INTERACTIVE FLOOD RISK FORECASTING WEB-APPLICATION USING OPENLAYERS API AND JAVASCRIPT

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ABSTRACT: Rainfall has always been a factor in every flood occurrences in most, if not all, of the floodplain areas of Caraga Region, Mindanao, Philippines. Apart from its intensity, another parameter that has significant value in assessing flood incidents is the depth and velocity of the flood water. Flooding is the underlying phenomenon that the Phil-LiDAR 1 Project of Caraga State University initiated the development of an interactive web-mapping application that may be used as a tool for flood preparedness. The application was devised as one of many ways to assist the communities and Local Government Units of Caraga Region in making a sound and efficient decision in preventing and alleviating flood risks. The application requires the user to specify parameters, like municipality, barangay, amount of rainfall and to draw a polygon or point on the Web map interface, which will serve as the basis in forecasting flood risks. The application will basically provide flood information such as flood depth, flood duration and recession time and the time interval the flood water reaches the polygon or point drawn. It can also suggest safe route to the nearest evacuation shelter. Map displays and map features were built using the Openlayers API, while the extraction of data, and the flood extent calculations and analysis were JavaScript's. Scripts retrieve the data from PostgreSQL spatial database and eventually display the tabulated information.

1. INTRODUCTION

Every year, the Philippines is frequently visited by several typhoons which brought heavy rains that causes flooding to the communities on the low-lying areas of the country. In Mindanao, heavy rains brought by tropical storms *Agaton* (International name: Lingling) and *Seniang* (International name: Jangmi) in 2014 caused rivers to overflow in the cities of Cagayan de Oro, Iligan and Butuan. The Project Nationwide Operational Assessment of Hazards (Project NOAH, 2016) reported that many houses have been submerged, properties destroyed, and human lives taken by rampaging waters from the overflowing rivers.

In preventing and alleviating these pronounced damages and devastations caused by flooding, the Local Government Units (LGUs) in the Philippines have been using flood susceptibility and hazard maps as part of their flood disaster risk reduction and management activities. Most of the LGUs rely on Mines and Geosciences Bureau (MGB) flood susceptibility maps (http://gdis.denr.gov.ph/mgbgoogle), and the flood hazard maps generated through the Project NOAH and displayed in its website (http://noah.dost.gov.ph; Lagmay, 2012) and the flood maps generated through the Disaster Risk and Exposure for Mitigation (UP DREAM)/Phil-LIDAR 1 program (UP DREAM, 2016). However, these hazard maps are static and only represent specific flooding scenarios and their use for localized flood disaster (e.g., in careful planning and preparation of evacuation strategies), may be limited.

In view of these, the Phil-LiDAR 1 project of Caraga State University (Makinano-Santillan and Santillan, 2015), initiated the development of flood event early warning tool. It is a web application that aims to:

- Present flood hazard information of a particular locality. These includes the flood water velocity (how fast the flood water can travel toward a certain location), arrival (time the flood water can finally reach a specific location), depth (the deepness of the flood water), duration (how lengthy is the flooding event, in time), recession (time the flood water totally retreat).

- Display location of nearest and safest possible evacuation shelters. Most common evacuation shelters are schools, gymnasiums and covered courts.

Using the various rainfall scenario-based flood hazard maps derived through the use of flood model simulation models, flood information (depth, velocity, duration, arrival and recession time) can be anticipated. Projecting the

flood water's behavior in a particular local area is the expected outcome of this application. This is beneficial to the local community and disaster managers as it provides information crucial for making disaster risk reduction methodologies in reducing the possible risks, if not avoided.

2. THE STUDY AREA

The study area of the application is the Cabadbaran River Basin (CRB) and the nearby Pandanon River and Caasinan River Watersheds. It is located in Agusan Del Norte, Mindanao, Philippines, with the total area of 238 km^2. These river basins are some of the areas affected by flooding and extensive damage in agriculture and infrastructures due to heavy rains caused by tropical storms (Agaton and Seniang last 2014), especially the city of Cabadbaran (Figure 1). These flooding incidents make the city an ideal site for the development of the application, and to illustrate how the application can be useful as an early flood warning tool.

