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Estimating Earthquake Risks: The Use of Rapid Earthquake Damage Assessment System (REDAS) in the Province of Pangasinan, Philippines

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Abstract — **The Philippines has 18 regions and Pangasinan is the biggest province in Region I with a land area of 536,819 hectares. It has high risk to earthquakes due to the Manila Trench. This study was conducted to estimate earthquake risk in the province with the use of Rapid Earthquake Damage Assessment System (REDAS) software. There were three barangays from Binmaley, one of the 44 towns in the province, where actual building survey was taken to represent residential, commercial, and mixed commercial and residential sites which were used in creating the Pangasinan data base for this study.**

Estimation of earthquake risk using REDAS was based on the 1796 historical earthquake event which had a magnitude of 6.9 and a depth of 35 km. Results show that the total estimated floor area damages in square meters were 5,902,337 and 272,064 for complete damage with no collapse, and complete damage with collapse. Based on number of buildings, the total estimated complete with no collapse and complete with collapse damages were 115,694 and 5,315, respectively. The total estimated economic loss in millions is 63,069. The number of injuries is 52,382 minor injuries, 10,949 serious injuries, 459 very serious injuries and 1,321 fatalities. The overall result show that the cities of Dagupan, Urdaneta and San Carlos and the towns of Mangaldan, Malasiqui and Calasiao are the most at risk based on estimated damage in terms of area in square meters, number of buildings, economic loss, number of injuries and fatalities.

Results of the study have shown that REDAS is a valuable tool to estimate the extent of damages from an earthquake. Information from the estimated extent of damages in particular areas in the province can guide those who are involved in disaster risk reduction planning and implementation.

Keywords* — *REDAS; earthquake risk; rapid assessment

I. INTRODUCTION

Natural disasters or calamities are natural occurrences that affect the world and cause changes in the lives of people who suffer from these. Typhoons, earthquakes, floods, landslides, tsunamis and volcanic eruptions are natural disasters commonly experienced not only in the Philippines but also in other countries in the world. The extent of damages in life and properties among victim countries vary depending on how government planned and prepared for the emergence of such disasters (WDCR, 2005).

An earthquake is one of the natural disasters that pose great risk to lives and properties. It is a term used to describe both sudden slip on a fault and the resulting ground shaking and radiated seismic energy caused by the slip, or by volcanic or magmatic activity, or other sudden stress changes in the earth. The location below the earth's surface where the earthquake starts is called the hypocenter, and the location directly above it on the surface of the earth is called the epicenter (Wald, 2009). An earthquake hazard is anything associated with an earthquake that may affect the normal activities of people. This includes surface faulting, ground shaking, landslide, liquefaction, tectonic deformation, tsunamis, and seiches.

In the Philippines, the Philippine Institute of Volcanology and Seismology (PHIVOLCS) of the Department of Science & Technology (DOST) is the mandated agency with a mission to provide timely and quality information and services for warning, disaster preparedness and mitigation. This is accomplished through the development and application of technologies for the monitoring and accurate prediction of, and determination of areas prone to, volcanic eruptions, earthquakes, tsunamis and other related hazards, and capacity enhancement for comprehensive disaster risk reduction (Bautista et al., 2011).

One of the strategies of PHIVOLCS to realize their mandate is the development of a simple and user-friendly simulation tool or software that can give a rapid estimate of the possible seismic hazards which can be used for inferring the severity of impacts to various elements-at-risk. This software is called "Rapid Earthquake Damage Assessment System" or REDAS. The software was developed by PHIVOLCS-DOST thru a Grant-in-Aid (GIA) from the Department of Science and Technology (DOST). REDAS aims to provide quick and near real-time simulated earthquake hazard information to disaster managers which will help them in assessing the distribution and extent of the impacts of a strong earthquake. This could help them to decide and prioritize the deployment of timely rescue and relief operations. The second objective is for the software to serve as a tool in convincing land use planners, policy makers, city and town development planners and even local government executives to consider earthquake hazards in their planning and development efforts so as to ensure long-term mitigation of seismic risks. Its potential to be a risk assessment tool is being enhanced by improving the exposure database, inclusion of a building inventory module, incorporation of vulnerability curves and enhancing its modeling capability to address other natural hazards (Bautista et al., 2011).

