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Floods in Ormoc City, Leyte on November 5, 1991
レイテー島 オルモク洪水 (1991年11月5日)

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1. Introduction

During the past year from 1991 November to 1992 October, a number of Asian countries suffered extensive damages from disasters associated with heavy rainfalls. The damages ranged from flash floods in Leyte, Philippines, slope failure in Hong Kong, inland flooding in Colombo, Sri Lanka, lahar flow in Luzon, Philippines, floods in Pakistan, etc. In Leyte, Hong Kong and Colombo, the rainfalls were the heaviest recorded in the history of each region. The author had made site visits to investigate these three floods and this paper describes the flood in Leyte island of the Philippines.

2. The Flood

The island of Leyte lies in the eastern part of the Visayas, between 10°–12° and 124°–125°, and Ormoc City is located at the eastern part of the island just north of the Ormoc Bay (Fig. 1). The city has an area of approximately 46,400 ha and a population of 120,000. Ormoc City is the common flood plain to two rivers which drain to the Ormoc Bay. The rivers, Anilao and Malbasag, form the Anilao-Malbasag watershed with a total area of 4,501 ha of which Anilao River has an approximate watershed area of 3,100 ha and Malbasag River 1,400 ha. The urbanized area of Ormoc City is relatively flat with a maximum relief of about 3 m. Approximately 200 ha of low land is subjected to flooding.

On the 5th of November, 1991, typhoon Thelma, called Uring in the Philippines, and termed Typhoon No. 25 in Japan, hit the Province of Leyte causing widespread damage. According to interviews, the chronological order of the events at Ormoc City were as follows. Intermittent heavy rainfall started at 6:00 AM with strong winds. By 10:00 AM, area along Anilao and Malbasag rivers was

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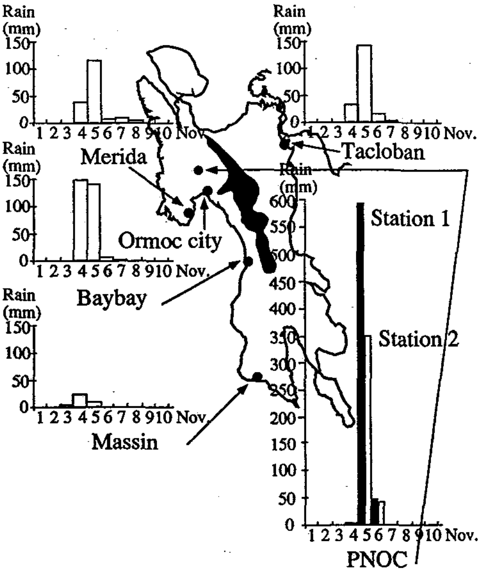

Fig. 1 Layout of Leyte Island and Rainfall Records

inundated due to river overflow, and the depth at Anilao bridge was 2-3 m. However, the flow was not very rapid. Soon flood flow containing a great quantity of debris and driftwood has surged over the areas down stream of Anilao bridge. The inundation depth has increased rapidly and the flood flow velocity too became rapid. At this time, Anilao bridge, located at the top of the city, collapsed discharging a huge amount of water. Parts of the city was inundated up to a depth of about 2m. Approximately about 45 min. later the floods have promptly subsided. The flood peak has not lasted more than a few minutes.

The extent of the damage became clear only after the subsidence of the flood waters. A small island named Isla Verde, made of alluvial deposits located within the river and populated by low income families was swept by the flood waters. A significant number of casualties were children trapped inside homes unable to open the doors