3. MATERIALS AND METHODS

3.1. Conceptual Basis

The development of the web application was conceptualized where a user can be able to get the 24 hour forecasts of the following flood information from the time the rainfall started:

- Flood depth in a particular area of the map.
- Flood water recession time.
- Time interval the flood water reaches the point or polygon drawn.
- Suggested safe route to the nearest evacuation shelter.
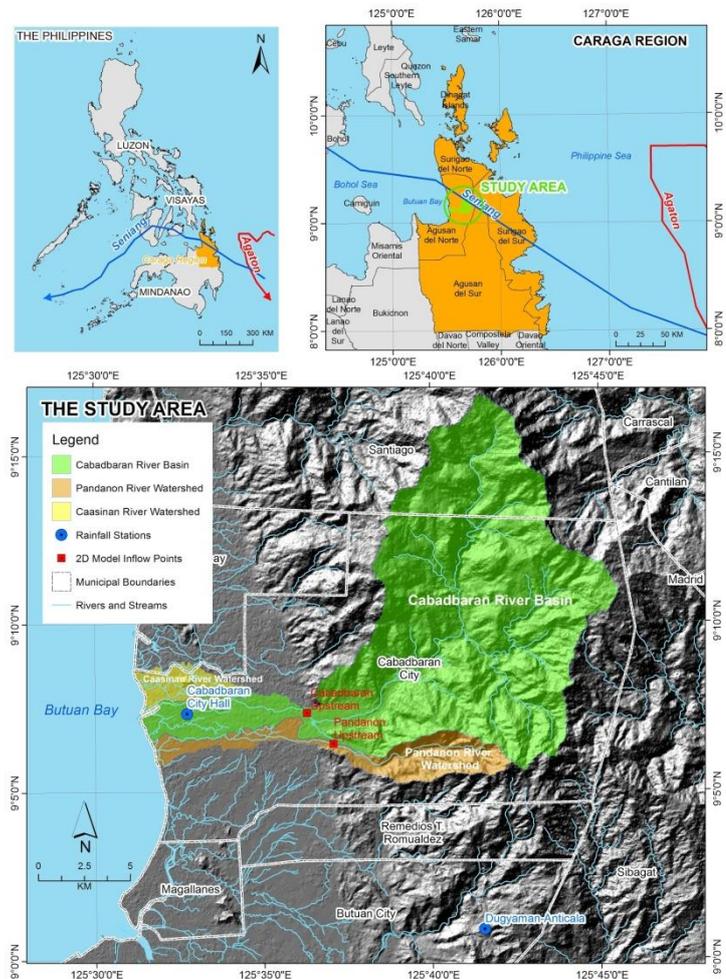

Figure 1. The test area of application which is the Cabadbaran River Basin (CRB) and the nearby Pandanon River and Caasinan River Watersheds in Agusan del Norte, Caraga Region. Map source: Santillan and Makinano-Santillan (2015).

In order to access this information, the application requires the user to specify parameters, like municipality, barangay, rainfall intensity (Light. Moderate, Heavy, Intense, Torrential) and draw a polygon or point on the web map interface. The point or polygon drawn will then be intersected to the flood hazard map stored in a spatial database.

Basically, the flood information displayed to the user through the web map interface was acquired through web server processing. The web proxy will accept the request from the user and then query the flood information from the spatial database. Such information will then be processed and displayed back to the web map interface in a tabular form. Figure 2 shows the framework of the above concept.
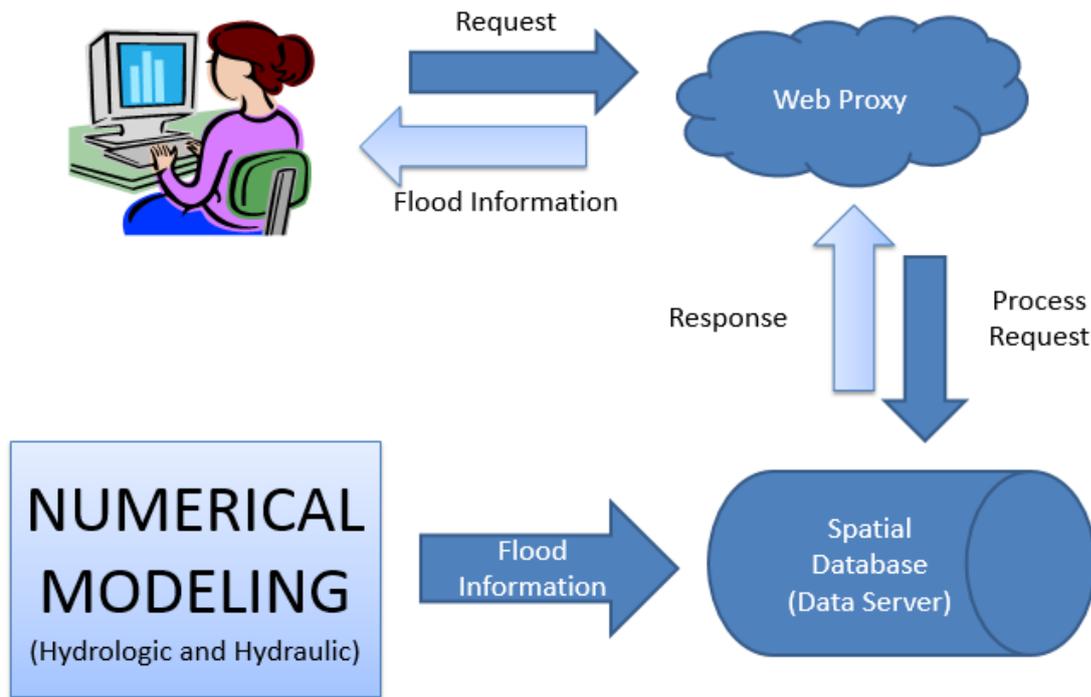
Figure 2 System Framework

