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Development of Flood Warning System

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ABSTRACT
Community-based early warning systems (CBEWS) is a “people-centered” system and empowers individuals and communities threatened by hazards to act on sufficient time and in an appropriate manner to reduce the possibility of personal injury, loss of life, damage to property, environment and loss of livelihood. These things lead to the development of the device necessary for the protection of the community against flood hazards as it allows people to get prepared with sufficient time. An alarm system was developed to monitor the water level on Salog River that overflows during heavy rains. The water level sensors were submerged in a canal of water to test the functionality of the device before its installation. Computer programs were created to enhance the monitoring of water level: the River Monitor Software and the Water Level Monitor. The LED arrays emit light according to water level; green for low, orange for medium, and red for high. A siren also alarms with different intervals (30 seconds for low, 15 seconds for medium, and a continuous alarm for high). Automatic emergency lighting was integrated in the design and lights up during power outages powered by rechargeable sealed battery that charges when ac power is supplied to the device. Levels were established based on available data; low water level means awareness; medium water level means preparedness and high water level means immediate response is necessary.

KEYWORDS: Early flood warning system, floods, water level, water level monitoring, Philippines, Asia

I. INTRODUCTION

A flood is an occurrence where water submerges land that is normally dry. Floods are a natural process that can be due to a number of factors and is affected by human activities. Floods happen at irregular intervals and no two floods are the same. Sudden, heavy and intense precipitation can cause floods to quickly rise in minutes or hours followed by flash floods, and are typically associated with small catchment areas. In large catchment areas, rainfall can build up over hours, days or weeks. Many factors contribute to floods however the main cause of floods is rainfall. When rain pours over a catchment, some rainfall are ‘captured’ by soil, vegetation and water storages such as farms and dams. The rest flows downhill into waterways. The amount and time the rainwater reach the waterways are dependent on the characteristics of the catchment, particularly its vegetation, shape, size, the way the land is utilized and the preceding weather conditions.

Early flood warning systems according to Grust (2008) are essential for the protection of the population against flood hazards as it allows people to get prepared. However, early flood warning systems will not prevent flooding. According to Perez et.al (2007), it is a community based flood warning system that can be used for disaster mitigation and disaster preparedness of the community because it provides an early flood monitoring and warning services. Based on studies conducted, flood warnings should be accurate, informative, timely, targeted to appropriate audiences, trustworthy and reliable to enhance flood forecasting and warnings.

Climate Change Vulnerability of Sorsogon City

The Province of Sorsogon where the City lies at 123° 53’ to 124° 09’ east longitude and 12° 55’ to 13° 08’ north latitude, has been identified by a study of the Manila Observatory and the Department of Environment and Natural Resources to be at a Very High Risk category relative to combined Climate Disasters.

According to the Manila Observatory, the combined risk to climate disasters map presented in Figure 1 represents the sum of the normalized, provincialized risks to typhoon, drought caused by El Niño, projected rainfall change and temperature increase. The top ten provinces are: Albay, Pampanga, Ifugao, **Sorsogon**, Biliran, Rizal, Northern Samar, Cavite, Masbate, and Laguna. Figure 2 presents Sorsogon City as situated in the country’s geographical Zone 6 where three typhoons/cyclones pass in two years.

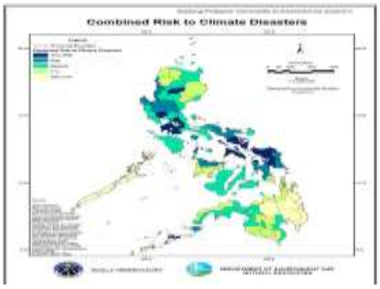

Figure 1 Combined Risks to Climate Disasters

Figure 2 Frequency of Tropical Cyclone Passage over each of the Philippine Geographical Zones (source: PINCC)

The impacts of climate change in the city considering its location and previous stresses are seen to be associated with the climate driven phenomena on changes in extremes such as tropical cyclones, storm surge, and extreme rainfall/flooding. Changes in means –increased precipitation, and sea level rise- are also foreseen by the local experts and communities based on both recorded and unrecorded local observations.

