Field Report

Investigation of the Landslide Dam in Chin Hill, Myanmar

Samjwal Ratna Bajracharya

Sudan Bikash Maharjan

Vishnu Dangol

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Sudan Bikash Maharjan
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International Centre for Integrated Mountain Development, Kathmandu
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Finally, we extend gratitude to the Myanmar Police and local residents for their hospitality and kindness during the field trip.

Salient features of Tonzang Landslide Dammed Lake in Chin Hill, Myanmar

Landslide Dam

1. Location
    a. Latitude 23° 40′ N – 23°.45′N
    b. Longitude 93° 50′ E – 93° 55′ E
    c. 52 kilometers upstream from the Yazagyo Dam

2. Dam features
    a. Length: 1,500 m; Height: 276 m
    b. Crest: 43 to 75 m; Freeboard: 9 to 38 m
    c. Elevation 1,126 to 1,402 m above sea level

3. Dam material and condition
    a. Fractured shale
    b. Weathered sandstone
    c. Silt and clay in small amount

Lake

4. Location
    a. Elevation: 1,364 m above sea level
    b. Upstream of Tonzang landslide dam

5. Size
    a. Length = 1,707 m
    b. Width = 563.5 m
    c. Average Depth = 50 m
    d. Area = about 41 ha
    e. Water volume = 15.5 million m^3

6. Existing condition
    a. Inflow into the landslide dam is $5m^3$ per second
    b. Leaks present at the abutment contact zones

Background

Heavy rainfall (480mm) on 16 July 2015 triggered a huge landslide (DGSE and GDKU, 2016) that dammed the Tui Lam Lui River approximately 52 km upstream of Yazagyo Dam near Hangken Village, Falam District in the Upper Chin Hill region in northwestern Myanmar (Figure 1).

The landslide dam was formed by quick deposits of landslide materials, which lack of sufficient compaction in damming material. In other hand it is lacking of seepage control and flood drainage facilities. For these reasons, the dam may breach and the consequent flood could create significant loss of life and downstream property. The stability of this landslide dam is a prime concern for local people.

In this regard the Ministry of Environmental Conservation and Forestry of Myanmar requested ICIMOD to undertake an assessment of investigation of landslide dam and to develop a comprehensive management plan to tackle the problem. The Director of the Chin State Forest Department had prepared a short field trip to the areas of landslide dams in order to assess the risk of the landslide dam. The ICIMOD team joined the group to investigate the landslide dam in May 2016. Most of the physical information was gathered through the study of satellite images, which was later verified in the field. Though the field trip was brief, the team was able to collect substantial data.

Figure 1: Location of the Tonzang landslide dam in Chin Hill, Myanmar

Introduction

The mountainous provinces of Myanmar, primarily the western ranges and eastern highlands, have an unstable geologic structure: steep slopes and higher than average seismicity that, when combined with monsoon rains, makes the area extremely hazard—prone.

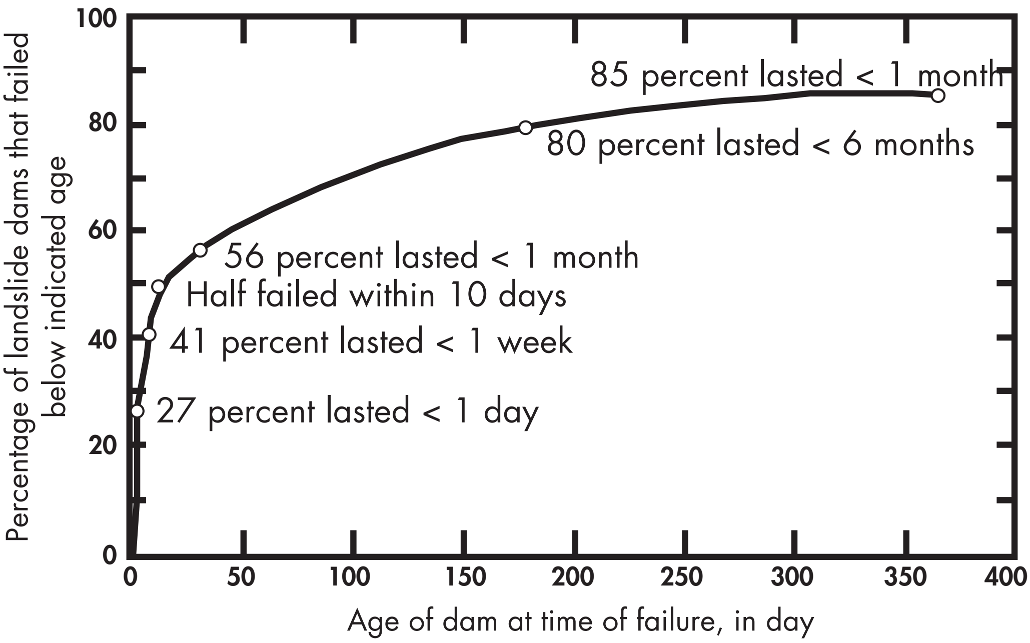
Landslide dams are natural dams formed by quick deposits of landslide materials. Since the landslide material are loose and lack of fines for cohesion, there is high possibility of dam breach. Knowing the extent of a dam's stability is quite important for people living in the area and downstream of the dam.

