Geophysical Risks and Exposure of Public School Buildings in Samar

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Abstract: Hazards are everywhere, and people are expected to prepare for the eventuality that the hazard will turn into a disaster. By doing so, the impact of a disaster is reduced. One of the most important facilities during a disaster is evacuation halls (which include school buildings) next to hospitals. Schools are also areas where people congregate and therefore must be resilient to any disaster to minimize casualties. The study was conducted to determine the different geophysical risks in Samar are and what the level of exposure of its public school buildings. Based on secondary data from authorities, and computer-aided simulations such as REDAS and NOAH, the public schools of Samar are exposed to varied intensity of earthquakes which may come from the Philippine Fault Zone, the Philippine Trench and the numerous lineaments in and nearby Samar Island. The risk rating for rain-induced landslides is greater than earthquake-induced landslide. It was also found out that a tsunami in the area directly attributed to an earthquake is unlikely.

Keywords: earthquake, tsunami, landslides, Western Samar, DRRM, moderate risk

1. Introduction

Greater casualties from natural hazards are caused by geophysical hazards (Rees et al., 2012). Earthquakes, volcanic activity including emissions, and related geophysical processes such as mass movements, landslides, rock slides, surface collapses, and debris or mudflows are categorized as geophysical risks (PreventionWeb, 2017) as well as a tsunami for being triggered by undersea earthquakes and other geologic events specifically under the sea. For natural-hazard death in the recent decade, about two-thirds are attributed to geophysical disasters (Rees et al., 2012). The largest recorded in the 9.5 magnitude earthquake in Chile sometime in 1960 (Kanamori & Anderson, 1975). The most recent disastrous earthquake in the world occurred in Haiti (7.0 magnitude) on Jan 13, 2010, killing about 316,000 people with more than 80,000 destroyed buildings (Thompson Reuters Foundation, 2017). It is followed by a 7.8 magnitude in China in 2008 (≈87,600 killed), and a magnitude of 7.8 in Nepal in 2015 (≈9,000 killed). A devastating tsunami occurred about 8,000 years ago when a volcano had an avalanche in Sicily estimated to have heights higher than a 10-story building (LiveScience, 2011). Other more recent tsunami includes that in northern Japan on March 11, 2011with water estimated at 10m (ibid) and September 28, 2018, in Indonesia with water of up to 3.8 m (ITIC, 2018). The United States Geological Survey (USGS, nd) listed the biggest historic landslide in 1980 caused by the eruption of Mount St. Helens, a volcano is found in the State of Washington, the USA involving 2.8 cubic kilometers of debris. Guinness World Records (nd) listed the landslides in Gansu, China as the worst with about 180,000 died sometime in 1920. Other deadliest landslides in the world include the one in Venezuela in 1999 (≈30,000 deaths), Colombia in 1985 (≈,000 deaths) and in Peru in 1970 with about 22,000 deaths (World Atlas, nd).

Since 1990, around 565 natural disasters have affected the Philippines claiming nearly 70,000 Filipinos and caused about $23 billion (PHP 1.21 trillion) worth of damages (GFDRR, nd). In the Philippines, the top three strongest earthquakes on record are the following; Magnitude 8.0 near Mindanao and Sulu in 1976 (≈8,000 deaths), 7.8 magnitude in Central Luzon on July 16, 1990 (≈2,412 deaths) and magnitude 7.5 on November 30, 1945, with approximately 600 deaths (Sabornido, 2015). To date, the country is preparing for the "Big One," a 7.2 magnitude earthquake in Metro Manila which is estimated to destroy 40% of residential buildings and damage 35 percent of public buildings (PNA, 2018; Reliefweb, 2017). The geographical characteristics of the Philippines compounded by the uncontrolled settlement in hazard-prone areas, high poverty rate, failure to implement building codes and construction standards, and degradation of forests and coastal resources, among others, make the Philippines among the high-risk countries worldwide against geohazard risks (UNICEF, 2017). It is estimated that around 27.6 million Filipinos who are among the poorest and marginalized felt the brunt of the hazards. People in the country are often trapped in a seemingly never-ending cycle of disaster, displacement, and rebuilding.

Most of the death from earthquakes is attributed to building collapse. In many cases, it collapses because of poor design and wrong construction methodologies (Figueroa Fernandez, 2014). Poor design of buildings may include the improper materials specification when not all probable loads and material capacities (including foundation) were included in the design (Calvert, 2002). On the other hand, even if the design was correct if the construction is defective (e.g., specified materials were not used, curing of concrete or care of materials during construction were not observed, or building procedure was not followed, and others) the likelihood of building failure is increased (Parfitt, 2012). Further, many structures may have been built on hazardous areas. To date, few municipalities have functional Comprehensive Land Use Plans (CLUP), others do not even have one (Quitalig and Orale, 2015).

Living with disaster is a new norm, and almost everyone is exposed to it on a daily basis. Knowing the hazards (specifically geophysical risks) is very crucial in the process.

2. Objectives

The study presents the different geophysical risks in Samar and the extent the school buildings are exposed. Specifically, the paper will;

2.1 Determine the critical areas to geophysical hazards, and

2.2 Estimate the disaster risk exposure of public school buildings in terms of the following risks; earthquakes, tsunami, and landslides risk

3. Methodology

The paper is descriptive research and used mostly secondary data. Only the exact location of the schools was collected using a global positioning system (GPS).