Risk is the expected losses (of lives, persons injured, property damaged and economic activity disrupted) due to a particular hazard for a given area and reference period. The unit of measure could be value of damaged property. Risk assessment includes the examination of risks resulting from natural events like flooding, extreme weather events, earthquakes, etc. that may pose threats to ecosystems, animals and people. It involves the process of quantifying and evaluating risk and their effects on economic activities and public services exposed to hazards in a given area. Quantitative risk assessment requires calculations of the magnitude of the potential loss, and the probability that the loss will occur. Quantified risk may be expressed as the number of elements lost, proportion of elements affected and monetary value of damaged property (NEDA, 2008). Republic Act (RA) No. 10121 otherwise known as the "Philippine Disaster Risk Reduction and Management Act of 2010" (PDRRM-2010) was enacted on May 27, 2010, to strengthen the Philippine disaster risk reduction system. It specifically provides for the development of policies and plans and the implementation of actions and measures pertaining to all aspects of disaster risk reduction and management, including good governance, risk assessment and early warning, knowledge building and awareness raising, reducing underlying risk factors, and preparedness for effective response and early recovery (COA, 2014).

This study used REDAS to estimate the earthquake risk in the province of Pangasinan in case an earthquake of magnitude 6.9 and impact estimation in case of an 8.5 earthquake occurs. The province of Pangasinan is located on the west central area of the island of Luzon along the Lingayen Gulf. It is 170 kilometers north of Manila and 50 kilometers south of Baguio City. It is considered as the "food basket" of Region I and the largest among the four provinces in the region both in terms of land area and population. It has a land area of 536,819 hectares and a total population of 2,956,726 based on the 2015 census on population (PSA, 2016). It consists of 44 towns, four cities and a total of 1,364 barangays. The Philippines lies within the "Ring of Fire", a region of subduction zone volcanism surrounding the Pacific Ocean which makes the country a hotspot for earthquakes and other geological hazards. Records of earthquakes in the Philippines traced to as far back as the 1600s show that tremors registering magnitude-6 and over on the Richter scale have been experienced all over the country. Pangasinan is prone to earthquakes,

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especially the deep-focused ones, due to the Manila Trench and Philippine fault zone (Bautista et al., 2011). For instance, on July 16, 1990, Central Luzon was rocked by the strongest quake to hit northern Philippines. The earthquake registered a magnitude 7.8 on the Richter Scale with epicenter at 15.6°N and 121.0°E near the town of Rizal, Nueva Ecija. The 1990 Luzon Earthquake was felt in many places at Intensity VIII (based on a modified version of the Rossi-Forel Intensity Scale of I to IX currently used in the Philippines). However, some modifications may be necessary because there were isolated areas, like Dagupan City, Baguio City and the town of Rizal in Nueva Ecija which seemed to have experienced the earthquake at Intensity IX based on observed wave-like motion of the ground surface (Torres et al., 1990) and documented occurrence of thrown-up boulders. Liquefaction effects of the 16 July l990 Earthquake was particularly pronounced in the provinces of Tarlac, Pangasinan, and La Union. An earlier historical earthquake event that have a high magnitude of 6.9 in 1796 with a longitude of 120.5045, latitude of 16.1095 and a depth of 35 km was recorded.

Thus, to provide a significant tool for earthquake disaster preparedness, this study was conceived to estimate earthquake risk for the province of Pangasinan using the REDAS. Specifically it aims to develop earthquake exposure database for the province; estimate risks and calculate losses due to earthquake; and evaluate the capability of the Rapid Earthquake Damage Assessment System.

II. METHODOLOGY

A. *Capacity Building*

Before the start of the project activities, a training on the use of the REDAS (Capacity Enhancement of Academic Researchers on Hazards, Risk Assessment and Exposure Database Development through the use of the REDAS software) was conducted at the Mariano Marcos State University (MMSU) in January 2016. Enumerators were also briefed with proper techniques in the conduct of the actual survey of buildings to be used in the study. Another seminar on earthquake risk assessment in REDAS using survey data was conducted in June 2016 at Don Mariano Marcos Memorial State University, Bacnotan, La Union.