3.2. System Development

3.2.1. Flood Information Generation

The flood hazard information was generated by CSU PhilLiDAR 1 Project. The project utilizes various set of geospatial data (e.g., LiDAR-derived datasets) in the development of flood simulation models. The flood simulation software used are the Hydrologic Engineering Center Hydrologic Modelling System (HEC HMS) version 3.5 and the HEC River Analysis System (HEC RAS) version 4.1. Using these modelling tools, scenario-based flood hazard maps were generated. Each scenario were characterized by flooding caused by rainfall events of varying duration and intensity (e.g. return periods of 2, 5,10,25,50 and 100 years). These flood hazard maps were stored in a spatial database (in Information Storage Component).

Flood hazard information generation consisted of analyzing and reconstructing of flooding event. Flood reconstruction process can be done through developing a hydrologic model of the river and a two-dimensional (2D) hydraulic model of the main river and its floodplain (e.g., Santillan and Makinano-Santillan, 2015). The purpose of the hydrologic model was to determine the volume of water coming from the various sub-basins (also called watersheds) due to rainfall brought by the tropical storms. 2D model is responsible for routing the discharge hydrograph from the upstream watersheds into the main rivers and floodplains.

3.2.2. Information Storage Component

After series of numerical modeling and processing of LiDAR-derived data, flood hazard maps (with the attributes: depth, arrival, duration, recession, percent, velocity and geometry) will be generated. This 5x5 meter resolution of flood map will be stored and loaded into a PostgreSQL (PostGIS) spatial database, capable of holding geospatial objects (shapefiles). This data storage is configured in a data server with internet connection.

3.2.3. Web Platform

The web platform for the application was built using Bootstrap and JavaScripts frameworks. Bootstrap is responsible for the system interfaces, modals, popups and displaying of textual information (e.g., anticipated flood water information of a polygon drawn). The information to be displayed to the user were retrieved from the PostgreSQL database. JavaScript is for map controls and map interactions and some sort of database interaction,

like data sending and retrieval. The web platform has two main functional parts, the web map control and the web map area.

The web map control allows the user to display flood forecast according to user specified parameters (e.g., rainfall intensity, time the rainfall start, municipality and barangay). The map will zoom automatically to the selected municipality or barangay. Rainfall intensity are based on the PAG-ASA data, Low ($<$ 0.5 m), Moderate ($>$ 0.5 m and $<$ 5.0 m), and Heavy ($>$ 5.0 m).