3.1 Research Design.

The study assessed the vulnerability of school sites to disasters specifically along geologic disasters (i.e., earthquakes, tsunami, and landslides); the vulnerability was determined through available simulation software such as the Rapid Earthquake Damage Assessment System (REDAS) and the Nationwide Operational Assessment of Hazard (NOAH).

3.2 Locale of the Study

The locale of the study is the Second District of Samar with 52 schools is found in 15 municipalities of the Second District of Samar and the City of Catbalogan.

3.3 Instrumentation and Sources of Data

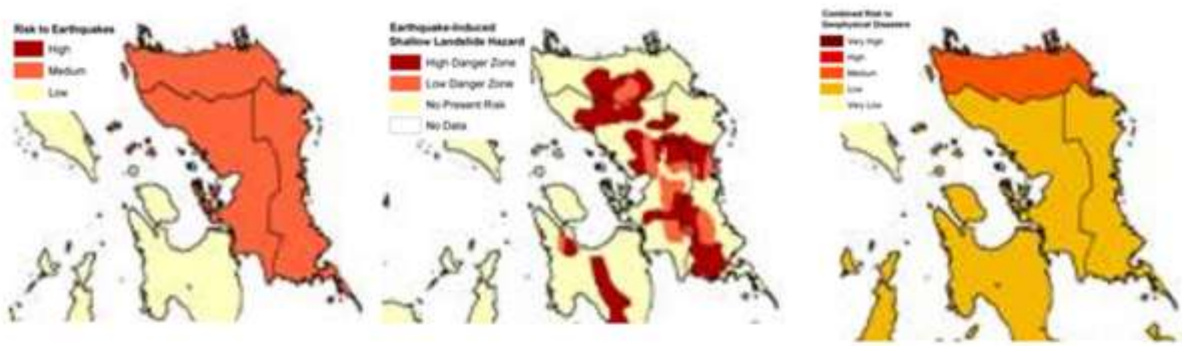
The study used secondary data such as disaster maps from DOST-MGB, DENR-NAMRIA. Disaster simulation for earthquake and earthquake-induced landslide and tsunami were done through REDAS and NOAH software/system of DOST. Satellite images from Google maps and Bing Maps were also used, video and still pictures were used to review gathered data through an actual survey. The results of the analysis were validated on site. Fifty-two campuses were considered in this study.

3.4 Data Processing and Presentation

Data were summarized in terms of tables, graphs (specifically cartograph/maps) and pictures.

4. Results and Discussion

As shown in Figure 1, the geophysical risk of Samar ranges from low to medium risk. The Province of Samar had a rating of low when the risk to an earthquake, a risk to a landslide, risk to tsunami and risk to volcanic eruption were all considered. There is no reported active volcano in the area, the recorded earthquakes and frequency is quite low in number, and the type of fault system in the area is not expected to cause a tsunami (Climate Studies Division Manila Observatory). On the other hand, rain-induced landslide (soil collapses due to a high amount of water in the soil matrix) is considerably higher.



$$\sum R_G = R_{EQ} + R_{LS} + R_{TS} + R_{VO}$$

Figure 1. (a) Risk to Earthquakes (b) Risk to Earthquake-induced Landslide (c) Combined Geophysical Disaster Risk

Source: Climate Studies Division Manila Observatory

Figure 1. Geophysical Risks of Samar Island

4.1 Critical Areas for Geophysical Risks in the Province of Samar.

Earthquakes. Geophysical events specifically earthquake occurs unannounced and in several cases are very destructive. Included in this group of risks are a volcanic eruption, tsunami, earthquake-induced landslide, and the triggering earthquake. Shown in Figure 2(a), the risk to an earthquake is medium and the impact of these earthquakes to cause landslide varies depending on the location. Earthquake-induced landslide ranges from low to a high danger zone. There is little danger from volcanic eruption and risk to tsunami after an earthquake is also low.

Tsunami. Tsunami may occur on every coastal area and river estuary, but it is more likely to occur on shores facing a megathrust directly (UNESCO-ITIC, nd; Earth Observatory Singapore, nd). It is estimated that almost 75% of tsunamis around the world occur in the Pacific Ocean where the subduction zones are common (Singapore Observatory, nd). The Philippines is one of those countries that are likely to experience tsunami together with countries Japan, Chile, Alaska, Aleutian Islands to name a few. A tsunami can also be caused by an underwater volcanic eruption or those very adjacent to water body such as what happened in Indonesia (Wei-Haas, 2018) and the Philippines (Volcano Live, nd).

A potential source of a tsunami is if the Philippine Fault Zone fronting the Samar Island is triggered. However, the Philippine Fault Zone is a strike-slip fault (William & Rutland, 1967; Acharya, 1980) where movement is predominantly horizontal – where portions of tectonic plates are grinding laterally past one another – and may not cause tsunamis (Earth Magazine, 2012). As shown in Figure 2, the tsunami risk rating is low because of the type of fault system in the area. The central Philippine Fault Zone where Samar is very adjacent is found to be the locus of great earthquakes, slow events and creep activity (Besana & Ando, 2005). A different simulation by ThinkHazard (nd) rated the Samar risk level at high. The high rating suggests that there is more than 20% chance of a potentially damaging tsunami occurring in the next 50 years. This different rating is associated with the Eastern part of Samar Island facing an open sea where fault systems found in the entire area may result in tsunami. This, however, will have no impact on the most coastal area of Samar.