Costa and Schuster (1988) studied an inventory of 73 landslide dams with the intention to investigate the longevity of dams that fail. They found that 27% of landslide dams fail within the first day, 41% within the first week, 80% within six months and 85% within the first year of existence (Figure 2).

The Ministry of Environmental Conservation and Forestry of Myanmar requested ICIMOD to assess the landslide dam and develop a comprehensive management plan to tackle the problem. The Director of the Forest Department of Chin State organized a short field trip to the landslide dam and lake area in May 2016 and the ICIMOD team led the investigation group. The team used of remote sensing data and field data to be analyzed in a geographic information systems environment. Based on collected data, the ICIMOD team concluded there was a strong probability this landslide dam would breach.

The present report is based on the analysis of available maps, satellite images, literature, and our related site investigations.

Figure 2: The longevity of rockslide dams that fail (Costa & Schuster, 1988).



Present Investigation

We conducted walkover survey at the Tonzang landslide dammed lake in May 2016, focusing on the following conditions for the purposes of risk assessment:

- Lake;
- The landslide dam and its composition; and
- The river course and river bed material.

Figure 3: The Lake formed after the landslide damming the Tui Lam Lui River. The foreground and right side of the photograph are the landslide dam material on 25 May 2016

Lake

The landslide dammed the Tui Lam Lui River and formed a large lake in July 2015. The lake area grew to 34 ha by 16 September 2015 and 40 ha on 17 October 2015 (reported by UNITAR-UNOSAT). The lake area grew further to 50 ha by 5 March 2016.

Figure 4 is a photograph taken during fieldwork on 25 May 2016. By this point, the lake area had decreased by 3 m from its maximum (Figure 4). The water level during the field work was 1,364 masl.

Figure 4: The lake water level reduced by 3m in dry season, 25 May 2016.

Observation: The lake area and water level had decreased in the dry season of 2015 and will increase in monsoon of 2016

Dam and dam material

The Tonzang landslide dam measured 276 m high with the toe of the dam at 1,126 masl and the top of the dam at 1,402 masl. The total length of the dam was approximately 1,500 m (Figure 5). Though we did not measure dam thickness, the dam crest width ranged from 43 to 75 m and the freeboard ranged from 9 m to 38 m. The inner side-slopes ranged from 7 to 17 degrees. The smaller the crest width the higher probability of breaching. The lowest free board had 7 degree slope towards the lake and 46 m length from crest to lake.

The landslide dam material was composed of highly fractured boulder-sized shale with subordinate cobble sized sandstones. The material size was generally smaller than 1 m, but some blocks are >3 m. Red and black clays were found at the middle and bottom parts of the dam (Figure 4). Owing to the fracture, the shale is easily shattered and sandstones were weathered, which made the dam material highly permeable.

Not all landslide dams are unstable or have the potential to fail. Some rockslide dams exist for millennia leaving behind persistent geomorphic features that influence the evolution of the landscape as a whole. For example, Phoksundo Lake in Nepal was formed by the Ringmo rockslide more than 30,000 years ago (Weidinger, 2011). The sedimentological character of the landslide dam, the mineral composition of the host rock, the size of the catchment area, the volume of the rock slope failure event, the pre- existing geomorphological domain where failure occurs, the climatic conditions, and the rate of sedimentation into the reservoir are all factors that influence the longevity of rockslide dams (Weidinger, 2011).

In case of the Tonzang landslide dam, it could fail by due to the following causes:

1. Over-topping which may lead to progressive upstream erosion and lateral widening of the overtopped channel. This might happen if the freeboard of the lake decreases due to heavy rainfall and a large inflow to the lake. The lowest freeboard of the dam is just 9 m.

Figure 5: a) Lake and landslide dam mapped from Landsat 8 satellite image of March 5, 2016; **b)** A zoom view of landslide dam and crest; **c)** the crest profile and inward slope; and **d)** the longitudinal profile of dam.