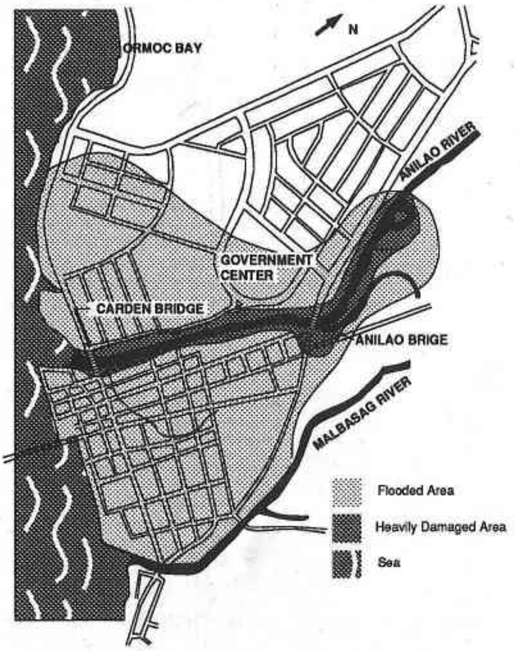

Fig. 2 Flooded Areas of Ormoc City

held by hyper concentrated flood waters. In that brief period over 6,000 lives were lost in Ormoc City. The heavily flooded area of the city is shown in Fig. 2.

In other municipalities, deaths and injuries were reported as 81 and 237 respectively. Altogether 38,294 families were affected in 13 municipalities of the province and in the Ormoc and Tacloban cities. The flash floods destroyed agricultural products, infrastructure facilities and utilities. Total damage affecting all sectors was estimated as between 620~860 million Pesos.

The floods took the city of Ormoc completely by surprise. Anilao and Malbasag rivers are gently flowing rivers overflowing only once in the past 50 years, but then too not causing much disruption. The city was not prepared for the floods, and temporary houses are built along the river flood plains. Soon after the tragedy, there were many explanations with regards to the cause of the floods. According to the newspapers, the Mayor of Ormoc City attributed the damage to a deadly combination of typhoon Uring, high tides and deforestation. The typhoon itself was classified as relatively weak by Philippines Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), and the topography of Ormoc City area shows that high tide cannot significantly affect the river flow. There were other speculations. During interviews conducted by National Economic and Development Authority (NEDA), survivors have said there were about 25 'buhawi' which means circulating-spinning wind with water. Others told of hearing explosions. Another explanation was the overflow of water from the lake Danao located in the high mountains. A visit to this lake made clear that it could not have contributed to the floods in Ormoc City. The lake is located in a different watershed and is divided from the Anilao-Malbasag watershed by a high mountain.

Along Anilao river, flood water marks as high as 6m above the river bed could be seen. Both in the high and middle reaches, the V-shaped slopes along the river provide ample storage for a rainfall of short duration. By the account of eye witnesses who described the rain as a "falling water sheet" and considering the amount of flood waters, it is clear that an unprecedented rainfall of sustained high intensity has caused the flash floods in Ormoc City.

3. Precipitation

Unfortunately there is no record of rainfall in Ormoc City or within the Anilao-Malbasag catchments. Daily rainfall amounts for the period of 1-10 th of November within the Leyte island are shown in Fig. 1. Significant rainfall records among them are shown in Table 1.

The PAGASA station in Tacloban City is located on the Eastern (Pacific Ocean) side of Leyte, separated from Ormoc City side by a mountainous area and is not very relevant to the rainfall in Ormoc City area. However, the 146.2 mm rainfall recorded there has fallen from 8.00AM to 2.00 PM and according to PAGASA 6hr duration 146.2 mm rainfall has a return period of 50 years.

Table 1. Significant rainfall records on November 05-06

Gaging Station	Rainfall (mm)	Period
Tacloban City (PAGASA)	146.2 (24 hrs)	8:00 AM 5th-8:00 AM 6th
Baybay, Visayas State College of Agriculture	138.0 86 hrs)	8:00 AM 5th-2:00 PM 5th.
TG-11 station EDC Hostel (PNOC)	350.0 580.5 (48 hrs)	8:00 AM 4th-8:00 AM 6th

The rainfall records of the Philippine National Oil Corporation (PNOC) stations provide the rainfall figures most relevant to the flood on November 5. These stations are located in Tongonan, on the western slopes of the Leyte Highlands overlooking Ormoc Bay to the south-