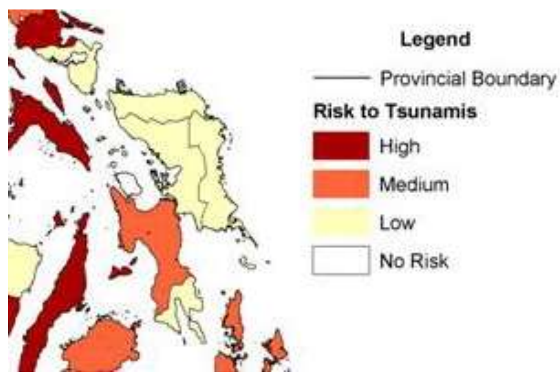


Figure 2. Tsunami Risk (Source: Manila Observatory & DENR)

Landslides. Samar is prone to landslides and most of which will be in rockslides or in rockfall form triggered by extreme precipitation or higher intensity earthquake (Orale, 2006). During an extreme precipitation event that lasted days caused a soil in a road cut in Catbalogan City to slide killing more 20 people (NDRRMC, 2015). More recently, major highways in Samar experienced landslides attributed to typhoon Samuel (international name Man-yi) in November 2018 (Meniano, 2018). Shown in Figure 3 are landslide zones. The brown colored (about 28.81% of all Samar) zones are areas where buildings can be built when there is slope reinforcement (Rabonza et al., 2013). On the other hand, the dark-colored areas (red colored when closed-up) are "strictly no build zone" is estimated to be 7.8% found mostly on the central mountainous part of the province (ibid). Landslide susceptibility is enhanced due to human activity such as road cuts or slope alteration to accommodate new buildings or other uses.

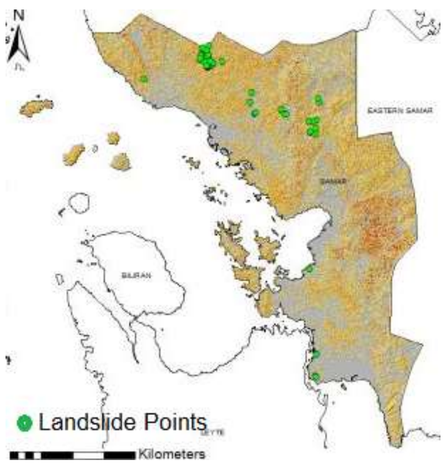


Figure 3. Shallow Landslide Susceptibility Map (Source: Rabonza et al., 2013)

4.2 School Exposure to Different Disaster Risks

Schools Exposed to Fault Lines. There is a medium risk of an earthquake in Samar as shown in Figure 1. Samar Island is very adjacent to the Philippine Trench which is found about 60 km in width and 1,400 km long (Alpha and Galloway, 1996). The Philippine Fault Zone traverses Leyte Island to Masbate and beyond is found on the western part of the Samar Island. The fault system is about 70 km from the nearest coast of Catbalogan City. There is also some lineament found in the Samar Island, the Southern Samar, the Northern Samar and the Central Samar lineament found near Catbalogan City. These trench, fault, and lineament are potential sources of earthquakes (USGS b, nd; Vashchilov & Kalinina, 2008).

The DOST-PHIVOLCS come up with a more recent map as shown in Figure 4. It identified at least 7, a slight change in its year 2000 map. The provincial-scale active faults map for the province of Samar was generated using geomorphic evidence of active faulting using satellite images. The map has shown certain and approximate location of active faults where the (1) Northern Samar Lineament extending to Calbayog City, (2) Central Samar Fault – Calapi Segment, (3) Central Samar Fault – Canavid Segment, (4) Central Samar Fault: Paranas Segment, (5) Eastern Samar Fault, (6) Southern Samar Lineament –Basey and the Southern Samar Lineament – Marabut Lawaan section.

Figure 4. Active Faults Map – Province of Samar (DOST-PHIVOLCS, 2018)

Based on the PHIVOLCS maps (see Figure 4), Tenani National High School is just about 126m from the Central Samar Fault (Paranas Segment) while the Calapi national High School is found around 879 m from the Central Samar Fault. Buildings or structures directly above a fault line are at greater risk than those that are far from it. Buildings built above the fault line (or very near to it) will experience greater stress which may lead to its collapse. Existing design criteria discourages building above a fault line, no amount of material strength is capable of standing against the force of a rapturing ground. If building structures cannot be avoided, structures on two sides of a fault line must be constructed independently from another. This is to allow the segments to move independently avoiding undue stress to the members of the structure.

