Assessment of Hazards Resulting from the July 11, 2005 Landslide, Barangay Mayana, Jagna, Bohol

A report to the Local Government Unit of Jagna, Bohol

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ABSTRACT

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INTRODUCTION

The Alihauan River Valley trends roughly NNW-SSE and is surrounded mostly by the Sierra Bullones Limestones. The northwestern and eastern boundaries of the valley for the most part are along structural lines which follows the trace of major faults. These faults normally bring thick cliff-forming limestones of the Sierra Bullones to form typical gray limestone walls, which stand out prominently. The gently rolling valley floors are underlain by the deeply weathered volcaniclastic rocks of the Carmen Formation and the Cretaceous to Paleocene Boctol Serpentinites south of Mayana.

The Alihauan River Valley erodes along belts of volcaniclastic sedimentary rocks and limestones, and along fault zones. Rivers that cut through limestones generally have steep valleys. The landslide of July 2005 occurred in the upper part of the Valley where the elevations lie at 400 to 800 m, producing high hills.

The average annual rainfall in Sierra Bullones, as transposed from the neighboring stations is about 2,170 mm/yr.

This report summarizes our ocular inspection of the landslide of July 2005. Upon the request of the mayor of Jagna, Hon. Exuperio Lloren, we recommend possible options to mitigate the impacts of hazards associated with this landslide. We conducted our field studies between August 11-13, 2005, exactly one month after the July landslide. We acknowledge the assistance and support of the Local Government Unit of Jagna, the Akbayan Citizens' Action Party, the Active Citizenship Foundation, Inc. and the Mines and Geo-Sciences Bureau Region VII, without whose cooperation we would not have been able to respond to this situation in such a timely manner.

BARANGAY MAYANA LANDSLIDE

The very large (52 ha. as of 13 August 2005) landslide originated as a rock fall along a very steep NW-trending fault scarp in the Sierra Bullones Limestone in Sitio Balikbayan. The rock falls started on 11 July 2005. Earlier, a surface-wave magnitude 4.9 earthquake with epicenter in Sierra Bullones (about 46 km east of Tabilaran City) occurred at 8:25 p.m. on 31 March 2005. The epicenter is roughly only 8 km west of the site of the landslide occurrence and is probably related to the movement along the East Bohol Fault. No typhoon had affected the province more than half a year before the landslide. The earthquake probably triggered the landslide in Barangay Mayana. The debris fell on an area underlain by older limestone landslide debris and thickly weathered soils from the underlying volcaniclastic rocks of the Late Miocene Carmen Formation. The slope of the landslide is only about 13% (7½º). The landslide is elongate, oriented east-west, and has a total length of 1.4 km as of 13 August, 2005.

The zone of depletion (proximal part) of the landslide debris occurs mainly in Sitio Balikbayan, has a width of about 400 m, and consists dominantly of blocks of limestones, whereas the debris in the zone of accumulation (distal part) in Sitio Ilaud, with a width of 260 m, consists of relatively intact soils derived from the weathering of the volcaniclastic sediments. The large blocks of limestones in Sitio Balikbayan are unlikely to be remobilized during the rainy season, but can have continued translational motion as they move as a single mass over a slip plane in the Carmen Formation; whereas, the landslide debris blocking the Mayana River is susceptible to remobilization as debris flows and cause landslide dam failure that could extend into populated areas on the lower reaches of the Alihauan River.

Field studies indicate that draining of the small Mayana River landslide-dammed lakes would pose a minimal flooding hazard. However, if the landslide debris would reach the Alihauan River, a catastrophic draining of an Alihauan lake would pose a serious hazard and warrants immediate action. Construction of a spillway across part of the dam could moderate the impact of catastrophic lake draining and the associated flood.

The Mayana River drains southeastward and is a tributary to the Alihauan River (locally known as the Subang Daku). Approximately 490 m northwest of its mouth, the Mayana River was dammed by the toe of the landslide debris last 12 August 2005. The estimated volume of the landslide debris is at least 6 million m^3. The landslide originated on the northeast wall of the valley (fig. 3) and is located about 1.4 km west of the toe of the landslide. Limestone fragments of the (Late Miocene) Sierra Bullones Limestone compose almost 60 percent of the landslide; volcaniclastic rocks of the (Middle to Late Miocene) Carmen Formation compose the remainder. The limestone fragments are mostly pebble to blocks in size that are as much as 60 m in diameter. The landslide has dammed the Mayana River, and streamflow in the river has been impounded to form very small lakes.

There are no streamflow records for the Mayana River.

The lakes in the lower Mayana River are about 10 to 20 m long, a few m wide, and are probably less than 0.5 m deep. The Municipal Information Officer, Mr. Catalino Berro, reported on August 19, 2005 that the lakes have disappeared due to the change in the course of the river to conform with the toe edge of the landslide. The flow is not effective in eroding landslide debris. Because the lakes are small and are temporary features which can disappear due to adjustment in the river course during a downpour, is it perceived that these lakes would make a negligible contribution to a flood; therefore, no further mitigation measures are needed for the landslide dam along the Mayana River.