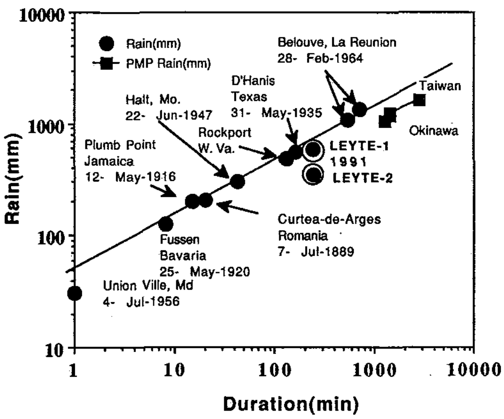

Fig. 3 World's largest recorded rainfalls

west. This area lies within the Bao river catchment, adjacent and to the northwest of Anilao-Malbasag catchment. The available readings of the PNOC stations are for 48 hour period. Although the readings are normally taken daily at 8.00 AM, the winds have been very strong with accompanying rainfall and no readings were taken on the 5th of November. According to the gauge keeper and the guard house personnel of the PNOC, the intense rainfall in the morning was concentrated approximately over 3 hours, peaking at around 11:00 AM. Therefore it can be assumed, that a major portion of the PNOC recorded rainfall occurred between 8:00-12:00 AM on the 5th of November.

Rainfall of this magnitude has never been recorded in this area in the past. The past significant rainfalls for 24hr. periods recorded in Leyte are, Typhoon "Undang" (November 1984) 153mm, Typhoon "Ruping" (November 1990) 98mm.

The rainfall records of National Irrigation Administration (NIA) at Valencia, Ormoc City, from 1980-1989 shows the highest monthly rainfall for the 10yr. period to be 223.5 mm for the month of September. By comparison, the PNOC records show extremely high precipitation for the region. Fig. 3 shows a comparison of these records with some of the highest rainfalls recorded in the world.

4. Typhoon URING

Typhoon Uring which caused this heavy rainfall was not considered a major threat until it hit the Ormoc area. On the average, about 20 typhoons come close to or hit the Philippines every year, and in 1991, 19 typhoons hit or came close to the Philippines. Four typhoons passed over the Visayas, central part of the Philippines, in 1991. The first was in April, the second and third were in June and the fourth named Uring was in November. The development and movement of typhoon Uring is described in Fig. 4. In the figures along the path, first number refers to the date, the second number to the hour and the third within brackets denotes the speed.

Just before Uring hit the island of Samar, when it became strongest, it was a relatively small-sized typhoon with a central atmospheric pressure of 992 hPa and