Figure 5. Left: Fault Line Traversing a Basketball Court in Ormoc (www.interaksyon.com, 2017). Right: A School Building above a Fault Line in Leyte)

Schools Exposed to Earthquake Hazards. Earthquake in Samar Island in the past two years (2016-2018) is shown in Figure 6. Earthquake intensity ranges from Magnitude 4.2 to 5.0 with depth epicenter found up to 150 km from g surface. There are minor fault systems within Samar, areas near this fracture zones are potential epicenters of earthquakes. The second longest fault is called the Southern Samar Lineament that runs 30.5 km long which is also located near Basey and Marabut. The third fault called the Central Samar Lineament is about 29.5 km and runs from Darahuway Islands of Catbalogan City to Mainland Catbalogan City and San Jorge town. This fault lines/lineament or fractures on the ground are risky areas not only in terms of potential epicenter for earthquakes but for structures stability. Structures built on top of a lineament may fail not because of shaking but liquefaction or shearing stress.

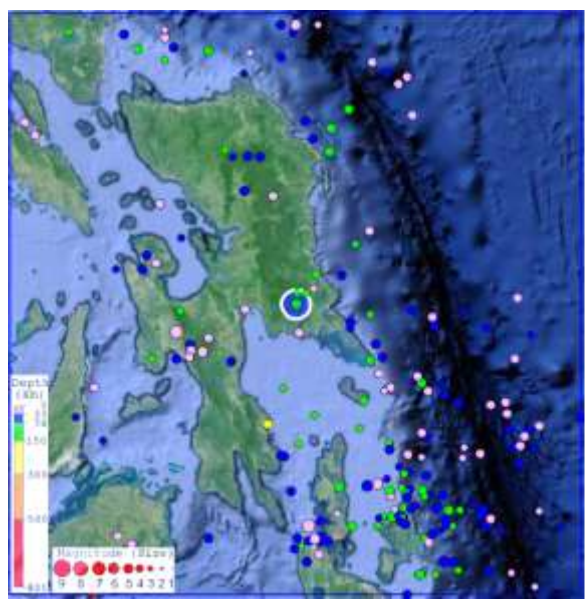


Figure 6. Earthquake Profile near Samar Island (2016-2018)

Using REDAS and simulating Magnitude 7 earthquake with epicenter found 5 km below the surface near the vicinity of the Central Samar Lineament (Catbalogan City) will result in a magnitude 6 to 7.5 earthquakes. As shown in Figure 7 and summarized in Table 1, about 46 schools (88.46%) are to experience magnitude 7.0-7.5 earthquake, and the remaining six (11.54%) are expected to experience a magnitude 6.0-6.9 earthquake. This distribution will change if the epicenter is at a different location. The same earthquake profile happening in Pinabacdao Samar (which is close to the South Samar Lineament) will result in a lesser number of areas experiencing higher intensity. Some 36 (69.23%) schools will feel the magnitude 7.0 – 7.5 and the rest (30.77%) will experience a magnitude of 6.0 – 6.9.

Table 1. Earthquake Exposure of School Campuses in Samar

Level of Vulnerability to Ground Shaking during Earthquake	Frequency
Magnitude 7.0 with Epicentre at Catbalogan City (Central Samar Lineament, 5km from Surface)	
Magnitude 7.0 – 7.5	46
Magnitude 6.0 – 6.9	6
Total	**52**
Magnitude 7.0 with Epicentre at Pinabacdao, Samar (Central Samar Lineament, 5km from Surface)	
Magnitude 7.0 – 7.5	36
Magnitude 6.0 – 6.9	16
Total	**52**

A magnitude of 6.1 to 6.9 earthquake is considered strong and may cause a lot of damage in very populated areas (MTU, nd). Damage is dependent on many other variables like distance from the earthquake epicenter, type of soil and others. Usually, damages occur when magnitude reaches somewhere 4.0 or 5.0 (USGS c, nd).

For the first case (Figure 7), schools that will experience a larger magnitude are those closer to the Central Samar Lineament. Schools that will experience lower magnitude (Magnitude 6.0 to 6.9) are schools in Marabut Samar (Marabut NHS and Osmeña NHS), Basey, Samar (Basey NHS, Old San Agustin NHS, San Fernando NHS) and Hinabangan Samar (Bagacay NHS). The rest of the sampled school will experience a Magnitude 7.0 – 7.5 earthquakes.

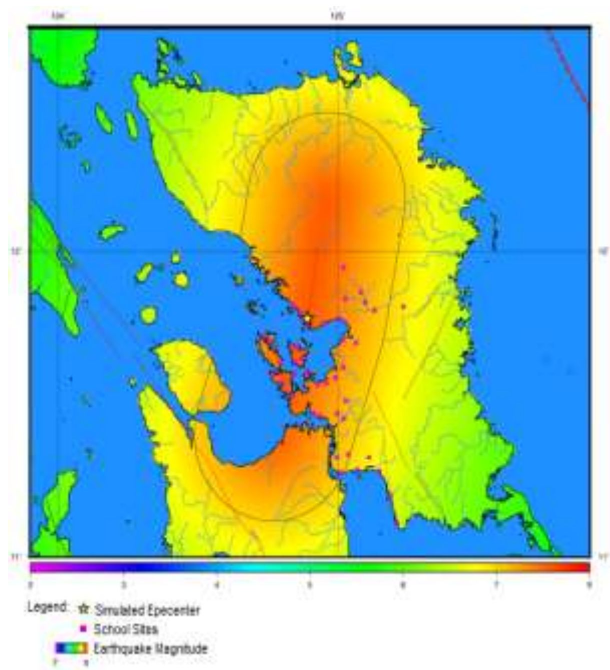


Figure 7. Magnitude Felt by School Campuses from a Magnitude 7.0 Earthquake with Epicentre found 5.0 km depth in Catbalogan City