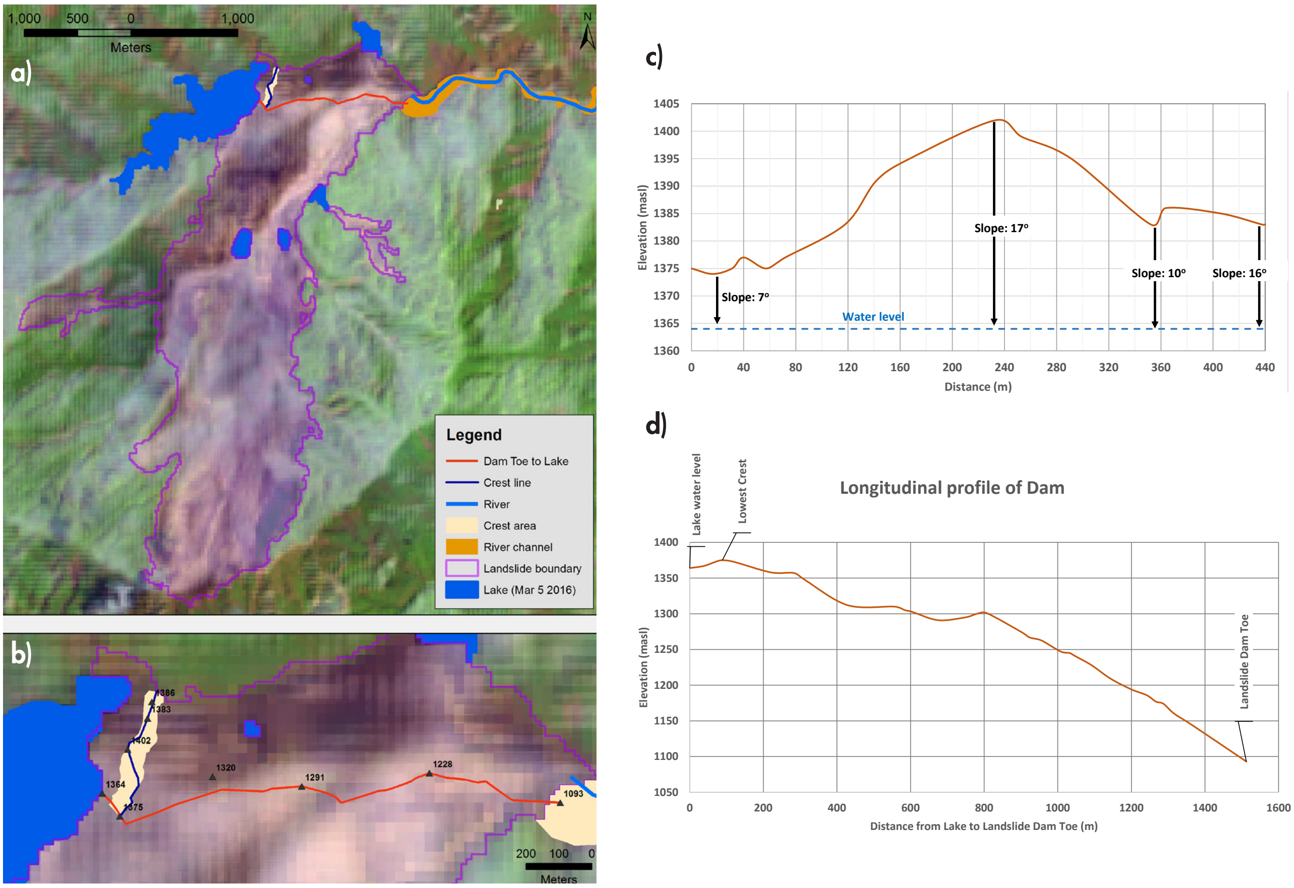


Figure 6: Dam material analysis; **a)** view from lake to highest crest; **b)** view from lowest crest toward lake; **c)** on lower crest at right side of the dam; and **d)** toe of dam.