IMPENDING ALIHAUAN RIVER LANDSLIDE DAM

The toe of the landslide as of 13 August 2005 is approximately 490 m upstream from the confluence of the Mayana and Alihauan Rivers. The landslide debris, composed of soil, is predicted to follow the course of the lower Mayana River until it reaches the said confluence. If the debris material completely blocks the Alihauan River, a landslide dam will form and very likely a lake upstream of the dam will also form. The total drainage area upstream of the dam is about 290 ha. The volume of the lake will depend on the height of the landslide dam. However, a considerable amount of lake water is expected to infiltrate into the ground through the highly permeable limestone on the eastern side of the Alihauan River.

The maximum discharge, Q_{max}, from the landslide dam failure can be roughly estimated based on the height of the dam, H, using the following empirical formula (Costa, 1988):

$$Q_{max} = 6.3H^{1.59}$$

The discharge of the upper Alihauan River for different heights of the river is estimated using the cross-section of the river based on the topographic map of NAMRIA and the Manning equation, given below.

$$v = \frac{R^{\frac{2}{3}} S^{\frac{1}{2}}}{n}$$

where v = stream velocity (m/s)

R = hydraulic radius (Cross sectional Area of river / Wetted Perimeter) (m)

S = slope of river (m/m)

n = Manning roughness coefficient

The discharge, Q, is calculated by multiplying the Area by the Velocity.

The following discharge values are estimated for different stage heights of the rivers (Table 1).

Table 1.

Stage Height (m)	Cross-sectional Area (m^2)	Wetted Perimeter (m)	Hydraulic Radius (m)	Slope of river (m/m)	Manning Roughness Coefficient	Velocity (m/s)	Discharge (m^3/s)
h	***A***	P_W	***R***	***S***	***N***	***v***	***Q***
1	3.8	7.9	0.48	0.16	0.04	6	23
2	15.1	15.8	0.96	0.16	0.04	10	146
3	33.9	23.7	1.43	0.16	0.04	13	431
4	60.3	31.6	1.91	0.16	0.04	15	928
5	97.0	36.8	2.64	0.16	0.04	19	1,851
6	133.1	40.6	3.28	0.16	0.04	22	2,937
6.5	164.3	44.5	3.69	0.16	0.04	24	3,927

Using the earlier formula, the following peak discharges are estimated for different heights of the dam (Table 2). This gives the projected stage heights of the upper Alihauan River at different discharges. The dam could probably reach a height of a few tens of meters due to the steep river valley of the upper Alihauan River.

Table 2.

Dam Height (m)	Peak Discharge (m^3/s)	Projected stage height (m)
H	Q_{max}	***h***
10	245	2.3
15	467	3.1
20	738	3.6
25	1,052	4.1
30	1,406	4.5
35	1,796	4.9
40	2,221	5.3
45	2,679	5.8
50	3,167	6.1

This table shows that peak discharges due to landslide dam breach can be in the range of a few hundred m^3/s for a dam height of 10 m, to about 3,000 m^3/s for a dam height of almost 50 m. For a dam height of almost 50 m, the flood height of the upper Alihauan River can reach 6 m.

Effects of Flooding Downstream of the Alihauan River

In the absence of detailed flood-modeling study, coupled with the absence of hydrographs for this river, it is difficult to accurately assess the effects of a flash flood.

Catastrophic failure of an Alihauan dam would generate a potential flash flood. Upon failure, the flood could reach a maximum discharge of a few thousand cubic meters per second and velocities of a few tens of meters per second.

If the lake breaches naturally, the landslide dam would erode rapidly because it is composed primarily of soil. A dam breach would release a considerable volume of water from the lake and may cause downstream flooding that could threaten people and property in the lower parts of the Alihauan valley. Based on the estimated peak velocities, a dam breach would allow only a few minutes for the lake waters to reach the low lying Barangays of Lanoy, Cambugason and Alejawan.

At Bgy. Lanoy, the Alihauan valley abruptly widens, and the river flows onto the broad floodplain. In the confined, narrow bedrock valley, a flood will retain much of its velocity, energy, and erosive power, but in the valley's broad lower reaches, a flood will spread across the floodplain, dissipating its energy but inundating large areas of the floodplain. A flood with a peak discharge of a few thousand cubic meters per second could inundate most of the river's floodplain.

Possible Mitigation Options

People are advised not to cross the landslide debris during and shortly after a heavy and/or prolonged downpour.

Tension cracks in the ground are the surface manifestations of movements in the subsurface. In plan, they are commonly concentric or parallel, and have widths of a few centimeters and lengths of several meters The formation of cracks and any increase in their rate of widening is a common measure of impending slope failure. These cracks have to be recognized, monitored, and local residents must be warned of impending slope failure over these cracks. If possible, cracks should also be monitored in the crown (source area).

A natural breach from an Alihauan landslide dam could quickly release a considerable volume of water. A flood generated by such a water release will flow at high velocities through the narrow valley, allowing little time to warn and evacuate downstream inhabitants. Downvalley in the broader floodplain, the effects of the flood are more difficult to estimate, but it will likely have detrimental effects. To minimize the impact of this flooding, a spillway could be excavated through the landslide debris that would reduce the volume in the impounded lake and reduce the size and effects of the potential flood.