In the report of Casimpan (2012) said that 29 towns in Eastern Visayas were identified as high-risk earthquake areas. Philippine Volcanology and Seismology (PHIVOLCS) in Eastern Visayas identified towns of Marabut, Basey, Pinabacdao and Hinabangan, Samar are subject to jolts by the movement of the lineament found in the area (ibid). The second case of earthquake shown on Table 2 and Figure 8 where the epicenter is in Pinabacdao Samar will result into exposure to a strong earthquake (16 schools) and Major earthquake or Magnitude 7.0 – 7.9 earthquakes will affect 36 of the 52 schools sampled.

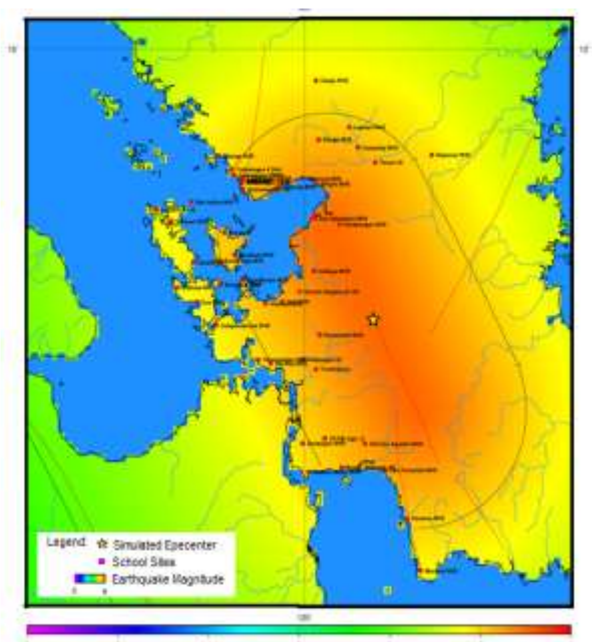


Figure 8. Magnitude Felt by School Campuses from a Magnitude 7.0 Earthquake with Epicentre found 5.0 km depth in Pinabacdao, Samar

These 16 schools which will receive lower magnitude (6.0 – 6.9) are those found in Daram, Samar (all eight schools), Sta. Rita (2 schools), Zummaraga Samar (1 school), Motiong Samar (1 school), Hinabangan (1 school), Marabut Samar (1 school), Catbalogan City (1 school), and Talalora (1 school). The rest of the 36 schools are expected to experience a 7.0 to 7.5 magnitude earthquake because of its proximity to the stretch of the Southern Samar Lineament which traverses about 60 degrees northwest from Basey, Samar.

According to the Earthquake Tracker (nd.-a) database, the largest earthquake in Samar Island was a Magnitude 7.2 with epicenter 20km from the surface sometime in 1994 in Eastern Samar and another in Northern Samar sometime in 1925. A magnitude 7.0 was recorded in 1946 and 1936 with an epicenter near the Philippine Fault Zone fronting (Western) Samar. Using the same database, it showed that the most recent earthquake with a magnitude above 6.0 occurred near Samar Island in 2003 with recorded magnitude of 6.5.

Mapping out where the fault line passes and designing buildings to withstand the strength of expected earthquakes even for one-story buildings should seriously be considered. Also if structural members are sturdily constructed if the soil where the foundation stands is weak, failure from uneven settlement may pose a greater danger to the structure itself. Soil investigation to determine bearing capacity, liquefaction potential and others must be studied. This information suggests the vulnerability to ground shaking of the Island of Samar. Earthquakes in the area are attributed to the presence of active fault and lineament in the Island and nearby provinces like Leyte.

Schools Exposed to Tsunami. A REDAS simulation of an 8.5 magnitude earthquake with an epicenter located in waters between Leyte and Masbate will not result in a tsunami. Various other scenario was tested (earthquake occurring at different waters fronting Samar), but no tsunami risk was identified. These do not, however, mean that the threat to the tsunami is zero; the result of the assessment is attributed to the information used by REDAS that earthquake occurrence in the simulated zones is strike-slip in nature. A strike-slip type of fault movement may still result in the tsunami on certain occasions as observed in some areas with similar earthquakes. Legg et al. (2003) listed two occurrences of tsunamis from strike-slip fault zones such as the 1906 San Francisco California, 1994 Mindoro, Philippines and 1999 Izmit, Turkey earthquakes. They theorize that there was and after an event that may have occurred such as an underwater landslide or massive chunk of the seafloor was displaced as a result of the strike-slip movement (ibid). A simulation of an earthquake with epicenter along the Philippine Trench threatens the coastal towns of Eastern Samar and Northern Samar for tsunamis but not Western Samar.

Other simulations like that of Tsunami Mapper suggests an intensity XI (devastating) and a tsunami range of 100km with up to 16m wave height will affect parts of Calbayog City, Pagsangjan, Santa Margarita, Tarangnan, Daram, and Catbalogan City. This scenario is however less likely.