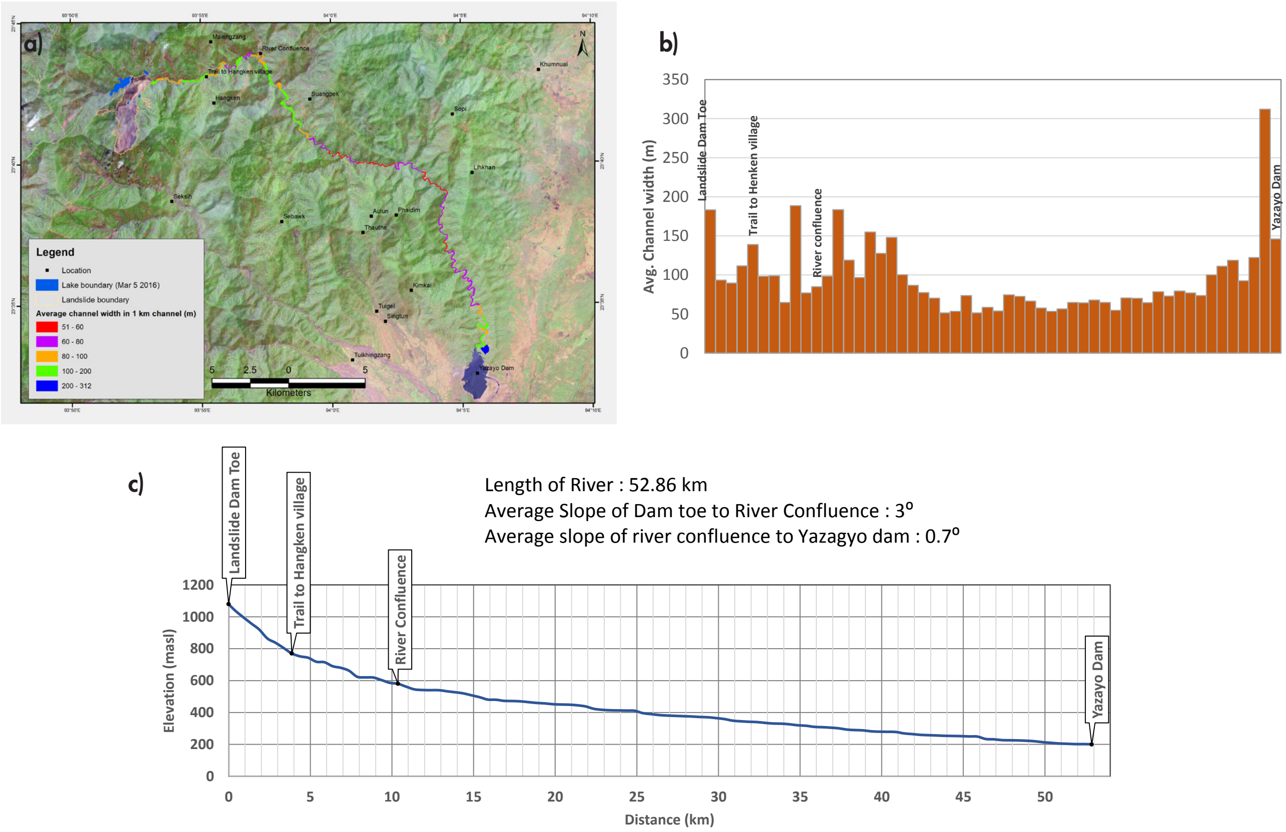
2. Piping: Since the dam is formed by quick deposits of landslide materials, which lack of sufficient consolidation and are internally unstable. Landslide dams tend to have seepage problems due to material permeability and internal stability. Internal stability refers to the ability for the coarse fraction of a soil to prevent the loss of its fine fraction due to seepage flow. A soil which is susceptible to loss of its fine fraction is internally unstable. For an internally unstable soil, once the fine particles are removed, the permeability of the soil will increase locally. Moreover, the dam material at the upper part has fewer fine particles, which results in high permeability. This could induce a reduction of shear strength and a mutation of hydraulic conditions. In severe cases, the loss of fine particles could induce concentrated flow and lead to piping failure eventually.

Observations: Shattered shale and weathered sandstone rocks. Highly permeable, crumbling rocks with no clays indicate a fragile dam.

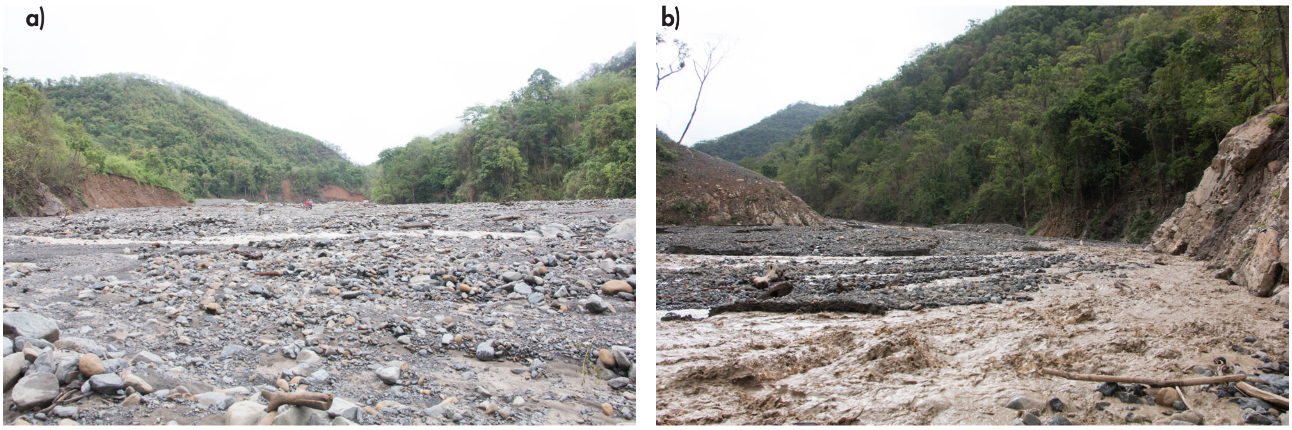
River course and bed material

The length of the Tui Lam Lui River is 52.86 km from the toe of the Chin hill landslide (Tonzang landslide) dam to the Yazagyo Dam. Though the river is generally wide ranging from 50 to 300 m in a stretch of 1 km, some sections are narrow, reaching only 30 m in the middle reaches of the river. The widest section of river channel (504 m) was observed near the Yazagyo Dam (Figure 6). The average slope of the river is 3 degrees from the toe of the landslide to the nearest big bend of the river confluence and about 0.7 degrees from the river confluence to the Yazagyo Dam. The river bed is mainly composed of shale, sandstone and quartzite with some boulders and cobble, but the highest percentage is gravel with little fines (Figure 7).

Figure 7: a) Location of landslide dam, lake and Yazagyo Dam showing average channel width within 1 km; **b)** Average channel width in 1 km from the toe of the landslide to Yazagyo Dam; and **c)** A longitudinal profile of the river from the toe of the landslide to Yazagyo Dam.