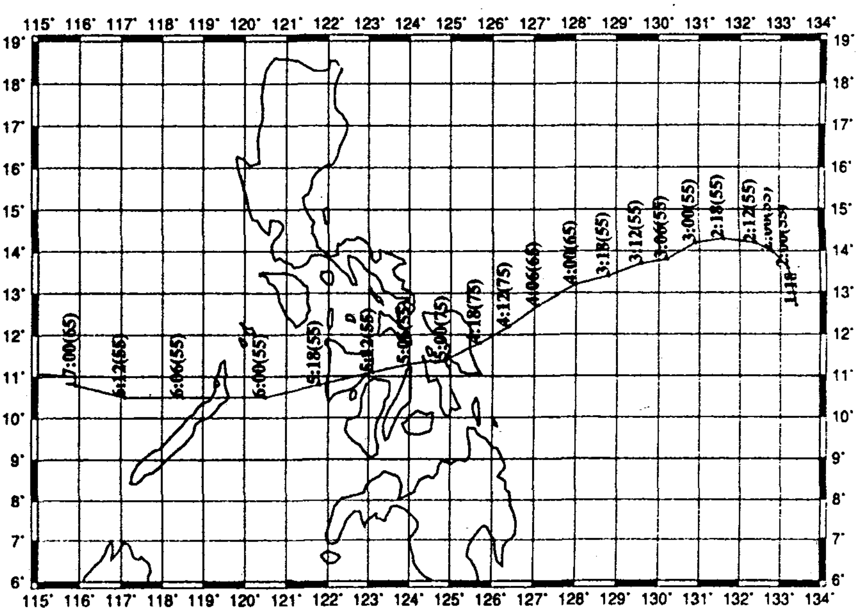

Fig. 4 Path of Typhoon Uring

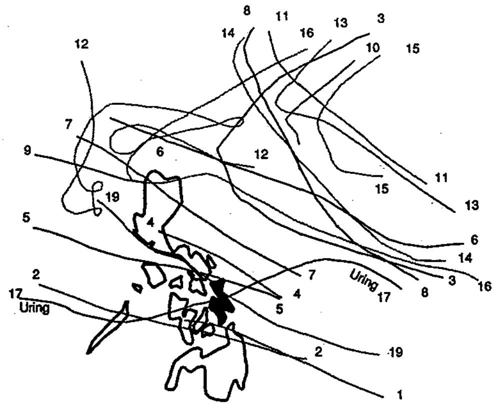

Fig. 5 Paths of typhoons in 1991

maximum winds of 20 to 21 m/sec. Uring, however had a strongly developed cumulonimbus of up to 15,000 m in height as of a big-sized typhoon. This cumulonimbus brought the intense rainfall to the mountainous area. Three factors can be considered as contributory to this extreme event.

1. The typhoon occurred late in the year, when the cold front coming from the north is already in the lower latitudes (approximately north of Luzon island).
2. The slow speed of movement of the typhoon (Westward at 11 kph).
3. The presence of a high mountain range in its path (Mt. Alto Peak, more than 1,000 m above sea level).

The 'normal' typhoon route is northwest towards Samar and Bicol/Southern Luzon. In the case of typhoon Uring, pushed by the cold front, it followed a southwesterly direction. The paths of all the typhoons to hit Philippines in 1991 are shown in the Fig. 5.

In the early morning of November 5th, upon interception by high ranges of Alto Peak, it was forced upward to high altitudes. The moisture-saturated air mass from the Pacific Ocean, pushed upwards to high altitudes created the orographic effect which resulted in rapid condensation of the vaporized moisture, which in turn was dumped in the headwaters in Alto Peak, Mt. Amandewing. This also explains the great volume of water that flowed towards the eastern towns of Leyte such as Burauen, Pastrana, Dagmi, etc. Due to the slow speed of the westward moving air mass, the heavy rainfall which lasted for about 3 hours (8:00 AM to 11:00 AM) was concentrated to a limited area surrounding Ormoc City area. If it had been moving faster, the rainfall would have been distributed over a wider area including Ormoc Bay.

5. Basin Characteristics and Geology

Generally, the terrain of the watershed is from moderate to rough and very rugged. Its slopes range from 3% in relatively flat areas to higher than 60% in steeply sloping places. Approximately 23% of area has a slope less than 18%. The highest elevation of the basin is about 830m. Leyte is classified as a volcanic terrain, with most of its volcanic centers concentrated on the north-central portion of the island. The general geology of Leyte is made up of a basement of Pre-Tertiary (>125 million years) basic igneous and metamorphic rocks concentrated along the mountain range traversing the length of the island. These are overlain by marine and terrace gravel deposits of Early Neogene, Late Paleogene Age. The youngest of the units exposed in the area is the Plio-Pleistone volcanic formation which has an andesitic composition.

In the Anilao-Malbasag watershed area, the headwaters are within the highly sheared andesites. Most of the drainage systems run on the moderately-dipping pyroclastic deposits which is mainly composed of thick accumulation of lahar. The lowlands are underlain by recent alluvial sediments of unconsolidated gravels.