The community-based flood early warning system

In the Philippines, flood mitigation before the '90s was centered on flood control projects such as the construction of dikes or levees and other hydraulic structures. During the International Decade for Natural Disaster Reduction from 1990 to 1999, activities in flood mitigation shifted towards non-structural measures. There are several reasons why the Philippine Atmospheric, Geophysical and Astronomical Services Administration promote the CBFEWS. The system empowers local government units and the communities to protect themselves against floods. The community and LGUs are in the best position to undertake preparedness measures against floods. It promotes a sense of ownership on the part of the LGUs, hence it is easier to sustain. It enhances the social and moral responsibilities of the locals. CBFEWS also enables the PAGASA to expand its operational hydrological services to the countryside and is a non-structural flood mitigating measure. It provides localized early warning system, which can be operated in a real-time basis. Simple and inexpensive to operate, it envisions monitoring, information exchange, warning and disaster preparedness response by employing locally-based volunteer observers.

Communication and dissemination

The communication network is the heart of the CBFEWS. The system preferably adapts existing communications that are already installed in order to achieve a sense of community participation in the transmission of observed data to the operation center. The implementation of a communication system by radios that works even when commercial power is down guarantees communication in cases of emergency. Mobile phones can also be used as alternatives.

The message content of the warning needs to be as simple as possible for end-users and to be provided in a timely manner to facilitate appropriate action. Message delivery systems must be as cost effective, replicable and simple as possible. Although false alarms are risks that must be acknowledged, the credibility of the message is crucial for initial project acceptance.

Deciding to do a CBFEWS

There are several factors, which may influence a community to do CBFEWS, such as hydrologic characteristics of the area; frequency of flooding, community's interest and awareness, flood loss potential (hazard vs. damage curve), warning time vs. benefits and costs of putting-up a system.

The key to facilitating the community's participation is rapport. As outsider and initiator, PAGASA accept the largely intuitive and indigenous knowledge of communities as equally important and reliable as its technical and scientific expertise. Therefore, consultation with the LGUs and certain members of the community is a prerequisite prior to commencement of the CBFEWS.

Comparison of the Flood Monitoring & Warning Device with Other CBFEWS

Most of the early flood warning systems today have advanced features that are very useful for disaster mitigation and disaster preparedness. These features include: receiving a message regarding a water level observed at a geographic area, using the message and one or more items of available data to generate a flood level prediction, and sending a flood warning if the flood level prediction exceeds a predetermined threshold. Others include a signaling element adapted for energization in response to a rise in water level above the preselected level, a power source for energizing the signal, a sensor for detecting the rise of water, and wires for effecting a series connection between the signaling element, power source, and sensor; a digital liquid level gauges, gauge actuated transmitters, a receiver, a decoder and validity logic unit, a data analysis unit, a central disaster alert station, and a plurality of disaster alert modules. Others include a stilling well having mounted therein a lowest level float switch, a middle level float switch and a high level float switch. The float switches are connected by cables to alarm dialer.While the features of the flood monitoring and warning device includes computer programs, the River Monitor Software and the Water Level Monitor for a real time monitoring of the water level on Salog River. The device is connected to the PC through a USB to serial cable (DB-9 connector) commonly used for serial ports (RS-232). It uses three colors of LED arrays for each water level; the green LEDs indicate low (1 meter), orange LEDs for medium (3 meters), and red LEDs for high (5 meters). A siren also alarms continuously at different intervals depending on the water level on the river along with the LED indicators. The device will also provide an automatic emergency lighting in the area during power outages.

