1. OVERVIEW OF THE EXTREME FLOOD

On January 22, 2019, ten regencies in the province of South Sulawesi experienced an extreme flood. The Jeneberang River is one of the major rivers and has the most extensive impact on flooding. The Jeneberang River has a length of 75 km and the area of the Jeneberang Watershed is 727 km$^2$. The Jeneberang River originates from Mount Bawakaraeng at an altitude of 2,833 above sea level. Bili-bili Dam is a multipurpose dam located on Jeneberang River, Gowa regency. The heavy rainfall that occurred on January 22 was marked by heavy rainfall from January 21 to January 23. The peak rainfall recorded at three measuring stations including 329 mm at Lengkese station, 308 mm at Bawakaraeng station, and 328 mm at Limbungan station. These numbers exceed the normal limit for daily precipitation in this area (150 mm/day). As a result of heavy rainfall, the discharge runoff from the upstream watershed was estimated to be 3500 m$^3$/s.

The heavy rainfall caused the Jeneberang River to
overflow, resulting in the overfilling of Bili-Bili dam on the Jeneberang River. The inlet data show that the discharge released through the spillway ranges from 1200 m$^3$/s to the maximum spillway capacity of 2200 m$^3$/s. This shows that the dam can function well even though the water level in the dam is close to the maximum height. However, the spillway door must be opened to avoid overtopping the dam; the water level in the dam reached 101.8, which is the maximal level of Bili-Bili dam (+103).

Bili-bili reservoir had been suffered from silting since the gigantic caldera wall collapsed in 2004, which produced 230 million m$^3$ of sediment deposited on the river and reduced the reservoir capacity. Jeneberang watershed is the 15th highest national priority in terms of Indonesian critical watersheds.

The flood downstream was a result of the river basin not being able to accommodate the water discharge from the spillway dam, as shown in hydrograph of Bili bili dam in Fig.3. Also there was additional discharge from the Jenelata river (1000 m$^3$/s). The flood hit the settlement area on the banks of the Jeneberang river, which should not be used for residences according to flood maps.

According to the Indonesian National Board for Disaster Management (BNPB), the water level reach roof level (1.5 meters to 4 meters), killed 78 people, and affected 5,825 people; 32 houses were swept away, 25 houses were heavily damaged, 14 were damaged, and 55 were buried under landslides. In addition, 2,694 houses and 11,433 hectares (28,250 acres) of farmland were inundated (as shown in Fig.2) along with damage to various public facilities.

2. CAUSES OF FLOOD

In addition to an extreme weather upstream, there were also problems in the middle and downstream.

2.1 Sedimentation in Bili-Bili Dam

The Bili-Bili Dam is located in Gowa Regency, South Sulawesi, Indonesia, on the Jeneberang River, about 30 km from the city of Makassar. It serves several purposes include flood control, irrigation, and hydroelectric power generation. Based on existing data, the Bili-Bili Dam is planned to accommodate a total volume of 375 million m$^3$ of water. It is an effective reservoir with 345 million m$^3$ and sediment storage of 29 million m$^3$, including flood control reservoirs of 41 million m$^3$ and spill-ability of debris flood of 2,200 m$^3$/s.

Sedimentation in the reservoir has been a concern since the gigantic landslide on Bawakaraeng mountain in 2004. The total volume of sediment deposits in 2009 was estimated to be more than 244.9 million m$^3$, and the unstable sediment deposits remaining in the caldera were estimated to be 82.7 million m$^3$. The total volume of sediment flowing along the Jeneberang main river channel is 162.2 million m$^3$ as shown in Fig.4.

This condition causes an increase in the sedimentation in the Bili-Bili reservoir, which causes silt build-up in the reservoirs that can threaten the sustainability of reservoir functions as shown in Fig.3. To control the sediment flow, a number of sediment control buildings were constructed, i.e., a sabo dam (SD; check dam), consolidated dam (CD), and sand pocket (SP) buildings.
2.2 Mining Activity

Mining is another problem along the river, but is an important income source for local people and governments. There are sediment control structures like SD, SP, and CD along the Jeneberang River, and these are expected to reduce sediment transport to the Bili-bili reservoir. These dams will optimally work as long as the pools holding the sediments upstream are empty. Mining activity releases sediments in accordance with the recommendations given. This can be controlled when done properly but our observations in the field suggest the mining did not follow the prescribed technical recommendations. As a result, a number of sediment control structures have collapsed due to material extraction that is too close to building construction. Hence, the stability is disrupted leading to building collapse as shown in Fig.5. There are shallow landslides in some areas along the river bank as shown in Fig.6.

2.3 Land cover change

The Jeneberang watershed is divided to three sub-watersheds, i.e. catchment areas: Bili-Bili Dam, Kampala, and downstream Jeneberang. From 1990 to 2017, the Jeneberang watershed experienced a very significant number of land cover change as shown in Fig.7. Shrub cover changed from 32,222.02 (40%) to 6,339.69 hectares (8%), and the farming area increased from 6,396.98 (8%) to 33,254.11 hectares (42%). Farming areas are dominated with corn, potatoes, carrots, cabbage, etc. located on a steep slope. In 1990, 17% of the area was covered by forest including primary forest, secondary forest, and plantation forest. This decreased to 16.6% in 2017. Land use change from high vegetation to medium vegetation or low vegetation. This affected the stability of the slope and may lead to landslides (Hasnawir et al., 2017; Soma and Kubota, 2017a, 2017b).

The average population growth rate is 1.31%, and the population density is 398.83 people/km², which is higher than the average population growth rate of South Sulawesi Province. The impact on land demand
continues to increase due to the high socio-economic activity of the population in this region. The main occupation of people in this region is agriculture, which requires land.

The reduced water catchment areas increase flood discharge. Dense residential areas impact the soil and have little water infiltration. During intense rainfall, most of the water will become surface runoff—this exceeds the capacity of the system and causes flooding.

2.4 Landslide

The condition of the rain catchment area in the upstream area continues to deteriorated due to land management that does not heed the conservation aspects of the land. This increases soil erosion and influences on sedimentation in the downstream area. This leads to reduced river drainage capacity due to siltation, drought in the dry season, and flooding in the rainy season. The field observations showed that there was a significant change in land use. There was mostly seasonal plants that further increased runoff and caused
Landslides and erosion in the upper watershed area.

The classification of the slope class for the Jeneberang watershed area is 0>8 degrees. This slope class is 32.38% of the area; slopes above 25 degrees are 28.72% of the area. There are 254 landslides, and the biggest area was 34.96 hectares. The total area of the landslide is 479.11 hectares as shown in Fig.8. Landslides caused a flash flood in the sub-watershed of Kampala, and this destroyed a bridge downstream. Landslides with extensive impacts occurred in the settlement area and buried half of the village in Pattalikang. Landslide also observed in agricultural land and along the road as shown in Fig.9 and Fig.10.

Fig.8 Landslide evidence on January 2019 using sentinel imaging resolution 10 m, recorded February 19th, 2019

Fig.9 Landslide view in agricultural land (January 30, P. Nurdin)
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Fig. 10 Shallow landslide along the road (January 30, P. Nurdin).