Schools Exposed to Landslide Risk. Landslide (technically known as mass wasting) is mostly triggered by hazards such as earthquake and heavy rainfall, but places will not experience the same due to varying geological conditions, slope condition, the ground cover as well as human activities (Orale, 2006). In an inventory derived from high-resolution satellite photos, around 12,588 landslides were recorded as of October 1, 2014, in the entire Philippines. About 614 (4.9%) are for Eastern Visayas. Of that 614, 98 was from Samar have been validated to be accurate (DOST, nd).

A simulated magnitude 7.0 earthquake with an epicenter in Catbalogan City will result in landslides in various campuses as shown in Table 2 (a). Only one (1.9%) school is located in a highly vulnerable to landslide zone which is the Marabut National High School. Lawaan National High School, Casandig National High School, Tenani Integrated School, Bagacay National High School in Hinabangan, Samar, and Hinabangan National School is in a low vulnerable area to landslides as an aftereffect of an earthquake in Catbalogan City, while the remaining 46 (88.46%) is not to expect a landslide.

Table 2. Schools in Critical Areas for Earthquake-Induced Landslide

Level of Vulnerability to Earthquake-Induced Landslide	Frequency
a) Magnitude 7.0 with Epicentre at Catbalogan City (Central Samar Lineament, 5km from Surface)	
High	1
Medium/Moderate	0
Low	5
None	46
Total	**52**
b) Magnitude 7.0 with Epicentre at Pinabacdao, Samar (Central Samar Lineament, 5km from Surface)	
High	3
Medium/Moderate	8
Low	0
None	41
Total	**52**

If the same earthquake occurs in Pinabacdao Samar, the number of schools safe from an earthquake-induced landslide is reduced to 41 (78.8%). However, the number of schools that are in highly vulnerable to landslide due to an earthquake in Pinabacdao Samar was increased to 3 (5.7%). Table 2 (b) shows that the majority or 41 public schools in the Province of Samar are not vulnerable to earthquake-induced landslides. Some of these areas which are not susceptible to earthquake-induced landslide include Basey National High School, Valeriano C. Yancha Memorial Agricultural School, San Fernando National High School, Old San Agustin National High School, Simeon Ocdol National High School, Calbiga National High School, Parasan National High School, and others, as shown in the map.

The table likewise shows that eight public schools are vulnerable to earthquake-induced landslide to a moderate level. These include Sua National High School, Bonga National High School, Casandig National High School, Tenani National High School, Lawaan National High School, Catbalogan 5 District, Mualbual National High School, and Guinsorogan National High School. Moreover, the table likewise shows that there are three highly critical areas to an earthquake-induced landslide. These include Daram National High School, Bagacay National High School of Hinabangan, Samar and Calapi National High School.

These schools rated high and moderate to earthquake-induced hazards are located beside or on sloping terrain. There are about 14 types of landslides identified that were associated with earthquakes; the most abundant of these were rock falls, disrupted soil slides, and rock slides. The most significant losses of human life were due to rock slides (Keefer, 1984). Each type of earthquake-induced landslide occurs in a particular suite of geologic environments such as overhanging slopes of well-indurated rock to slopes of less than one degree underlain by soft, unconsolidated sediments (ibid). Weakly cemented rocks, more-indurated rocks with prominent or pervasive discontinuities, residual and colluvial sand, volcanic soils, granular alluvium, granular deltaic deposits, and granular human-made fill are prone to landslides caused by an earthquake (ibid).

Schools Exposed to Rainfall-Induced Landslide. Another cause of landslide is attributed to too much water in the soil, primarily due to extreme precipitation or other means. Water alone does not cause landslide as it occurs together with other factors such as soil type and slope. Mass of soil sliding is attributed mainly due to gravity. When the intact strength of the soil is surpassed with the pull of gravity, the soil will slide or fall. Mountains and other slopes are stable on normal condition. When these normal conditions are altered by natural or human-made causes, the stability is affected, soil shearing resistance is changed. Earthquakes often cause the soil or rocks to fracture or to be sheared resulting in instability and block of soil or rock slides or fall (Keefer, 1984).

On the other hand, the shear strength of soils is profoundly affected by the amount of water it carries especially when the soil is clay (Blahova, K. et al., 2013). Soils with higher water content tend to have lower shear strength capacity, while cohesion of soil increases at a small amount of water but decreases very rapidly after its optimal moisture content is reached (Huang et al., 2012). Most of the landslide in Samar occurs after heavy rainfall. The sudden drop in the mechanical properties (shear strength, cohesion) of the material associated with an increase in water content results into a landslide.

Samar Island risk to increased precipitation is categorized as very high according to the Climate Studies Division of the Manila Observatory (2005). In the study of Orale (2015), there were two days (excluding the prior day's continuous rain) wherein the precipitation has reached to more than 300mm. It was during December 2014 when 20 people perished due to a landslide primarily attributed to extreme rainfall (NDRRMC, 2015).

Shown in Figure 9 are the sites where landslides are expected to occur due to extremely high precipitation. Table 3 categorized the number of schools exposed to a different level of risks. There are about six schools which are highly critical to landslides while only 16 have low risk.