B. *Site Selection, Survey Proper, and Exposure Database*

Three barangays of Binmaley, Pangasinan were the chosen barangays to gather building survey data that was used in the study. The barangays of Calit, Gayaman and Poblacion were chosen to represent residential area, commercial area, and combination of residential and commercial area, respectively. The Exposure Database Module (EDM) for android was used to gather the needed data which include among others the building use, structure, period built, geography, and estimated number of occupants. The exposure database for the province of Pangasinan was one of the outputs of the study. It shows us the elements at risk due to ground shaking from an earthquake with an assumed specific magnitude. Among the information that were extracted from the database are the number of buildings, population and others for the surveyed barangays of Binmaley. These data were used to estimate the earthquake risk for the entire province.

C. *Risk Calculation and Loss Estimation*

Out of the data from the three barangays, the assessment of the impact of ground shaking using the historical 6.9 magnitude earthquake in 1796 was estimated for the province following the REDAS steps in conducting seismic hazard assessment (REDAS Manual). There are equations in the REDAS program used to calculate risk and estimate loss due to earthquake. These estimated damages, losses, injuries and fatalities were plotted as maps and figures.

III. RESULTS AND DISCUSSION

A total of 1,908 buildings were surveyed from the three barangays of Calit, Gayaman and Poblacion of Binmaley, Pangasinan. From these building survey data, the exposure database for Pangasinan was developed and used in the seismic hazard assessment specifically for ground shaking using REDAS. Figures of the loss maps and graphs were developed for easy interpretation.

Hazard Maps and Impact Graphs of Magnitude 6.9 Earthquake Scenario in Pangasinan

The succeeding figures show some of the loss maps for Pangasinan due to Magnitude 6.9 earthquake using survey data. The light color indicates less concentration of damage and the dark color indicates maximum/extensive damage. The star shows the epicenter of the earthquake.

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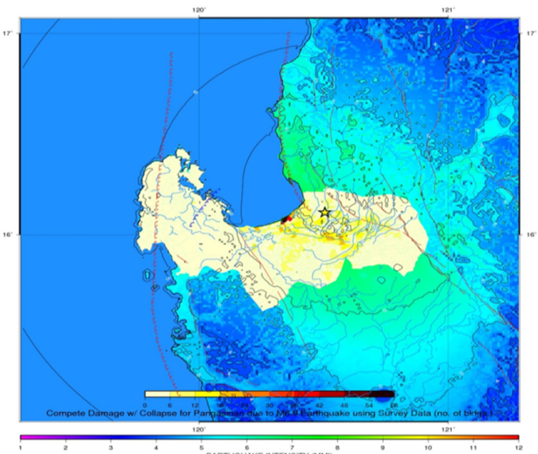

Figure 1. Complete Damage with Collapse for Pangasinan due to Magnitude 6.9 earthquake using survey data (in number of buildings).

The highest number of buildings that would incur complete damage with collapse is shown in Figure 1. The most affected cities and municipalities include Dagupan City (375), Urdaneta City (345), San Carlos City (327), Malasiqui (250) and Mangaldan (246). The least affected is Agno with 2 buildings.

The economic loss in millions of pesos in case a magnitude of 6.9 earthquake occurs in Pangasinan is shown in Figure 2. The cities and municipalities that have the highest number of economic loss are the cities of Dagupan (5,121), Urdaneta (4,524), San Carlos (3,804) and the towns of Mangaldan (2,679) and Calasiao (2,627). The municipality of Burgos has the lowest estimated economic loss of 50 million.

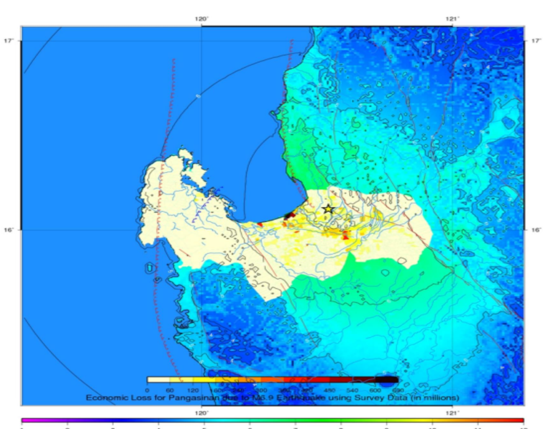

Figure 2. Economic loss for Pangasinan due to Magnitude 6.9 earthquake using survey data (in millions).

