landslide. By the afternoon of 21 July, a total of 8379 persons were evacuated from the vicinity of the landslide. As a result, neither the landslide nor the landslide dam caused any casualties.

Discussion and conclusions

The Shaziba landslide in Mazhe Village, Enshi City, was a large landslide induced by unprecedented heavy rainfalls from June to July 2020 with a total landslide volume of 1.0×10^7 m^3. Part of the sliding mass was brought by gully water into the Qingjiang River in the form of debris flow, which formed a landslide dam on 21 July 2020. The discharge channel in the upstream reservoir was opened to control the height of the landslide dam, while the downstream reservoir controlled the water level to protect Enshi City, located further downstream; these measures avoided the risks associated with the potential breakage of the landslide dam. As a result of the timely warning by local patrolmen, the local government evacuated residents efficiently and ensured zero casualties in the whole process. This approach was quite different from that followed in the Tangjiashan landslide dam in Sichuan, China (Chen et al. 2011; Shi et al. 2015), and landslide dams in the Higashi-Takezawa district of Japan (Nagai et al. 2008).

Our observations of this successful disaster management raise two questions for discussion. First, why did the whole landslide not move a long distance downstream and dam the Qingjiang River completely? Second, why was the landslide dam easily flushed and broken by the water flow? Although we could not enter the landslide area due to strict prohibition regulations, we did observe that the sliding mass was composed mainly of clay with a few limestone boulders, which was confirmed by borehole drilling at the crown part about 50 m behind the main scarp and by the material in the landslide dam. The composed material and structure of this landslide dam were different from those of the Yigong landslide dam (Delaney and Evans 2015) and the Baige landslide dam (Fan et al. 2019) in China. For the landslide dam, when the sliding mass in the west gully was carried by the water and flowed into the Qingjiang River, the mass structure was almost destroyed and, while falling off the cliff, the structure of the sliding mass further disintegrated, and the loose deposit of the sliding mass in the Qingjiang River was flushed away easily.

We hope that the analysis of the process and structure of the landslide and landslide dam, and the experience acquired from the Shaziba case, will serve as references in disaster management for landslides in future cases. A more detailed study of the initiation and motion mechanisms of the landslide is planned and will be carried out as soon as the site is accessible to the public.

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