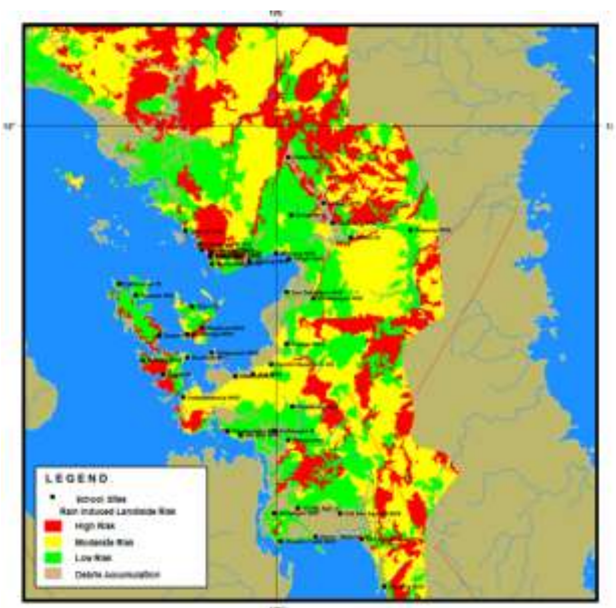


Figure 9. Rainfall-Induced Landslide Exposure of School Buildings

The four (4) public schools which were identified to be within the moderate level of risk for rain-induced landslide are; Baclayan National High School, Zumarraga National High School, Independencia National High School, and Igot National High School.

Table 3. Schools in Critical Areas for Rain-Induced Landslide

Level of Vulnerability to Rain-Induced Landslide	Frequency
High	6
Moderate	4
Low	16
Debris	26
Total	52

Table 3 presents the vulnerability of school buildings to a rain-induced landslide. The six (6) public schools identified to be within the high susceptibility for rain-induced landslides are; Mualbual National High School, Sua National High School, Cabiton-an National High School, Daram National High School, Catbalogan 4 District and Catbalogan 5 District.

Table 3 likewise shows that 16 public schools are located in a low level of vulnerability to a rain-induced landslide. These schools are the Calbiga National High School, Parasan National High School, Bakhaw National High School, Hinabangan National High School, Bagacay National High School of Hinabangan, Samar, Tenani National High School, Bonga National High School, Parasanon National High School, Sta. Rita National High School, Tominamos Integrated School, Hinangutdan National High School, Bioso Integrated School, Silanga National High School, Guinsorongan National High School, and Simeon Ocdol National High School.

On the other hand, the remaining 26 areas are expected to receive debris accumulation as a result of a rain-induced landslide. Some of these areas include Basey National High School, Valeriano C. Yancha Memorial Agricultural School, San Fernando National High School, Old San Agustin National High School, Osmena

National High School, Motiong National High School, Calapi National High School, Wright National High School, Casandig National High School, Tenani Integrated School, Lawaan National High School, and others, as shown in the map. Some of those who perished in the Catbalogan City landslide in December 2014 was outside of the susceptible slope but were very near. A zone very close to landslide susceptible slopes is equally exposed to the risk.

The susceptibility assessment is entirely based on the general information used by DOST. Landslide risk level can be magnified when there is an alteration of the natural conditions, and these are very dynamic and ever-changing. These sometimes are not incorporated in the landslide susceptibility assessment. A more adept landslide susceptibility calculation focusing on actual data on site, taking into consideration the current slope condition (the one used in the evaluation are based on old maps, not real time), actual geotechnical properties of soil (one used in the assessment are based on indirect information about soil condition; i.e., Type of plants and color of the plants from a remotely sensed image), drainage condition, ground cover and many more must be conducted.

5. Conclusion and Recommendation

Samar is expected to experience various types of geophysical risks such as earthquakes, rainfall-induced landslides but lower likelihood to none on earthquake-induced landslide and tsunami.

Earthquake intensities to be experienced by the public schools in Samar will vary depending on the location of the epicenter. Most of the earthquakes higher than magnitude 6 occurred in Eastern Samar, Northern Samar and other areas outside of Samar Island and none in (Western) Samar. Shocks are a common phenomenon in the area due to its proximity to active faults (trench off the coast of Eastern Samar side, Philippine Fault Zone off the coast of Samar and the several lineaments within the Samar Island. Tenani National High School and the Calapi National Highschool are located about 251 m and 879m from an active lineament respectively.

Because the Philippine Fault System is of strike-slip, a tsunami in Samar is unlikely. The likelihood of an earthquake-induced landslide is rated low.

6. Bibliography

Acharya, HK. (1980). Seismic Slip on the Philippine Fault and its Tectonic Implications. Geology, 8(1).

Alpha, TR and Galloway, JP. (1996). Ocean Trenches, A Computer Animation, and Paper Model. United States Geological Survey

Besana, GM & Ando, M. (2005). The Central Philippine Fault Zone: Location of Great Earthquakes, Slow Events, and Creep Activity. Earth Planets and Space, 57(10).

Blahova, K., Sevelova, L., and Pilarova, P. (2013). Influence of Water Content on the Shear Strength Parameters of Clayey Soil in Relation to Stability Analysis of a Hillside in BRNO Region. Acta Universitatis Agriculturae Et Silvuculturae Mendelianae Brunensis, 61(6).

