An overview of destruction and recovery in the Mt. Mayon volcano region, Bicol, Philippines, resulting from lahars initiated by Supertyphoon Reming

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Abstract

On November 30th 2006 the southern eye-wall of Supertyphoon Reming (aka Durian) crossed the Luzon coast close to Mayon Volcano at Legaspi, Bicol, with gusts up to 260 km/h. That day Legaspi recorded 466 mm of precipitation with the maximum hourly rainfall intensity at 3 p.m. reaching 135 mm. Reming continued across Mt. Mayon where orographic effects augmented these rainfall totals. Winds buckled hydro pylons, flattened wooden structures, and damaged coconut plantations. Flooding caused rivers to undermine river banks while rice irrigation channel overflow damaged low-angle terraces. Most devastation and loss of life resulted from lahars initiated on the southern and eastern flanks of Mayon. So rapidly did they form and so extensive were they that many communities around Mayon’s base were completely overwhelmed as lahars cut new paths and breached existing sabo structures (dikes). The number of dead exceeded 1,250 while tens of thousands were displaced. Post-typhoon lahar-mitigation and recovery included immediate steps to re-channelize ash filled river beds, the building of ash banks to redirect any subsequent lahars from the unstable slopes above and the building and repairing of concrete sabo dikes close to settlements.

Key words: lahar, Supertyphoon Reming, sabo structures, Mt. Mayon

Introduction

Natural disasters resulting directly from volcanic eruptions and indirectly from such activity as lahars (ash debris flows) are characteristic of the Pacific Rim (Neall 2007). The 1985 eruption of Nevado del Ruiz in Columbia melted part of the ice-field causing lahars to descend the surrounding valleys, killing 23,000 people, mostly in the town of Armero. The devastating eruption of Pinatubo in west-central Luzon in 1991 filled surrounding valleys with ash to depths often exceeding 60 m and for at least the following four monsoon seasons major lahars caused widespread destruction and death in the lowlands. The worst Pinatubo lahars developed in June 1991 when monsoon and typhoon rains joined to produce 780 mm of precipitation in one 24-h period (Neall 2007). Historically the Mt. Mayon region of the Philippines has also been particularly hard hit by lahars because of volcanic eruptions that produce ash deposits on steep volcanic slopes which may later become mobilized by heavy cyclonic rains (Orense 2007). As volcanic materials often develop into fertile soils capable of supporting highly productive plantations and rice, humans are attracted to lower volcano slopes and are placed in harms way during typhoon passage (Figure 1).

This paper reviews the circumstances surrounding the impact of lahars which were responsible for more than 1,250 deaths on the lower slopes of Mt. Mayon, that resulted from ash remobilization as Supertyphoon Reming (aka Durian) crossed south-eastern Luzon on November 30th, 2006. The paper focuses on lahar damage as well as the rehabilitation of drainage channels, and the construction and repair of sabo structures. Sabo is a Japanese term that generically refers to all engineering structures built in an attempt to control mass movements, flood waters and related events in order to reduce damage to infrastructure, farms, homes and humans (Fano et al. 2007). In the case of the Philippines most sabo engineering structures are lahar-confining concrete and ash dikes built to contain flows...
and protect populations in the lowlands below (Figure 2). Their construction is directed by the ‘Flood Control and Sabo Engineering Center (Department of Public Works and Highways)’, Pasig City, Manila, which receives both financial and technical assistance from the Government of Japan.

This paper concludes with a review of potential Mayon lahar damage mitigation in the future. The author first carried out field research around the base of Mt. Mayon in January 1979. Two additional field periods were carried out in February 2007, and January 2009, specifically to examine the aftermath of Supertyphoon Reming.

The Regional Setting

Mt. Mayon possesses almost perfect symmetry and is one of the most active composite volcanoes on the planet. It rises from sea level to a height of 2,462 m with a diameter of 20 km (Figure 3). Upper slopes are quite steep while slope angle diminishes in a very regular way with descent to sea level (Fano et al. 2007) (Figure 4). It is constantly degassing and has erupted violently 54 times in the last 400 years (Ramos-Villarta et al. 1985). Most eruptions involve large ash-cloud discharges, though pyroclastic and lava flows are also common, and magma composition is basaltic to olivine-bearing pyroxene andesite. Regionally the lahar event of November 2006 was the largest since a comparable event in 1814 when the Cagsawa church (Busay) was destroyed by a lahar following a major eruption (Ramos-Villarta et al. 1985; Paguican et al. 2009) (Figure 5).