A spillway will have to pass through the most likely breach point of the dam. It is important to monitor closely the filling of the lake to better gauge when the water will cause failure of the breach point and, therefore, when flood waters will flow down the Alihauan channel.

A spillway excavated across the landslide should be as deep as possible given the constraints on time before the lake fills, and the available equipment and resources. The deeper the spillway, the less water will be impounded in the lake.

As the lake level approaches the spillway elevation, all residents in the downstream parts of the Alihauan River (Boctol, Lanoy, Cambugason and Alejawan) should be warned and evacuated in advance of a flood. Finally, the landslide dam should be monitored regularly throughout the rainy season to constantly assess any significant changes in the dam's stability.

People should keep away from areas that could be flooded by this portion of the river if it reaches 6 m deep.

The preceding discussion focuses on possible mitigation measures related to failure of the dam by dam breach or overtopping. A more difficult problem is to determine the possibility of a dam failure induced by piping, in which water from the lake percolates through the dam, causes caving and the formation of conduits in the dam through which the lake water can drain. As the depth of the reservoir increases, the potential for piping increases because the impounded water exerts increasing pressure on the dam. Thus as the reservoir fills, the dam should be checked regularly for evidence of significant seepage. If seepage develops, then it should be routinely monitored for changes in the rate of seeping water, which could be evidence of increasing piping and decreasing stability of the dam.

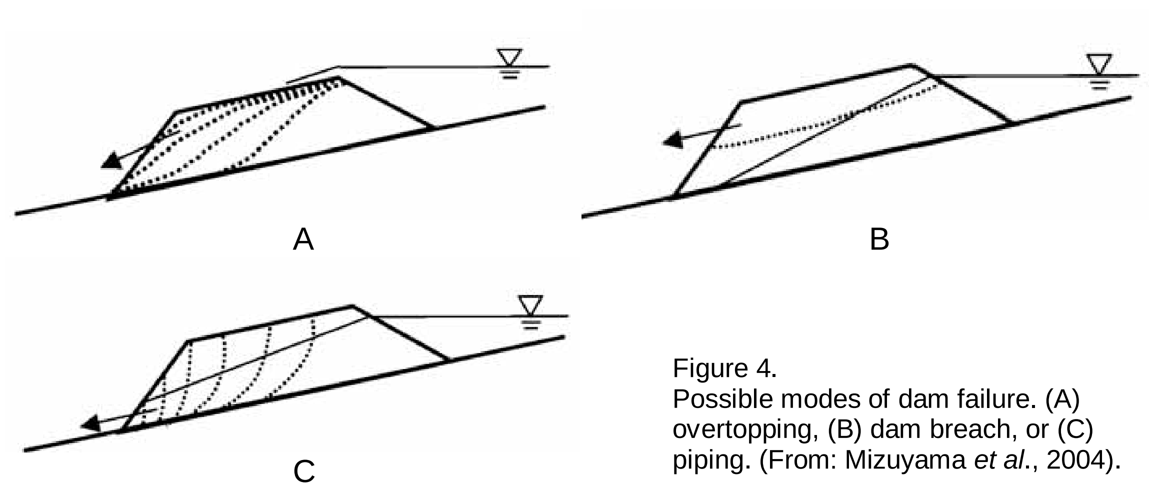

Figure 4.
Possible modes of dam failure. (A) overtopping, (B) dam breach, or (C) piping. (From: Mizuyama *et al.*, 2004).

Another possible hazard is debris flows during the rainy season. Landslide debris that has clogged the Mayana River and probably part of the Alihauan River with soil may be remobilized as debris flows during the rainy season. Large flows may extend down to the broad, gentle slopes of Barangay Lanoy. Areas in Lanoy that are inundated during normal floods are likely to be affected by debris flows. Residents in these areas should be evacuated during a typhoon.

R E F E R E N C E S

Costa, John (1988). Floods from Dam Failures. In: Victor Baker, Craig Kochel, and Peter Patton, *Flood Geomorphology*, John Wiley and Sons, pp. 439-463

Takahisa Mizuyama, Shigekiyo Tabata, Toshio Mori, Fumito Watanabe, and Kimio Inoue (2004). Outbursts of Landslide Dams and their Prevention. 10th Congress Interpraevent 2004. Available at www.sff.or.jp/Prevention01.pdf.

Mines and Geo-Sciences Bureau (1981). *Geology and Mineral Resources of the Philippines, Vol. 1 – Geolog*y. Ministry of Natural Resources.

Municipality of Sierra Bullones, Province of Bohol. Available at http://elgu.ncc.gov.ph/ecommunity/sierrabullones-bohol/

Philippine Institute of Volcanology and Seismology (2005). Latest Earthquake Information. Available at http://www.phivolcs.dost.gov.ph/EQLatest.html

Philippine Institute of Volcanology and Seismology (2005). Distribution of Active Faults and Trenches in the Philippines. Available at http://www.phivolcs.dost.gov.ph/GGRDDpage/projects/fault/philfault/philfault.htm