EFFECTIVENESS OF THE LEVEE AGAINST FLOODING AT DIFFERENT RAINFALL RETURN PERIODS IN MANDULOG RIVER, ILIGAN CITY, PHILIPPINES

Alan E. Milano (1), Sheila N. Frias (2), Peter D. Suson (3), and Daniel S. Mostrales (4)

[1,2,3,4]MSU-IliganInstitute of Technology,GeoSAFER Mindanao Project, Tibanga, Iligan City, Lanao del Norte, Philippines, 9200

Email:
aemilano1960@yahoo.comfrias.sheila123@gmail.competer.suson@g.msuiit.edu.phdsmostrales@gmail.com

Abstract: The Mandulog river levee located in Hinaplanon, Iligan City, Philippines is one of the engineering mitigating measures undertaken by the national government in order to prevent another devastating flood, like the one brought by TS Washi (locally known as Typhoon Sendong) that badly hit Iligan City and Cagayan de Oro City in December, 2011 resulting to thousands of death toll. The study determines the effectiveness of the levee against possible flood overtopping using a 50-year and 100-year rainfall return periods. Hydrologic simulation and 2D flood modelling were done using HEC-HMS 4.1 and HEC-RAS 5.0.3. The LiDAR dataset and bathymetric river survey in 2012 was used in river and floodplain geometric data generation. Results of the 2D flood model shows that the levee can prevent river flooding for the two rainfall scenarios. However, it blocks the runoff from the land side outside the levee, thereby causing flooding in densely populated areas. It is imperative to provide a device that will overcome the blockage. Otherwise it nullifies the usefulness of the levee, squander substantial resources and above all put to risk densely populated communities.

***Keywords**: levee, rainfall return period, flooding*

I. INTRODUCTION

The plan to construct a flood control structure in particular a flood levee along the banks of the MandulogRiverwas a source of great joy and relief among the inhabitants of Iligan City as it was in that basin where the Mandulog River flows through that were worst hit during the tropical storm Washi (Sendong) December 17, 2011 where a substantial number of people died, perished,injured and displaced and a vast amount of propertiesand infrastructure were either lost or damaged[1].

However to theseauthors, the euphoric response led to a sobering concern during the public hearing of the flood levee project where it was revealed that tributaries that drain to theMandulog River will be blocked by the levee[2] (Figure 1).

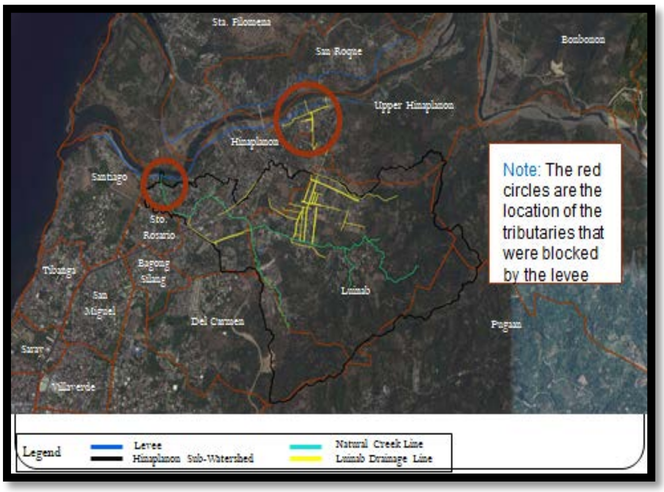

Fig. 1. Blocked Tributaries

Based from the original plan of the government construction agency, no pump is provided to drain water from the tributaries to hurdle the levee but rather only a sluice gate is provided. However, the sluice gate will open only if the depth of the main river is lower than the depth of the tributary that drains to it[3]. But in a storm event, it is most likely that the depth of the main river is higher than the depth of the tributary that drains to it. So when such event occurs, it is expected that drained water from the tributary will be blocked, accumulate and thereby rise up causing flooding. The risk for flooding disaster is high as the affected area is densely populated.

So for decision makers to see the authors' grave foreboding and to act upon it, the authors have embarked on this study to simulate the scenario where drained water from the tributary is blocked by the flood levee and the resulting flood magnitude. Furthermore this study will also assess the effectiveness of the flood levee to control flooding that emanates from the river.