Soil in the upstream, particularly those along very steep slopes is of volcanic origin developed mainly from andesitic rocks. Characteristically, they are loose, unstable and highly susceptible to erosion. Numerous scars can be seen on the steep embankment of Bao, Malitbog and other headwaters of river channels of Ormoc watershed resulting from landslides.

Infiltration tests have been conducted by DENR-8 personnel in the Anilao-Malbasag watershed from 29-30 November, 1991. These measurements are shown in Table 2.

Three soil samples were taken from areas near to the Malbasag and Anilao rivers and were tested at the University of Tokyo. The saturated conductivity values obtained were as follows.

Table 2. Infiltration tests Conducted by DENR Team

Land Use	Infiltration rate (mm/hr)	% of basin
Cogon, Talahib & Colopogonium	54.09	25%
Corn on bare land	3.37	15%
Newly furrow-plowed sugar field	13.57	60%

Malbasag down stream 45.4 mm/hr
Anilao up stream 60.12 mm/hr
Anilao mid stream 136.1 mm/hr

The moisture retention curves for the samples are very similar to that of Kanto-Loam soil, another soil of volcanic origins found in Japan.

The dominant vegetation of the basin is agricultural crops composed of sugar cane, paddy and coconut. Non-agricultural areas are open grasslands and shrub-lands, used as pasture or maintained under fallow. About 86% of the watershed is under agricultural land-use, and 13% under grasslands and shrubs.

6. River Condition

Fig. 6 shows the location of Ormoc City and the two rivers, Anilao and Malbasag. The bed of Anilao river near Anilao bridge at Ormoc City is 5 m above sea level. It gently slopes upward between 2%–10% up to an elevation of 500m above sea level and then rises up to 20%–40% in its highest reaches at about 820m above sea level. Malbasag river follows a similar course reaching a maximum of 10% at its upper reaches at elevation of 800 m. The main features of the two rivers are summarized in Table 3.

Table 3. Characteristics of the Rivers

Item	Anilao River	Malbasag River
River Length (km)	13.80	0.42
Drainage Area (ha)	3,100	1,400
Height of Headwaters (m)	860	800
Average Stream Profile in Urban areas	1/19 1/140	1/15 1/90
Average Channel width (m)	40	20
Average Channel depth (m)	3	3

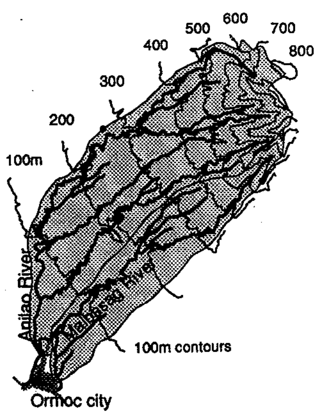

Fig. 6 Anilao-Malbasag basin

The stream channels are V shaped, deep and narrow with steep to very steep banks. Riverbed material consists of sand with gravel downstream of both rivers, while large boulders can be observed in the upstream river channels. Retaining walls and stone masonry or concrete revetment are constructed at important points in the urbanized area. The two rivers are connected to each other by an irrigation canal which lies just north of Ormoc City.

7. Flood Estimations

To estimate the floods it is necessary to know the rainfall as well as basin parameters to be used in a flood model. As there are no recorded observations, it is not possible to calibrate any such parameters. Rough estimation of peak discharge is possible using the rational formula and the rainfall records of PNOC (355.7 mm~580.5 mm) assuming a rainfall duration of 4 hrs. Then with time of concentration (tc) 3hrs (less than rain duration) and peak runoff coefficient (f) taken as 0.8 , peak flood discharges are given by,

for Anilao River: $540m^3/s$–$900m^3/s$.
for Malbasag River: $240m^3/s$–$400m^3/s$.