This research project develops a flood monitoring and warning device with automatic emergency lighting for Barangay Salog, Sorsogon City to help in disaster mitigation and disaster preparedness of the community. Based on city reports, it is one of the identified barangays/villages with a population of 2,586 that is at risk to flooding and landslidesbecause itis located along Salog River that overflows during heavy rains. The affected areas are seen on the community hazard map of the barangay in figure 3, Salog River is shown in figure 4.

Figure 3. Community Hazard Map of Brgy. Salog Figure 4. Salog River

II. OBJECTIVES OF THE STUDY

The general objective of the study is to develop a flood monitoring and warning device with automatic emergency lighting for Barangay Salog, Sorsogon City to minimize the hazards brought by floods when Salog River overflows. The specific objectives are: (1) to develop an alarm system to monitor the water level on Salog River; (2) to design a program to have a real time PC based monitoring of water level; (3) to establish levels based on available data; (4) to construct a prototype for water level monitoring and alarm system; and (5) to test the functionality of the device in a separate location before its installation.

III. CONCEPTUAL FRAMEWORK

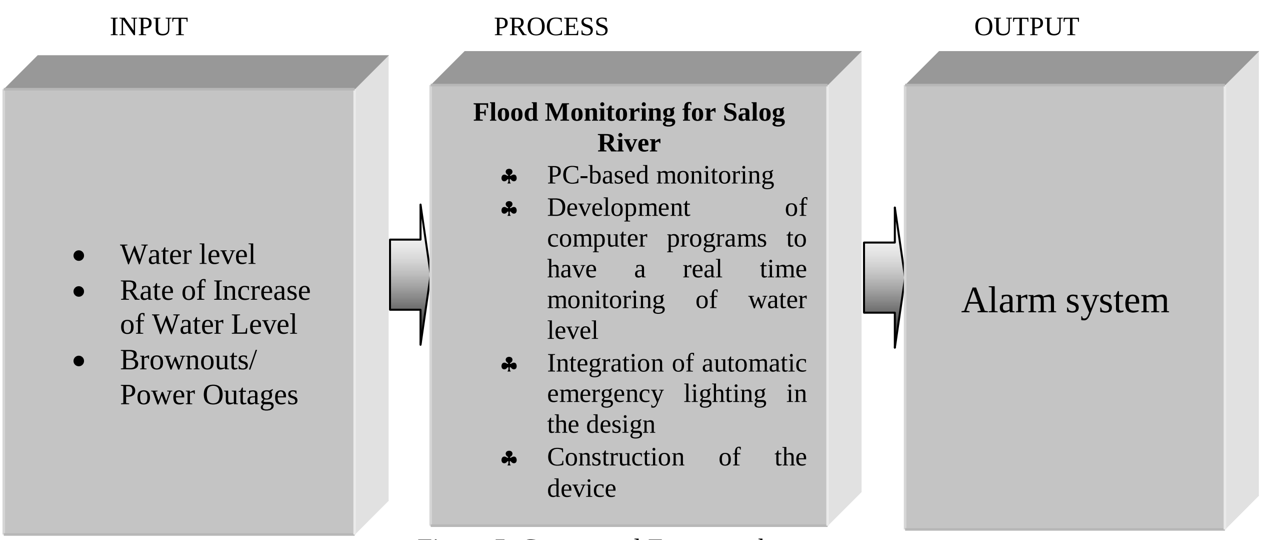

Figure 5. Conceptual Framework

MATERIALS AND METHODS

This section discusses the methods or procedural steps to be considered in making this study feasible, meeting its objectives. It also provides the materials, tools or equipment needed. The first step is the formulation of the statement of the problem. Second step is consultation meeting with the barangay officials of Barangay Salog, Sorsogon City;this includes coordination and signing of memorandum of agreement. The third step is procurement of electronic components and the fabrication of equipment that involves the development of River Monitor Software and the programming of the microcontroller and construction of the device. Fourth step is the testing of the device before its installation. The device was tested in a canal of flowing water to test itsfunctionality, together with the water level sensors, the LED arrays, and the computer softwares created for a PC-based real time monitoring of water level. The final step is the installation of the device along Salog River.