The estimated number of serious injuries in case a magnitude of 6.9 earthquake happens for Pangasinan is shown in Figure 3. The cities and municipalities that would have the highest number of serious injuries are the cities of Dagupan (868), San Carlos (3719), Urdaneta (718), and the towns of Mangaldan (567), and Malasiqui (531). The municipality of Agno would have the lowest number of serious injuries which is 2.

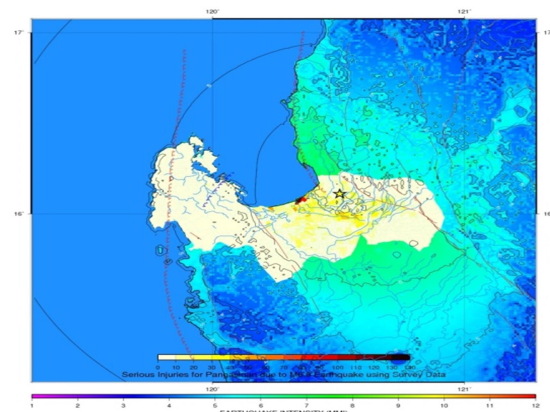

Figure 3. Serious injuries for Pangasinan due to Magnitude 6.9 earthquake using survey data.

The estimated fatalities in case a magnitude of 6.9 earthquake happens in Pangasinan is shown in Figure 4. The cities and municipalities that would have the highest number of fatalities include Dagupan City (109), Urdaneta City (94), San Carlos City (92), and the towns of Mangaldan (73), and Calasiao (63). The estimated total number of fatalities was estimated to be 1,321.

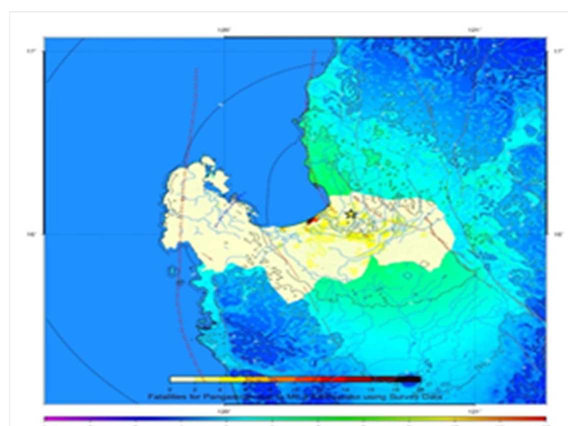

Figure 4. Fatalities of Pangasinan due to Magnitude 6.9 earthquake using survey data.

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IV. Conclusion

The estimation of earthquake risk using the REDAS with a magnitude of 6.9 earthquake scenario revealed that the three cities with the highest damages in areal extent would be Dagupan City, Urdaneta City and San Carlos City. On the other hand, the top three municipalities are Mangaldan, Calasiao and Malasiqui. The municipality with the least estimated damage is Burgos. Based on the number of buildings, cities of Dagupan, Urdaneta, and San Carlos would have the highest damage in number of buildings, also are the municipalities of Mangaldan, Calasiao and Malasiqui. The municipality with the least estimated damage would be Burgos. The total estimated economic loss is 63,069 million of pesos with Dagupan City, Urdaneta City and San Carlos city incurring the highest losses.

The total estimated number of injuries would be 52,382 minor injuries, 10,949 serious injuries, and 459 very serious injuries. As to the total estimated number of fatalities, the result is 1,321. The cities of Dagupan, Urdaneta and San Carlos and the towns of Mangaldan, Malasiqui and Calasiao would be the most at risk as to the assessed number of injuries and fatalities.

The overall result show that the cities of Dagupan, Urdaneta and San Carlos and the towns of Mangaldan, Malasiqui and Calasiao are the most at risk based on estimated damage in terms of area in square meters, number of buildings, number of injuries and number of fatalities. The cities of Dagupan, Urdaneta and San Carlos are characterized as business or commercial centers and the towns of Mangaldan, Malasiqui and Calasiao have many commercial establishments as well. In addition, the epicenter of the earthquake is also close to these cities/municipalities.

This study has shown that REDAS is a valuable tool to estimate the extent of damages from a natural phenomenon like an earthquake. Information from the estimated extent of damages in particular areas of the province can guide those who are involved in disaster risk reduction planning and implementation.

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