Figures 8 a and b: Field photographs of river bed materials showing a wide river channel.



At two locations, called Section 1 and Section 2 (Figure 9), we measured the river cross-sections and the large-sized river bed material. Details of this material are provided in Annexes 1 and 2. Fine particles were in small quantity and visually estimated to be less than 5%. The measurement of the river bed material shows that the percentage of boulders (material larger than 256 mm) at Section 1 was 54.41%, whereas the boulder percentage at Section 2 was 54.39%. Therefore, the river bed in these locations can be classified as boulder-bed types (Table 1). The riverbed material was mainly composed of sandstone (36.8% at Section 1 and 43.9% at Section 2), and shale (35.3% at Section 1). However, the composition of shale and quartzite were equal (28.1%) at Section 2. The composition of quartzite was minimal (27.9%) at Section 1.

Figure 9: Location of river bed survey.

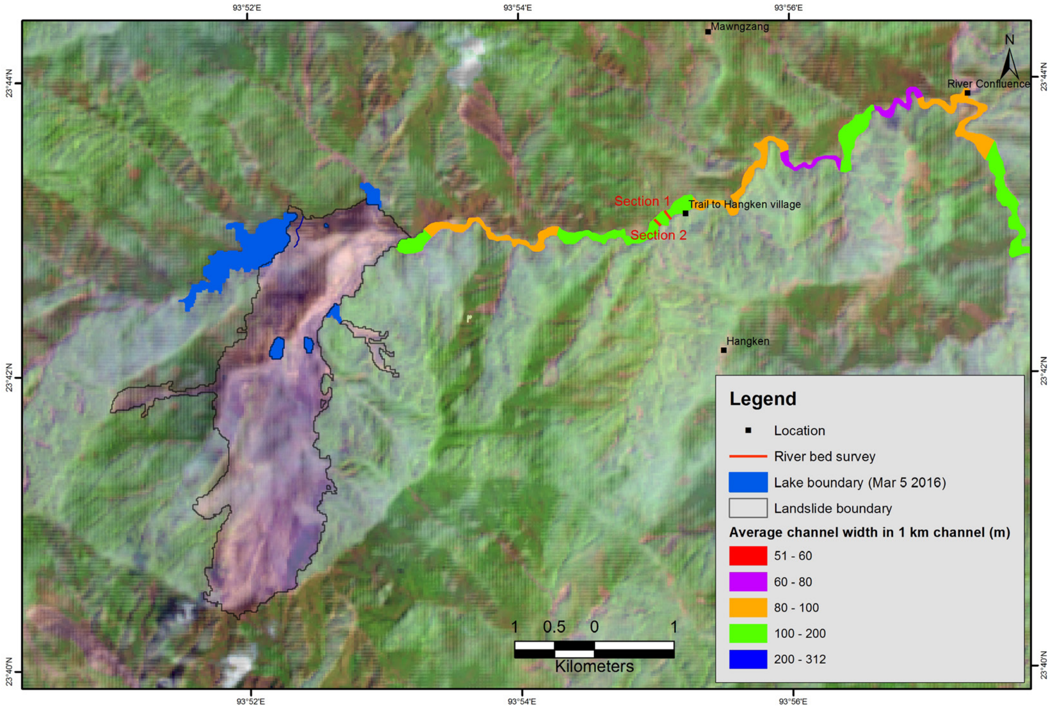


Table 1: Stream classification based on the median bed-material particle size

Stream type	Range of median bed-material particle size (mm)
Sand-bed stream	0.063 - 2
Gravel-bed stream	2 - 64
Cobble-bed stream	64 - 256
Boulder-bed stream	256 - 4096

As the landslide dam lacks of seepage control and flood drainage facilities, a large water head difference may trigger seepage deformation of soil and influence dam stability with rising lake water levels, which may lead to a dam breach. Breach floods can cause huge loss of downstream life and property. However, there are no large settlements along the river down to the Yazagyo Dam.

Observations: In case of a landslide dam outburst flood (LDOF), no significant damage to settlement and infrastructure along the river is envisaged. The existing river width with numerous meanderings is sufficient to dissipate the flood, debris flow, and sediment load before the river reaches the Yazagyo Dam.

Conclusions

By combining remote sensing data with a short field investigation, complemented by analysis with geographic information systems, we draw the following conclusions:

- The Chin Hill landslide (Tonzang landslide) dam is composed of highly shattered shale with scattered sandstone boulders indicating further compaction would result in the reduction of the freeboard.
- The highly shattered rock with no clays has high permeability. Therefore, chances of leakage from the shallow depth of the dam is high, which in turn might trigger the breaking of the landslide dam.
- At present, the lowest freeboard is only 9 m and it will decrease rapidly during the monsoon season.
- If the freeboard decreases to less than 3 m due to an increase in lake water levels and consequent compaction and erosion of dam material, the dam may breach. The possibility of a breach will increase during monsoon.
- Torrential rainfall and high volumes of rain water may overtop the dam and trigger the breach. The weather forecast from the Meteorological Department predicts at least 1 storm per month in the monsoon season of 2016.
- If the Chin Hill landslide dam breaks and causes a flash flood, an additional landslide may occur within 10 km from the dam, and debris deposits may continue downstream. Fortunately, there are no settlement nor infrastructure along the river up for 52 km. This will keep human life loss and property damage at a minimum.
- Though there would be no structural damage to the Yazagyo Dam in the case of a landslide dam breach, but the possibility of additional sedimentation is high.
- During monsoon, there is a strong possibility the Chin Hill landslide dam will breach.