II. METHODOLOGY

LeveeCondition, Cross Section and the Flood Model

Currently, both the left and right bank levees are not fully completed. For simulation purposes, the levee was assumed to be fully completed in the model. Annex1 shows the GIS representation of the levee alignment with respect to its centreline. It is composed of the right and left bank levees referenced facing downstream. The plans acquired only showed the levees in green and blue lines. The levee in red line was already constructed before the study was made. Hence, it was included in the simulation using the elevation of the downstream portion of the left levee in blue line. The culverts along the levee were not considered in this study. The hydraulic model uses the LiDAR DEM integrated with levee. The roadway width of 6.7 m and additional 2 m on both sides for the shoulder were raised along its alignment with reference to the elevations.Annexes 2 and 3 shows the typical cross-section of the levee, its crown is designed to be a roadway.

The boundary conditions used were the inflows identified in the hydrologic model with respect to the defined floodplain area. Another boundary conditions used were the storage area represented by the floodplain and the portion of theMandulog River from the upstream todownstream of the study area. The tidal data is part of the limitation. Hence, there was no tidal condition set for the model.

Flood Modelling

The flood magnitude which is in terms of flood extent and flood depth was compared between the presence of the levee (with levee) and the absence of the levee (without levee) at two rainfall scenarios (50 and 100 year rainfall return period). To do it; a flood simulation study was conducted using the softwares: HEC-HMS 4.1,HEC-RAS 5.03 and ArcMap 10.2 and GIS datasets such as raster files (IFSAR-DEM and LiDAR-DTM) and shape files (watershed, flood plain and levee polyline).

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To determine the flood depth, there are four (4) major steps involve. First determine the run-off in terms of peak run-off, total run-off volume and lag time using the HEC-HMS 4.1, IFSAR-DEM. For the second step, a geometric data was prepared where the flood plain and flood extent in cross section intervals were defined/ The output of the first and second step becomes the input of the third step which is the generation of the flood depth raster file. The third step makes use of the HEC-RAS 5.03, LiDAR-DTM and flood plain). The fourth and the last step was to define and convert the flood depth raster file into a shape file. This makes use of ArcMap 10.2. This is done by reclassifying the flood depth raster file into three new classes or values with corresponding values of 0.5, 1.5 and the next highest value with respect to the highest value of the raster. After reclassification, the reclassified flood depth raster file is converted into shape file. This procedure is true for the condition where there is no flood levee.

However for the condition where there is flood levee, the preparation of a geometric data is more tedious. As this involve the integration of the newly generated Levee DTM with the LiDAR-DTM and to mark it as the Levee- LiDAR-DTM to distinguish it from the natural terrain. This process interchangeably usesArcMap 10.2 and HEC-RAS 5.03softwares and the GIS dataset: LiDAR-DTM and the levee polyline shape file. Once the process in preparing geometric data is finished, the step in generating a flood depth raster file now proceeds.

Finally for the flood extent, the flood depth result in shape file is used as an input using ArcMap 10.2. In the attribute table of the flood depth, another field was added naming that field as Area. The area was computed using Hectares as the unit for area. This will populate the Area attribute of the corresponding flood extent polygon for the selected rainfall scenario and according to flood depth classification which is low (≤ 0.5 m), medium (0.5 – 1.50 m) and high (> 1.5 m).

III. RESULTS AND DISCUSSION

Flooding with and without levee

The simulation results show that when the water from the tributary cannot drain to the Main or the Mandulog River due to levee blockage then there is flooding and that the depth and extent has very narrow differences at both rainfall scenarios (Figures 2 and 3). Furthermore at high flood depth under the 100 year rainfall return period (RRP)the extent of flooding is higher when there is levee (Figure 4).

In the absence of a device that guarantees drainage of tributary waters to the main river, the presence of a levee might even make flood disaster more risky compared in the absence of a levee that is because the location where the tributary water is blocked is located in a highly densely populated areas (Figure 1). Also because the extent of flooding is higher when there is levee at high flood depth level at 100 year rainfall return period (Figure 4).

During the public hearing discussion, the provision for a pump to drain water from the tributary was mentioned by one among the participants, however the agency responsible for the project mentioned that in a storm event an electrically powered pump will be useless due to brownouts. But another participant said why not a fuel fed pump. The same agency countered that the person responsible to start the pump might be the first to flee. Such concern can be resolved by using sensors to automate the pump to start and to use renewablesource of energy as additional power source to run the pump.