Mt. Mayon’s upper slopes are bare rock or ash covered and, in descending order, are surrounded by Miscanthus grasslands, grazing lands, coconut plantations, and a mixture of low-angle rice terraces, and other agricultural field-crop activities including sugar cane and acaba (Manila hemp). Through this sequence run gullies of varying capacities and depths down which most lahars would flow when activated. A major variable is the un-equal provision of ash following frequent pyroclastic discharges and the rate these new layers become at least temporarily locked in place by invading Miscanthus and soil profile development. New gullies can form when lahars overflow gully banks or encounter recent lava or lahar deposit barriers. Most Mayon lahar ash never arrives at the ocean directly, as on reaching gentler lowland slopes hydration levels decrease and they cease flowing. As these are the very regions where settlements are most common, the consequences are home and field burial and valley infilling. An effusive event from Mayon’s crater occurred in July-August of 2006 providing both fresh upper-slope pyroclastics and a major lava flow that required the temporary evacuation of 40,000 residents (Figure 6). This new ash later made a major contribution to the lahars initiated by Reming. Renewed ash and lava discharges began again in December 2009 when again over 40,000 people were evacuated to displacement centres (PHI-VOLCS 2009). As of 3 January 2010, rockfall events, volcanic earthquakes and sulfur dioxide degassing were continuing.

Control Measures in Place Between November 30, 2006

The Flood Control and Sabo Engineering Office of the Philippine Department of Public Works and Highways (DPWH-FCSEO) has responsibility for providing protection from flooding and debris flows in the Philippines and in the construction
Figure 3: Satellite image of the area most impacted by typhoon Darien-initiated lahars, 30 November 2006. Image of 12th December, 2006 (UNOSAT 2006).

Figure 4: Mayon volcano viewed from Ligñon Hill on February 15, 2007, eleven weeks after the devastation caused by typhoon Reming initiated lahars of 30 November 2006. A large grey-coloured lahar has filled the river bed and floodplain in the right portion of the photo while coconut plantation damage caused by typhoon winds is visible.

Figure 5: The belfry of Cagsawa church, Busay, left standing after the lahar episode of 1814. Large rocks carried by the 1814 lahar are clearly visible in the church yard.
of new control structures and in highway protection (Fano et al. 2007). With the assistance of sabo engineers from the Japan International Cooperation Agency (JICA) two reports were prepared to help direct mitigation: 1) Study on Mayon Volcano Soba and Flood Control Project (1978-1981) and 2) Study on Comprehensive Disaster Prevention Around Mayon Volcano (1998-2000). Based on the first study it was recommended that P2.1 Billion be spent on sabo structures over the following ten years. Unfortunately, so little money was released by the Philippine Government that sabo construction was deferred until 1984 when a renewed volcanic eruption and lahar episode created the impetus for construction and infilled-valley dredging to begin. With JICA financial and technical assistance sabo construction consisted primarily of ash/soil dikes (spur or ring dikes) designed to redirect lahars away from significant or populated areas. Ash core dikes were occasionally reinforced with thin steel bars and veneered with at least 4 to 7 cm of concrete. The simple dredging of lahar deposits from infilled valleys with the displaced fill being formed into dikes later also proved valuable. Where this was not done waterway banks were more easily overtopped (Fano et al. 2007).

Supertyphoon Reming and Lahars of November 30, 2006

North-west Pacific tropical storms and typhoons are particularly common between the months of September and December. In 2006 four Category 4 supertyphoons (winds > 210 km/h) crossed Luzon, each producing swaths of devastation. Reming developed into a typhoon on November 28th and reached supertyphoon status on the 29th before its eye crossed Legaspi, making an almost direct hit on Mayon the following day (Figure 7). Legaspi rainfall between 10 a.m. and 4 p.m. on the 30th exceeded 450 mm (PAGASA, 2006) with an hourly total at 3 p.m. reaching 135 mm (Figure 8). Orographic effects on Mayon undoubtedly augmented this, as earlier research had shown rainfall intensities at 600 m were normally enhanced at least two fold during typhoon passage (Rodolfo and Arguden 1991). While storm surge activity was easily predictable and coastal communities had ample warning, the onset of heavy rains was so sudden that warnings of impending lahar activity did not reach the general population quickly, a problem exacerbated by the collapse of the power grid caused by typhoon winds. Rivers initially filled with sediment-laden runoff and then lahars started flowing from the lahar-initiation fields on the upper slopes. These upper-slope Miscanthus grasslands had been anchoring the predominantly ash soils but started to become unstable as saturation and increasing mass caused overloading (Figures 9-11). Breaking loose almost in unison, this liquified ash took only 9 to 21 minutes to descend Mayon, overrunning at least six lowland communities before subsiding in a matter of minutes (Paguican et al. 2009). Lahars inundated all of these communities at approximately 2 p.m. with widespread damage occurring as they overtopped river bends, eroded many ash dikes and breached six concrete sabo dikes. Only on the eastern flanks between Legaspi and to just north of Lidong, where Mayon slopes intersect the coastline, did lahars enter the ocean directly (Figure 3). Since subsequent river flow began to excavate in-filled river beds, additional fines continue to be transported to lower levels and to the ocean.