Recommendations

- Install a Automatic Weather Station (AWS) and Automatic Water Level Station (AWLS) with real-time satellite connection to monitor the precipitation and lake water levels.
- Monitor the lake water level and dam conditions using a web camera with image feeds to concerned authorities/stakeholders.
- Install immediately a flood warning system for people to stay away from the river valley bottom down to the Yazagyo Dam in the case of a breach.
- Execute a dam break model to understand the discharge, flood height and arrival time of water at different locations along the river for hazard zoning.
- Restrict activities along the river from the landslide dam to the Yazagyo Dam.
- Conduct detailed geotechnical investigations for evaluating the stability of the landslide with due consideration of future seismic risk.
- Consider artificial breaching of the dam and controlled release of the lake water in case the dam does not breach this monsoon season.

References

Costa, J.E. and Schuster, R.L., (1988). The formation and failure of natural dams. Geological Society of America Bulletin, 100(7), 1054-1068.

Department of Geological Survey and Exploration (DGSE) and Geology Department of Kalay University (GDKU), (2016). Risk assessment Report of Landslide-dam in West of Hankeng Village, Tonzang Township, Chin State and Geological Field Survey Report

Unitar/UNOSAT (2015), Landslide induced dam over Tonzang Township, Chin division, Myanmar (Poster). http://www.unitar.org/unosat/maps/MMR

Weidinger, J. (2011). Stability and life span of landslide dams in the Himalayas (India, Nepal) and the Qin Ling Mountains (China) Natural and Artificial Rockslide Dams (pp. 243-277): Springer.

Annexes

Annex 1: Measurement of riverbed materials at Section 1

Table A1.1: **Size and composition of riverbed materials at section 1**

SN	a (mm)	b (mm)	c (mm)	Aggregate Class	Composition
1	450	170	120	Boulder	Shale
2	350	200	100	Boulder	Quartzite
3	400	100	70	Boulder	Quartzite
4	320	180	120	Boulder	Sandstone
5	250	100	150	Gravel	Sandstone
6	250	200	100	Gravel	Shale
7	300	280	150	Boulder	Quartzite
8	380	200	100	Boulder	Shale
9	450	200	100	Boulder	Quartzite
10	300	180	150	Boulder	Shale
11	400	200	150	Boulder	Shale
12	400	200	180	Boulder	Shale
13	400	230	100	Boulder	Sandstone
14	370	320	170	Boulder	Sandstone
15	320	180	80	Boulder	Quartzite
16	350	200	90	Boulder	Sandstone
17	520	240	140	Boulder	Quartzite
18	700	250	200	Boulder	Shale
19	500	180	140	Boulder	Sandstone
20	350	190	90	Boulder	Quartzite
21	330	220	160	Boulder	Sandstone
22	330	200	120	Boulder	Quartzite
23	300	220	170	Boulder	Sandstone
24	400	170	130	Boulder	Quartzite
25	330	250	250	Boulder	Shale
26	470	260	240	Boulder	Sandstone
27	700	300	200	Boulder	Sandstone
28	350	220	190	Boulder	Quartzite
29	420	200	160	Boulder	Shale
30	450	260	180	Boulder	Sandstone
31	400	200	120	Boulder	Shale
32	380	230	120	Boulder	Sandstone
33	460	170	120	Boulder	Quartzite
34	350	240	100	Boulder	Quartzite
35	380	280	100	Boulder	Quartzite
36	400	320	230	Boulder	Quartzite
37	500	220	140	Boulder	Sandstone
38	140	90	50	Gravel	Shale
39	120	100	70	Gravel	Quartzite

SN	a (mm)	b (mm)	c (mm)	Aggregate Class	Composition
40	110	80	50	Gravel	Shale
41	170	80	50	Gravel	Sandstone
42	100	70	40	Gravel	Shale
43	280	200	100	Boulder	Sandstone
44	170	130	50	Gravel	Sandstone
45	130	120	50	Gravel	Shale
46	110	90	50	Gravel	Shale
47	140	90	60	Gravel	Shale
48	240	150	70	Gravel	Shale
49	100	50	30	Gravel	Shale
50	120	100	40	Gravel	Shale
51	130	120	90	Gravel	Shale
52	110	90	40	Gravel	Quartzite
53	150	70	50	Gravel	Shale
54	140	70	50	Gravel	Sandstone
55	110	60	50	Gravel	Shale
56	150	80	40	Gravel	Sandstone
57	130	80	30	Gravel	Shale
58	170	50	50	Gravel	Sandstone
59	150	100	50	Gravel	Sandstone
60	130	80	30	Gravel	Sandstone
61	160	120	50	Gravel	Sandstone
62	100	80	40	Gravel	Shale
63	180	160	150	Gravel	Sandstone
64	160	100	70	Gravel	Sandstone
65	160	110	80	Gravel	Sandstone
66	120	110	80	Gravel	Quartzite
67	170	140	70	Gravel	Quartzite
68	280	200	90	Boulder	Quartzite