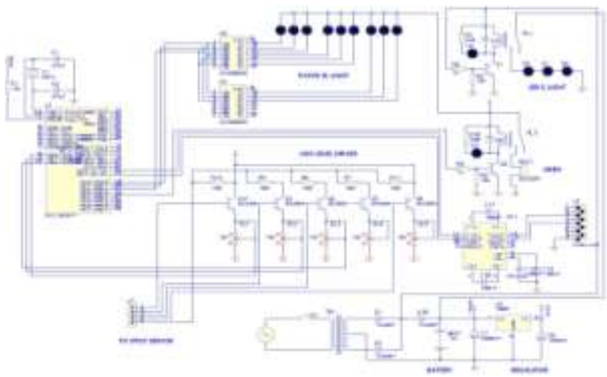

Figure 6 Schematic Diagram of Flood Monitoring & Warning Device

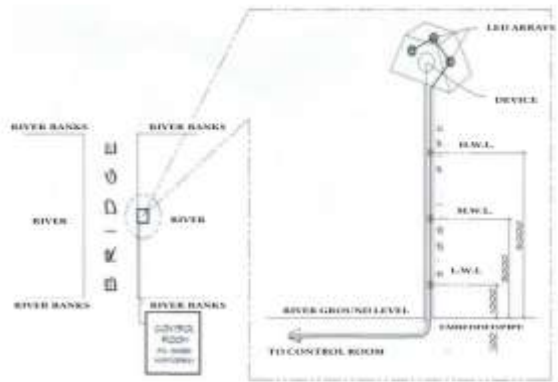

Figure 7 Set –up Diagram of the Flood Monitoring & Warning Device

Data Analysis and Procedures

In the development of the flood warning device, the following materials were used: PIC microcontroller (PIC16F87XA), green, red, and orange LED arrays, resistors, transistors, capacitors, sealed lead acid battery (LCR 12V 7.2 Ah), transformer, MAX 232, RS-232 port, printed circuit board, voltage regulators, diodes, wires (AWG #16, #22), HG relays, pvc pipes, water level sensors (LED sensor and zinc wire) and a mini siren alarm (110 dB), emergency light (LED DC 12V 4W). The tools and other materials needed for the assembly of the device are: soldering iron, soldering gun, lead, multitester, pcb drill, drill bit, desoldering pump, electrical tape. Estimated cost of the device is 26,000.00 Php exclusive of the computer programs.

For the flood monitoring system, the River Monitor Software was created to monitor the water level at Salog River through a PC. Windows XP is the most compatible operating system for the software. However, Windows 2007 can also be used but Visual Basic 6 must be installed for program compatibility. Visual Basic 6 was used as the programming language to create the program. For the Water Level Monitor, the microcontroller was programmed to activate the siren and LED arrays to give a warning signal for low, medium and high water levels as well as when the device is disconnected from the PC. A pop up window on the PC gives a real time monitoring with a corresponding alarm for each water level. Visual Basic was the programming language used to program the microcontroller.

The DB9 connector was used to interface the device with the computer which is commonly used for serial ports (RS-232). The maximum cable length for RS-232 is 50ft, but in practice depends on baud rate, cable specific capacitance and ambient noise. The RS-232 standard 9600bps port will drive 15 meters of shielded cable.

To test the functionality of the device before its installation, the water level sensors were submerged in a canal of flowing water. This is a must to test whether all the water level sensors, the LED indicators, and the siren alarm for each water level are functioning. This is also necessary to assess what will be seen on the PC for each water level either using the River Monitor Software or the Water Level Monitor.

The emergency light was also tested whether it will function using the back-up battery during power outages.

The results of the test were used as the data for the research.