Immediate Aftermath: Short and Longer-Term Needs

Following Reming, DPWH-FCSEO was faced with initiating a combination of both short- and longer-term projects. Important short-term needs included: 1) channelization of river beds to re-establish drainage networks, 2) rehabilitation of chan-
Figure 8: Hourly rainfall at the PAGASA research station (# 444), Legaspi, 30 November, 2006 (modified from Fano et al. 2007). PAGASA is the acronym for the Philippine Atmospheric Geophysical and Atmospheric Services.

Figure 9: Erosion scars in the lahar-initiation fields visible on the south-western flanks on Mt. Mayon together with the deep gullies down which they flowed. Photo taken in February 2007, 10 weeks after the lahar event of 30 November 2006.

Figure 10: Valleys on the south-western mid-slopes on Mt. Mayon carved by lahars and deepened by subsequent rainfall. February 2007.

Figure 11: Lahar initiation field gully cut through Miscanthus grassland just below the crater of Mt. Mayon. This view is southeast to the lowlands east of the large lava flow of July-August 2006 (see Figure 6). Here lahar gullies fan out before many reach the coast between Lidong and Legaspi. Photo by Troy Scott, February 2007.
nels under bridges, temporary bridge construction and highway clearing and rehabilitation, and 3) immediate construction of ash dikes to help mitigate any new lahar activity that could still descend from Mayon’s upper slopes following new rain storms. Immediately following the passage of Reming, DPWH assigned heavy equipment to lahar-damaged areas. Large sections of the National Highway north of Legaspi were eroded and/or buried and required immediate attention. Figure 12 shows efforts to remove ash from an infilled valley floor near this highway at Lidong with the excavated ash and boulders being used for ash dike construction adjacent to the same river (Figure 13). Figure 14 shows remedial action to clear the bridge channels under the National Highway just downstream of these two examples.

Sabo construction activity of this type was repeated throughout the disaster zone and occurred in tandem with the efforts of other government agencies to rehabilitate homes, public buildings and agricultural lands. Because of its historic and economic importance, numerous ash and concrete sabo were quickly constructed upslope and around the historical site at Cagsawa (Figure 15) where only the church belfry survived the 1814 catastrophe (Figure 5). Lahars initiated by Reming flowed around both sides of the site with one actually coming up against the north wall of the compound before being deflected to the east around the site where both lahars then joined (Figure 16). Viewing Cagsawa from the north of the wall shown in Figure 16 demonstrates how quickly the low rice terraces were rehabilitated and cropped (Figure 17a, b). Some farmers adapted ash-covered fields often within just a few months. One field illustrated in Figure 18 shows that sweet potatoes were planted within only ten weeks of field burial by ash. Many salvageable homes and Barangay (Municipality) schools were also rehabilitated quite quickly (Figures 19-21). The hot humid climate of the region is also beneficial in terms of the recovery of such things as coconut, abaca and banana plantations and natural vegetation. Figure 22 illustrates the fate of one tree on Ligñon Hill which appeared killed by the supertyphoon winds but which recovered almost completely within two years.