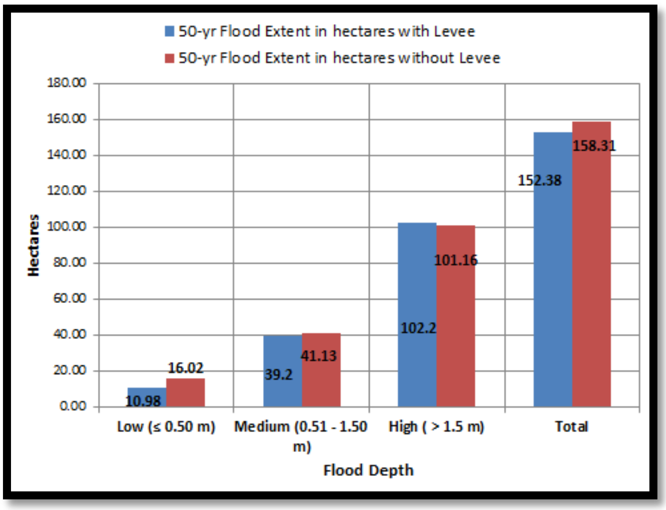

Fig.2. Flood extent at 50 year Rainfall Return Period

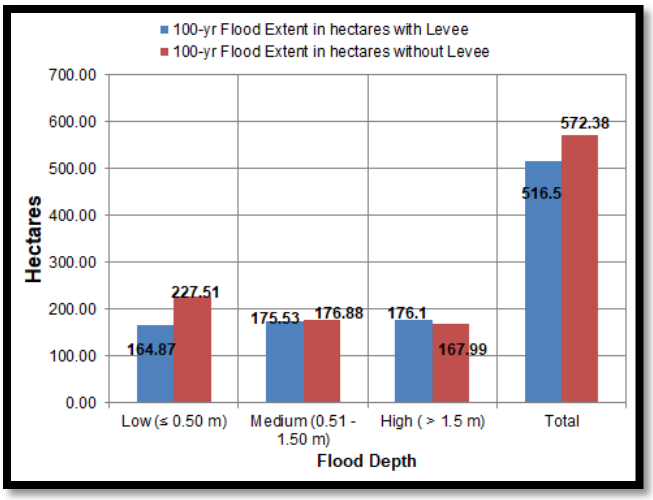

Fig.3. Flood extent at 100 year RRP

Table 1. Levee height and water surface elevation for 50year and 100 yearRainfall Return Period

	(m)	Average Maximum Water Surface Elevation for 50-yr RRP	Difference (m)	Average Maximum Water Surface Elevation for 100-yr RRP (m)	Difference (m)
Average Levee Height at Right Bank facing downstream	8.084				
Average Levee Height at Left Bank facing downstream	9.420				
Average	8.752	5.17	3.582	5.57	3.182

Note: Left and right bank levee naming convention is referenced facing downstream.