IV. RESULTS AND DISCUSSIONS

Low water level (1 meter) is indicated by the green light and a siren alarm with an interval of 30 seconds. On the PC where the device is connected using the Water Level Monitor, the green light indicator lights up and the ‘Low’ text flashes with a corresponding alarm. ‘Water Level 1 m’ text appears on the screen. When the River Monitor Software is used, the Water Level Monitoring System shows a line graph at 1 m for every second. A green bar at 1m appears on the chart, together with the red bar at the critical level of 6 meters, the height of the device. A message of 'Water level is at 5 meters from the Critical Level' appears on the bottom of the screen.

Low water level means awareness on the residents that there is water build-up on the river caused either by flooding due to continuous rains or by high tide. The flood warning specifies 'ready'.


Figure 8.a Green LED Array Turns onFigure 8.b Low Water Level Sensor Submerged in the Water

Figure 8.c Water Level MonitoringFigure 8.d Water Level Monitor at System at Low Water LevelLow WaterLevel

Medium water level (3 meters) isindicated by the orange LED and a siren alarm with an interval of 15 seconds. On the PC where the device is connected using the Water Level Monitor, the green and yellow light indicator lights up but only the 'Medium' text at the yellow light indicator flashes, with a corresponding alarm. A 'Water Level 3m' text appears on the screen. If the River Monitor Software is used, the Water Level Monitoring System shows a line graph at 3 m for every second. A green bar at 3m appears on the chart together with the red bar at the critical level of 6 meters. A message of 'Water level is at 3 meters from the Critical Level' appears on the bottom of the screen.

Medium water level means the river is near spillage; evacuation must be initiated or started. The flood warning specifies 'get set'.


Figure 9.a Orange LED Array Turns On Figure 9.b Low & Medium Water Level Sensors Submerged in the Water

Figure 9.c Water Level Monitoring SystemFigure 9.d Water Level Monitor at at Medium Water Level Medium Water Level

High water level (5 meters) is indicated by the red LED and a continuous siren alarm. On the PC, using the Water Level Monitor, the green, yellow and red light indicators light up but only the 'High' text at the red light indicator flashes. A 'Water Level 5m' text appears on the screen. If the River Monitor

Software is used, the Water Level Monitoring System shows a line graph at 5 m for every second. A green bar at 5m appears on the chart, together with the red bar at the critical level of 6 meters. A 'Warning!' sign appears and a message of 'Water level is at 1 meter from the Critical Level' appears on the bottom of the screen.

High water level means the river is already on spillage. The flood warning specifies 'go'. Immediate response is necessary; evacuation is a must. Residents are advised to proceed to the evacuation centers.

Figure 10.a Red LED Array Turns On Figure 10.b Low, Medium & High Water Level Sensors Submerged in Water

Figure 10.c Water Level Monitoring Figure 10.d Water Level Monitor at System at High Water Level High Water Level

Water level assessment is summarized in table 1.

Table 1. Water Level Assessment

	Actual Water Level (m)	**Meaning**	**Flood Warning**
Low Water Level	1 m	Awareness	**READY**
Medium Water Level	3 m	Preparedness	**GET SET**
High Water Level	5 m	Response	**GO**

Using the River Monitor Software, if the water level does not reach 1 meter, a line graph does not appear on the Water Level Monitoring System and only the red bar at 6m appears on the chart. A message 'Water level is at Normal Level' appears at the bottom of the screen. If the Water Level Monitor is used, the green, yellow and light indicators are turned off and the 'Water Level 0m' text appears on the screen.

Figure 11.a Water Level Monitoring SystemFigure 11.b Water Level Monitor at at Normal Water Level Normal Water Level

Using the Water Level Monitor, if the device is accidentally disconnected from the PC through the DB9 connector a 'SYSTEM FAULT!' appears on the screen. This is shown in Figure 12. This can be due to several factors (a) power outage; no power is being supplied to the device that the PC is not able to communicate with the device; (b) the device might have been disconnected from the PC; (c) the device is not working properly.