The stream velocities at Ormoc City, estimated by DENR post-flood measurements using Manning's Formula are as follows,

River	Slope	Velocity (m/s)	Discharge (m^3/s)
Malbasag	0.02124	6.9	401
Matugnao	0.0266	8.2	680
Anilao	0.0199	8.47	1457

Comparing with the average stream discharges from the DENR measurements, it can be seen that the rainfall is closer to the higher value of the rainfall record. These flood peaks are compared with the highest flood discharges recorded in the Philippines in Fig. 7.

8. Aggravating Factors

Landslides and soil creeps have been noted along the steep embankments of the rivers and creeks. Together

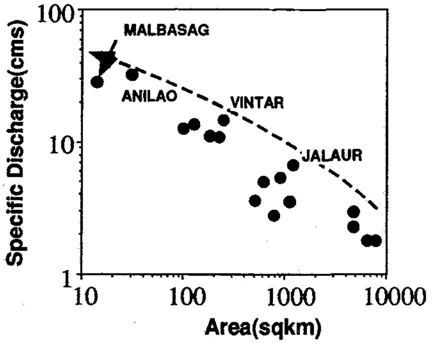

Fig. 7 Comparison of Ormoc Flood with the largest floods recorded in the Philippines

with thousands of tons of soil and rocks, trees and coconut trunks greatly increased the damage and played a role in temporarily damming up Anilao bridge. 95 trees and 357 coconut trunks have been inventoried along Malbasag river, whereas 200 trees and 1031 coconut trees were found along Anilao river, excluding those washed to the sea.

The river channels have a number of acute natural bends and constrictions in many places. Temporary dams could have been formed at these places by the soils and debris from upstream. Even along the upper reaches of the rivers, traces of water line during the flood could be traced to 6-10m above the riverbed.

Channel width is not longitudinally uniform, so that drainage capacity too is rugged. Anilao river has almost a 90° bend just above Ormoc City. Anilao bridge is situated immediately after this bend. The damming up caused by driftwood at the bridge inundated Isla Verde, an islet formed by alluvial deposits lying in the middle of Anilao river upstream of the bridge and densely populated by low income families. The flood waters overflowed the upstream river banks inundating the city. The bridge itself collapsed releasing voluminous water suddenly.

9. Concluding Remarks

As summarized by the DENR report, the flooding of Ormoc City was not caused by illegal logging; there is nothing to log in the Anilao-Malbasag Basin. The whole watershed (99%) has been converted to agricultural use decades ago.

The floods of Ormoc were caused by extraordinary rainfall concentrated in the mountainous region of Ormoc and Baybay area. The damage is not limited to the Anilao-Malbasag watershed. Almost all the bridges along the highway from Ormoc to Baybay have been damaged requiring replacement or extensive repairs. The only available rainfall records suggest this to be 350~550 mm, falling within about 4 hours. The rivers did not have the capacity to carry the resulting flood waters.

A number of landslides seemed to have occurred in the highly erodible soils owing to the geology of the basin, creating temporary dams in the narrow portions or bends along the river. The position of Anilao bridge has been instrumental in the rapid rise of water in the city due to its damming and subsequent collapse. Sprawl in to the flood prone area has contributed to the high rate of casualties.

It is important to recognize the possibility of such disasters in other parts of the Philippines with the large number of typhoons hitting the island each year. Hydroloigical studies with continuous measurements in different parts are needed for flood warning and preparedness as well as for the establishment of design criteria for construction of new civil structures. There is a need for greater coordination between donors to make integrated development plans which include flood mitigation measures.

(Manuscrict received, January 14, 1993)

References

1 Report of The Scientific Study Group, Department of Science and Technology (DOST), Philippines, November 1991.
2 Investigation Report of Ormoc City Disaster, Department of Environment and Natural Resources(DENR), Philippines, December 1991.
3 Technical Assessment of the Causes of Ormoc City Flood, Department of Environment and Natural Resources-(DENR), Philippines, December 1991.
4 Survey Report on Ormoc City Flood of November 1991, JICA Survey Team, February 1992.
5 Situational Report Action Report as of 16 November, 1991, Department of Public Works and Highways Region - 8, Philippines, December 1991.