Boulder Percentage = 54.41%

Figure A1.1: Grain size distribution of riverbed material at section 1

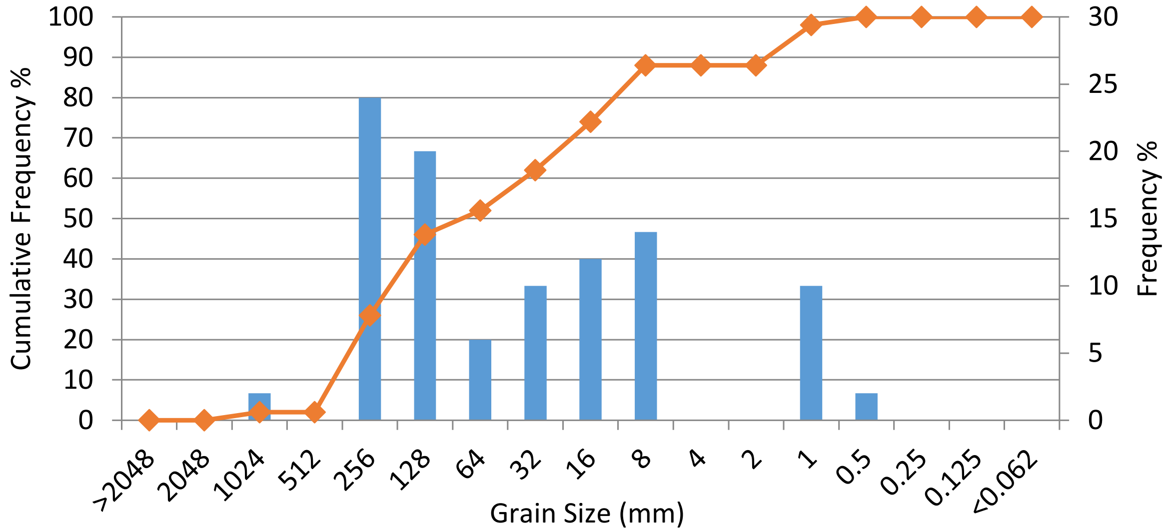
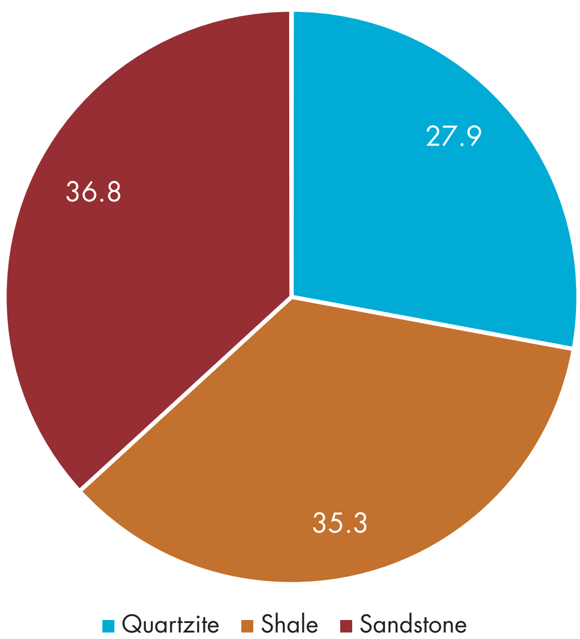