The web map uses Open Street Map (OSM) as a base map layer. The map area displays the flood hazard of the selected polygon and the forecasted flood hazard information in a tabular form. Basically, the user will draw polygon or point on the map and then an openlayers script will be called to get the geometry of the polygon. The geometry derived from polygon drawn will then be converted to GeoJSON file format which shall be the input for getting the map intersection. To get the intersection between the polygon drawn and the flood hazard layer from the PostgreSQL (PostGIS), the PostGIS query (ST_Intersection) is to be executed. The results of the query will be forwarded back to openlayers, to handle the GeoJSON conversion and for map display. Other attributes of the JSON encoded polygon will be rendered using the Bootstrap modal and Java Scripts.
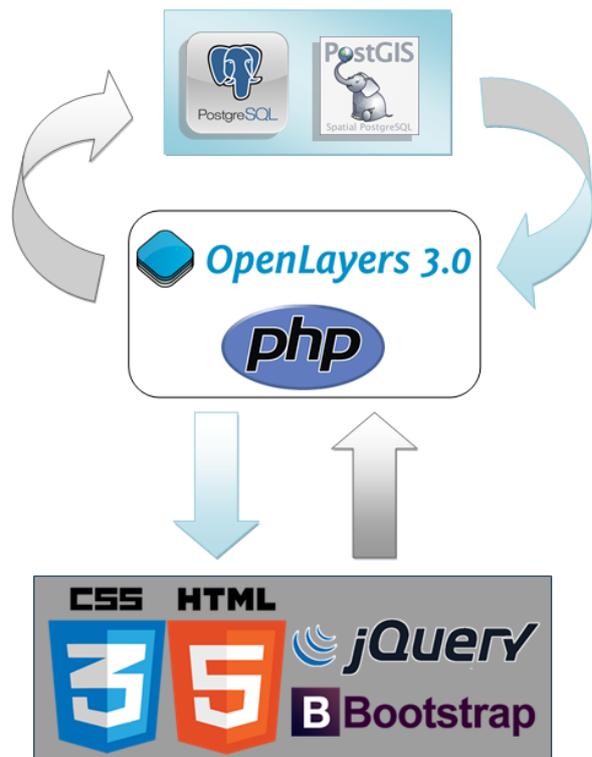
Figure 3 shows the framework of the whole process.

Figure 3. Web Platform Framework

3.2.4. Technologies Used

The following open source technologies were utilized in the development of the interactive flood risk forecasting web application.

- Bootstrap (http://getbootstrap.com/) – a popular HTML, CSS, and JS framework for developing responsive, mobile first projects on the web.
- OpenStreet Map – used as base map of the application.
- JavaScript - a high level, dynamic, unitized, client-side scripting and interpreted programming language of HTML and the Web.
- Openlayers (http://openlayers.org/) - An open source JavaScript library to load, display and render maps from multiple sources on web pages.
- PostgreSQL (https://www.postgresql.org/) - a powerful, open source object-relational database system
- PostGIS (http://postgis.net/) – is an open source software program that adds support for geographic objects to the PostgreSQL object-relational database

4. RESULTS

Figure 4 shows the user interface of the application as accessed through a web browser. The black side bar portion of the page is the map control, while majority of the page is occupied by map area.

To use the application, the user can start by setting the parameters, like municipality, barangay, rainfall intensity and the type of polygon he likes to draw. After drawing the polygon the extent of the flood enclosed to the polygon drawn will be displayed (Figure 5).