Figure 12. A 'System Fault!' appears on the screen when the device is disconnected from the PC

Figure 13. Water Level Monitoring System showing changes in the water level

The water level can rise or drop. The graph in Figure 13 shows the changes when there is a rise or drop in the water level. There is also a corresponding change in the color of the LED arrays depending on the water level, and a change in the level of the bar graph at the water level monitoring chart.

The emergency light has a power output of 4 Watts and the device has 144 W power output because the output of the battery is 12V DC and the current passing through the device is at 12 A. It has a high power output that the alarm produces a deafening sound.

V. CONCLUSIONS

The research project addresses the general objective of the study. A flood monitoring and warning device with automatic emergency lighting was developed to monitor the water level on Salog River that would help in the disaster mitigation and disaster preparedness of the community. The emergency light lights up during power outages supplied by the rechargeable lead acid battery to provide lighting.

It also addresses the specific objectives of the study: (1) an alarm system was developed to monitor the water level on Salog River using the LED arrays that emit light according to water level; green for low, orange for medium, and red for high. A siren also alarms with different intervals (30 seconds for low, 15 seconds for medium and a continuous alarm for high); (2) computer programs were created that enhanced the monitoring of the water level on a real time basis; the River Monitor Software and Water Level Monitor;(3) water levels were established based on available data. Low water level means awareness that there is water build-up on the river caused either by flooding due to continuous rains or by high tide. The flood warning specifies 'ready'. Medium water level means the water level is near spillage;evacuation must be initiated or started. The flood warning specifies 'get set'. High water level means the water level is already on spillage. The flood warning specifies 'go' and immediate response is necessary, evacuation is a must; (4) a prototype was constructed to provide monitoring on the water level on Salog River with an alarm and warning system; and (5) the water level sensors were submerged in a canal of water to test the functionality of the device before its installation. The device is functioning and providing appropriate outputs for its intended purpose.

VI. RECOMMENDATIONS

In view of the foregoing findings and conclusions, the following recommendations are made to enhance the functionality of the flood monitoring and warning device: (1) develop a stilling well with a level float switch capable of providing a continuous monitoring of water at all levels; (2) enhance the river monitor program to monitor every meter per second (m/s) rate of increase of water level; (3) modify the sound of the siren alarm for every water level aside from the intervals/ gaps to differentiate each water level; (4)modify the transmission of the signal from the device to the PC to a wireless-based transmission instead of using a DB-9 connector.

REFERENCES

[1.] Plate, E.J. & Insisiengmay, T., Early warning system for the lower Mekong River. *Water International* 30 (1),2005, 99-107.

[2.] Price, R.K., Handout on Floods and Flood Management - Unit 1.2 of *I-Learning Module on Flood Management for Modelling, Unesco – IHE, Institute for Water Education*, 2006.

[3.] Mamonong, Ma. Adelaida M. and Flores, Reinero M., Climate Change Vulnerability Adaptation Assessment Report Sorsogon City, Philippines, http://goo.gl/jjdiwU

[4.] Price, R.K., Handout on Hydroinformatics for Flood Management-Unit 1.3 of *I-Learning Module on Flood Management for Modelling, Unesco–IHE, Institute for Water Education*, 2006.

[5.] Perez, Rosa T., Espinueva, Susan R. & Hernando, Hilton, Community-based Flood Early Warning Systems, Philippine

Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), http://goo.gl/Gsy5F4

[6.] De Guzman, Rosalina G., Climate Information in Sorsogon, Climatology and Agrometeorology Division, Philippine Atmospheric, Geophysical and Astronomical Services Administration – Department of Science and Technology (PAGASA-DOST),http://goo.gl/1PKGvF

[7.] United States Patent and Trademark Office, Patents on Early Flood Warning Systems,www.**uspto**.**gov**/**patents**/process/search/