Figure A1.2: Composition of riverbed material at section 1



Annex 2: Measurement of riverbed materials at section 2

Table A2.1: **Size and composition of riverbed materials at section 2**

SN	a (mm)	b (mm)	c (mm)	Aggregate Class	Composition
1	620	380	180	Boulder	Quartzite
2	380	200	190	Boulder	Shale
3	430	250	180	Boulder	Sandstone
4	500	200	180	Boulder	Sandstone
5	380	200	100	Boulder	Shale
6	300	170	100	Boulder	Sandstone
7	270	140	120	Boulder	Shale
8	400	120	100	Boulder	Sandstone
9	380	150	120	Boulder	Sandstone
10	550	200	150	Boulder	Sandstone
11	400	300	180	Boulder	Sandstone
12	500	300	200	Boulder	Sandstone
13	500	250	220	Boulder	Quartzite
14	400	200	170	Boulder	Sandstone
15	320	250	200	Boulder	Sandstone
16	380	240	170	Boulder	Sandstone
17	400	250	200	Boulder	Quartzite
18	440	190	170	Boulder	Sandstone
19	630	400	200	Boulder	Shale
20	560	230	180	Boulder	Sandstone
21	250	220	200	Gravel	Sandstone
22	500	200	180	Boulder	Sandstone
23	370	220	200	Boulder	Quartzite
24	290	250	180	Boulder	Quartzite
25	400	220	190	Boulder	Quartzite
26	300	170	160	Boulder	Shale
27	420	170	120	Boulder	Sandstone
28	380	160	120	Boulder	Sandstone
29	200	150	100	Gravel	Shale
30	180	80	80	Gravel	Sandstone
31	100	120	100	Gravel	Shale
32	180	120	100	Gravel	Sandstone
33	180	170	160	Gravel	Sandstone
34	60	50	40	Gravel	Sandstone
35	300	60	50	Boulder	Quartzite
36	150	60	50	Gravel	Shale
37	150	130	130	Gravel	Quartzite
38	180	100	80	Gravel	Shale
39	180	120	100	Gravel	Quartzite
40	200	180	50	Gravel	Sandstone
41	180	100	100	Gravel	Shale
SN	a (mm)	b (mm)	c (mm)	Aggregate Class	Composition
42	200	100	80	Gravel	Shale
43	150	120	60	Gravel	Quartzite

SN	a (mm)	b (mm)	c (mm)	Aggregate Class	Composition
44	200	100	70	Gravel	Quartzite
45	150	100	60	Gravel	Shale
46	170	140	110	Gravel	Shale
47	180	160	80	Gravel	Sandstone
48	120	80	60	Gravel	Shale
49	160	150	60	Gravel	Quartzite
50	160	160	140	Gravel	Quartzite
51	170	160	70	Gravel	Sandstone
52	150	150	100	Gravel	Shale
53	150	100	80	Gravel	Quartzite
54	290	80	60	Boulder	Quartzite
55	150	100	50	Gravel	Sandstone
56	270	160	150	Boulder	Quartzite
57	280	200	120	Boulder	Shale

Boulder Percentage: 54.39%

Figure A2.1: Grain size distribution of riverbed material at section 2

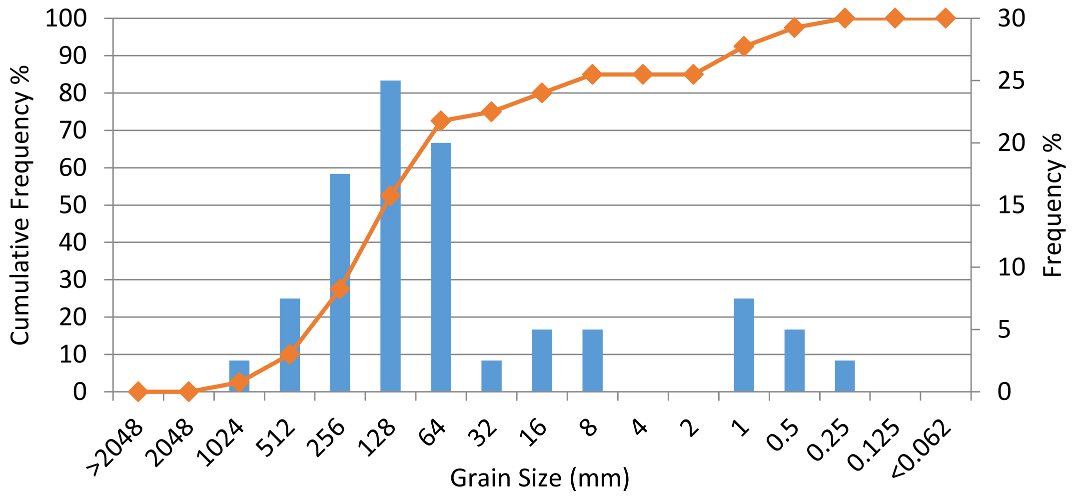
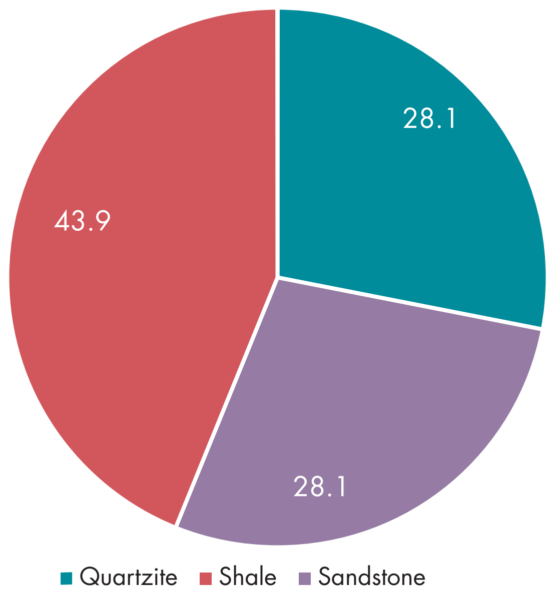


Figure A2.2: Composition of riverbed material at section 2



International Centre for Integrated Mountain Development
GPO Box 3226, Kathmandu, Nepal
Tel +977-1-5003222 **Fax** +977-1-5003299
Email info@icimod.org **Web** www.icimod.org