To view other information of the flood, the user can click the '**More Details**' button in the map overlay's popup. A modal form will then appear showing more details of the flood (Figure 6).
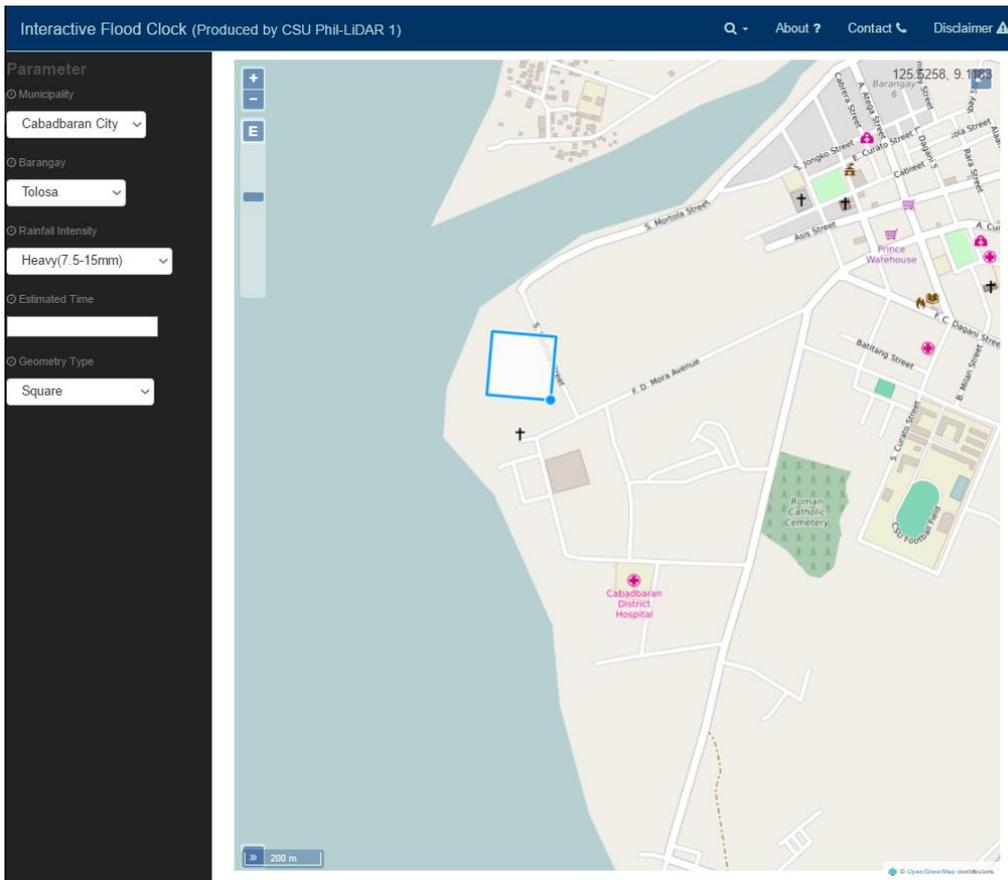
Figure 4. The web interface of the application, showing the map area and the map control segments.
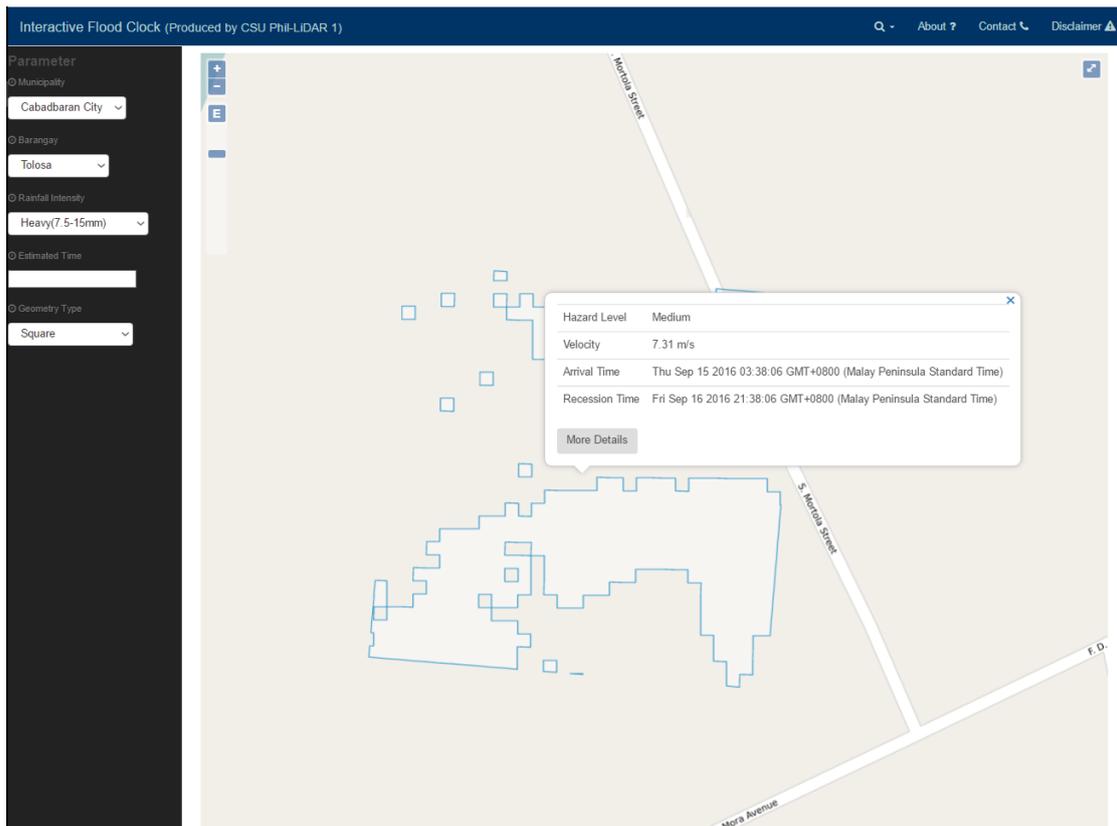

Figure 5. The web map interface, showing the extent of the flood base from the polygon drawn.