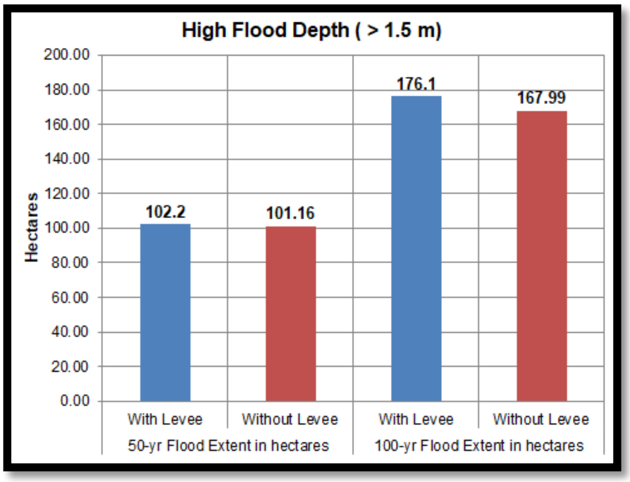

Fig.4. High Flood Depth at 50 year and100 year Rainfall Return Period

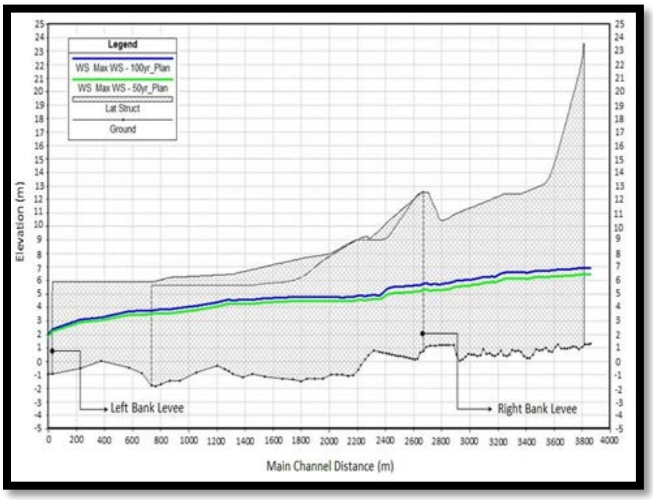

Figure 5. Levee height and water surface elevation

Flooding emanating from the Main River

The flood levee is very effective in controlling river flooding in both 50 year and 100 year rainfall return period (Table 1 and Figure 5). For 50 year RRP there's still remaining clearance of 3.582 m and 3.182 m for 100 year RRP. However its effectiveness is nullified by flooding from the landward side due to the blockage of tributary water to drain into the main river.

IV. CONCLUSION AND RECOMMENDATION

The effectiveness of the flood levee is nullified by flooding from the landward side due to tributary blockage. It is imperative that a device should be provided to guarantee drainage of water from the tributary to the main river. That device could be a form of a pump[3] powered by renewable energy and programmed to pump once tributary blockage commenced or the construction of retention ponds[4]. In the absence of any device to drain water from the tributary will render the flood levee project as a waste of substantial resources and put to risk a large portion of Iligan residents to flood especially in an age when extreme weather conditions is becoming a norm.

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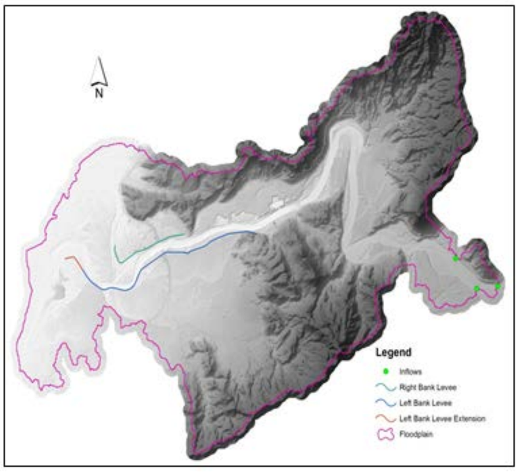
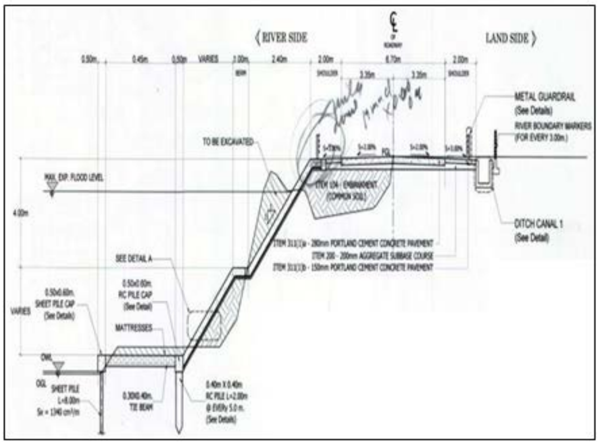
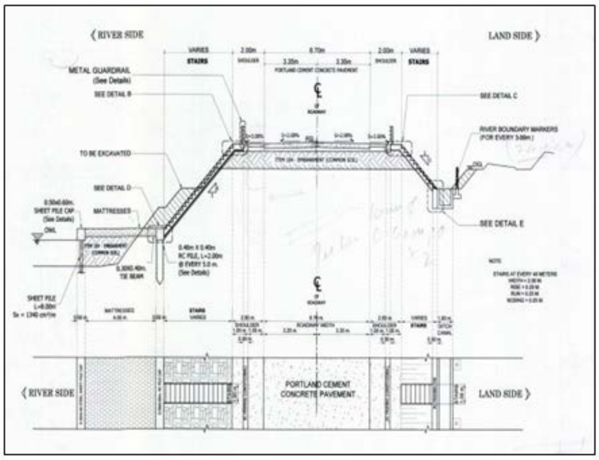
ANNEXES



Annex 1



Annex 2



Annex 3