Longer-term needs include: 1) the continued repairing of old ash and concrete dikes and the building of new ones close to settlements, 2) the continued removal of re-worked lahar ash that aggraded river beds, and updating the mapping of lahar flow channels. Concrete sabo construction has already advanced in some of the Baranguays where deaths were in the hundreds. Figures 23-25 illustrate concrete dike conditions before February 2007 and after January 2009 at Guinobatan, Daraga and Pawa. A concrete dike has also been constructed on the southwest flanks of the Cagsawa site. Other strategies which clearly help with the reduction in loss of life include: 1) developing better lahar forecasting models based on precipitation events (as in Figure 8), 2) broadening valley dredging operations that function as lahar ash settling basins, 3) improving automated rain-gauge monitoring systems or acoustic flow monitors in the lahar initiation zones at higher elevations, 4) improving vulnerability assessments following every lahar and eruption event, 5) better co-ordination among the major government agencies involved, 6) construction of elevated evacuation sites, and 7) possible community relocation (Fano et al. 2007; Paguican et al. 2009).

Conclusion

Forecasting Mt. Mayon volcanic events by PHIVOLCS is so well advanced that forced evacuations before the eruptions of the summer of 2006 led to no loss of life. By contrast, a mere three months later the difficulties in quickly forecasting lahars and issuing forced evacuation notices led to over 1,200 deaths. While better forecasting of lahar events and the related issuing and execution of evacuation notices is needed, such events are extremely difficult to predict. This is because their formation depends on so many variables, the more important of which are the availability of easily removed ash on steep slopes and the prediction as to where the centre of a cyclone or the eye of a ty-
Figure 14: Cleaning ash from an in-filled bridge at Lidong on the National Highway, north of Legaspi (February 2007).

Figure 15: Ash dikes constructed upslope of Cagsawa, Busay, in 2007. Note Miscanthus grass which has germinated from seed transported down slope by a November, 2006 lahar. Photo taken in January 2009.

Figure 16: A lahar came up against but did not overtop the retaining wall of the Cagsawa National Museum site and was deflected to the left. A stream has re-established itself and continues ash sediment transport. February 2007.
Figure 17: a) Damage above the northern wall surrounding the Cagsawa site shown in Figure 16 (February 2007). b) The same view following rehabilitated and cropping to rice, January 2009.

Figure 18: a) Cropping sweet potatoes on ridges in an ash-covered field at Lidong 10 weeks following burial by a thin layer of lahar (photo in February 2007). b) The same field in January 2009 planted to cassava.

Figure 19: a) A primary school at Lidong in February 2006, and b) in January 2009.
Figure 20:  

a) This building in Padang doubles as both a Barangay office and a day care centre (photo taken in February 2007), and 
b) the same building in January 2009.

Figure 21:  Damage and rehabilitation of the lahar damaged day care classroom in the building shown in Figure 20. 

a) In February 2007 volunteer plants growing in the lahar ash include banana and taro, while the message on the blackboard warns people to stay away; 
b) the same room in January 2009.

Figure 22:  

a) Photo taken one week after Reming crossed Bicol in early December 2006 from Lignon Hill of an apparently ‘dead’ tree in the foreground behind which is seen the Mayon volcano lava flow of July-August 2006 (from Rice Today 2006: 6(1) – original supplied by the International Rice Research Institute, Laguna, Philippines, with permission), 
b) the same tree on 15 February 2007, after only ten weeks of recovery, 
c) the same tree on 19 January 2009, looking quite normal.
Figure 23: a) Destruction caused along the river passing Guinobatan by lahars on 30 November 2006 (photo February 2007) and b) post concrete sabo construction (January 2009) at the same site.

Figure 24: a) Destruction caused along the river passing through Daraga by lahars on 30 November 2006 (photo February 2007) and b) post concrete dike construction (January 2009) at the same site.

Figure 25: a) Destruction caused along the river passing Pawa by lahars on 30 November 2006 (photo from Ligion Hill, February 2007) and b) post concrete dike construction (January 2009) at the same site.
phoon will pass to provide the necessary precipitation. As a caution it had been noted that in 1967 a typhoon brought more than 475 mm of precipitation to the Legaspi area in a 24-h period but no lahars were reported. This was attributed to the fact that new pyroclastic deposits had not developed since an eruption in 1947 so stabilization and soil profile development kept most slopes intact (Paguican et al. 2009). With Reming, fresh ash from the eruptions of the summer of 2006 was available along with deposits from some years earlier, so the potential for lahar activity was being monitored. Now that these 2006 deposits and more vulnerable previous lahar layers have been reworked by Reming it might be assumed few major lahars can now form. Unfortunately, the current eruptive phase which started in December 2009 continues (see http://www.phivolcs.dost.gov.ph/ for updates), so any such assumption should be dispelled. Since Mayon volcano lahar events are a problems which will simply not go away, the need to remain vigilant is paramount.

References


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