Flood Hazard Information

Municipality	Cabadbaran City
Barangay	Tolosa
Time Rainfall Start	Wed Sep 14 2016 10:28:47 GMT+0800 (Malay Peninsula Standard Time)
Hazard Level	Low

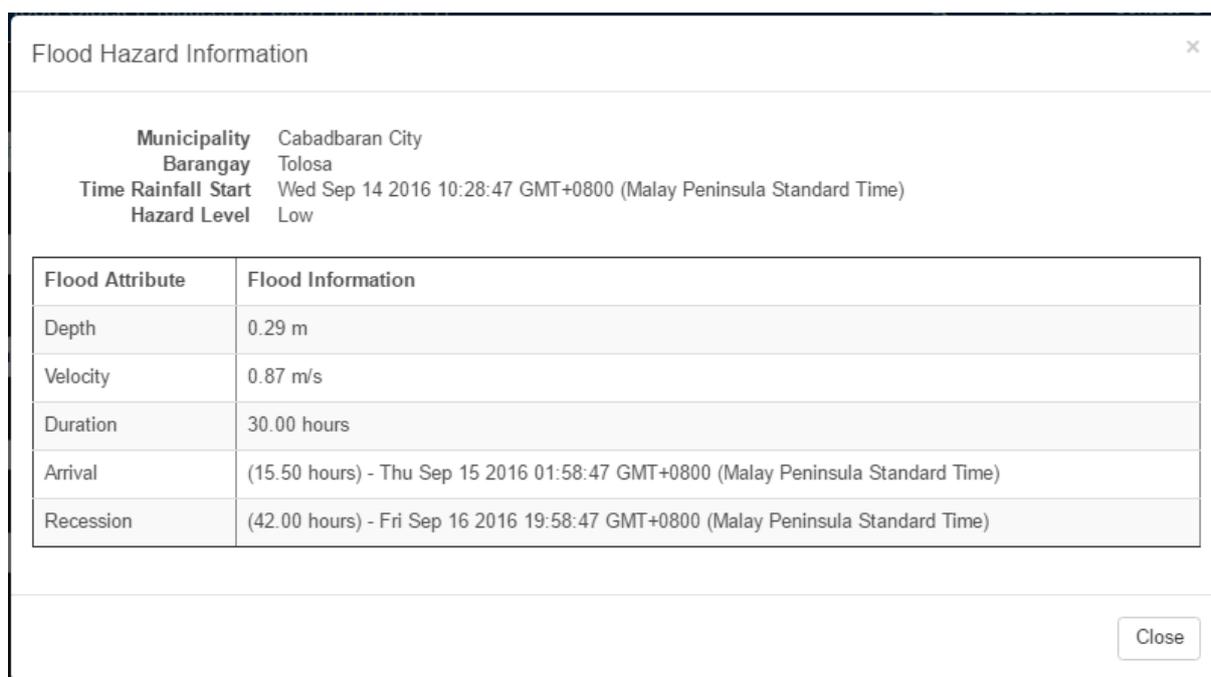| Flood Attribute	Flood Information
Depth	0.29 m
Velocity	0.87 m/s
Duration	30.00 hours
Arrival	(15.50 hours) - Thu Sep 15 2016 01:58:47 GMT+0800 (Malay Peninsula Standard Time)
Recession	(42.00 hours) - Fri Sep 16 2016 19:58:47 GMT+0800 (Malay Peninsula Standard Time)

Figure 6. The Flood Hazard Information, showing the forecasted time of arrival and recession.

5. CONCLUDING REMARKS

In this paper, we described the development of a localized, interactive flood risk forecasting web-based application. The application was devised as one of many ways to assist the communities and Local Government Units of Caraga Region in making a sound and efficient decision in preventing and alleviating flood risks. The application requires the user to specify parameters, like municipality, barangay, amount of rainfall and to draw a polygon or point on the Web map interface, which will serve as the basis in forecasting flood risks. The application will basically provide flood information such as flood depth, flood duration and recession time and the time interval the flood water reaches the polygon or point drawn. It can also suggest safe route to the nearest evacuation shelter.

At present, the web application is being improved and tested.

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