Calvert, JB. (2002). The Collapse of Buildings – Why the World Trade Center Towers Collapsed. The University of Denver.

https://mysite.du.edu/~jcalvert/tech/failure.htm Accessed June 3, 2018

Casimpan, AJ. (2012). 29 Towns in EV Identified as Earthquake Hi-Risk Areas. PIA Report posted at Reliefweb. https://reliefweb.int/report/philippines/29-towns-ev-identified-earthquake-high-risk-areas Accessed June 12, 2017

DOST-PHIVOLCS, (2018). Active Fault Map, Province of Samar. Department of Science and Technology-Philippine Institute of Volcanology and Seismology. https://gisweb.phivolcs.dost.gov.ph/phivolcs_hazardmaps/09.%20Region%20VIII/2%20Province/Samar/Active%20Fault/1%20Samar_AF_2018.png Accessed June 30, 2018

DOST, (nd). Nationwide Operational Assessment of hazards. Department of Science and Technology. www.wcdrr.org/wcdrr-data/uploads/544/6_SE539_websafePhilippines_wcdrr2.pdf Accessed June 1, 2017

Earth Magazine (2012). Sumatran Strike-slip Earthquakes Challenge Seismologists. https://www.earthmagazine.org/article/sumatran-strike-slip-earthquakes-challenge-seismologists Accessed June 3, 2018.

Earth Observatory of Singapore (nd). Where is Tsunami Most Likely to Happen? https://earthobservatory.sg/faq-on-earth-sciences/where-tsunami-most-likely-happen Accessed June 3, 2018

Earthquake Tracker, (nd). Biggest Earthquake Near Samar, Philippines. https://earthquaketrack.com/r/samar-philippines/biggest Accessed June 3, 2018.

Figueroa Fernandez, RH. (2014). Strategies to Reduce the Risk of Building Collapse in Developing Countries. Dissertation at Carnegie Mellon University.

ITIC (2018). 2018 Tsunamis. http://itic.ioc-unesco.org/index.php?option=com_content&view=category&layout=blog&id=2289&Itemid=2815 Accessed November 2, 2018

GFDRR (nd). The Philippines. Global Facility for Disaster Reduction and Recovery. https://www.gfdrr.org/philippines Accessed November 4, 2018

Guinness World Records (nd). Worst Landslide Disaster – Death Toll. http://www.guinnessworldrecords.com/world-records/worst-landslide-disaster-death-toll, Accessed June 2, 2018

Huang, K., Wan, JW., Chen, G., and Zeng, Y. (2012). Testing Study of Relationship Between Water Content and Shear Strength of Unsaturated Soils. Rocks and Soil Mechanics, 33(9).

Kanamori, H., & Anderson, D. L. (1975). Theoretical basis of some empirical relations in seismology. BSSA, 65(5).

Keefer, DK. (1984). Landslides Caused by Earthquakes. Geological Society of America Bulletin, 95. https://pubs.geoscienceworld.org/gsa/gsabulletin/article-pdf/95/4/406/32154/i0016-7606-95-4-406.pdf Accessed June 3, 2017

Legg, MR., Borrero, JC., & Synolakis, CE. (2003). Tsunami Hazards From Strike-Slip Earthquakes. American Geophysical Union, Fall Meeting 2003.

LiveScience (2011). History's Biggest Tsunamis. https://www.livescience.com/13176-history-biggest-tsunamis-earthquakes.html Accessed November 5, 2018

Manila Observatory (2005). Philippine Risk Assessment Maps. https://nrojas.files.wordpress.com/2008/09/risk_assessment_materials_mo.pdf Accessed January 3, 2017

Meninano, S. (2018). Landslides Hit Major Samar Highways Due to 'Samuel.' Philippine News Agency. http://www.pna.gov.ph/articles/1054484 Accessed December 1, 2018

MTU (nd). Earthquake Magnitude Scale and Classes. UPSeis, an Educational Site for Bidding Seismologists. http://www.geo.mtu.edu/UPSeis/magnitude.html Accessed June 2, 2017

NDRRMC (2015). National Disaster Risk Reduction Management Council (NDRRMC) Update. SitRep No. 21 re Effects of Tropical Storm "Seniang," January 6, 2015.

Orale, RL. (2015). Flood Risk Assessment in Post Antiao River Control Project in Catbalogan City, Philippines. *Countryside Development Research Journal*, *3*(2). http://ojs.ssu.edu.ph/index.php/CDRJ/article/view/89/77 Accessed June 3, 2017

Orale, RL. (2006). Landslide Susceptibility Assessment in Catbalogan, Samar: Proposed hazard Control Program. The Engineering Pebble (2005-2006), 4.

Parfitt, MK. (2012). Why Buildings Fail: Are We Learning From Our Mistakes? Buildings 2012, 2.

PNA (2018). Government Scales Up Info Drive for Big One. Philippine News Agency. http://www.pna.gov.ph/articles/1026872 March 10, 2018

PreventionWeb (2017). Hazard. https://www.preventionweb.net/risk/hazard Accessed June 3, 2018

Rabonza, ML., Felix RP., Ortiz, IJG., Alejandrino, IKA., Aquino, DT., Eco, RC., & Lagmay AMFA. (2013). Shallow Landslide Susceptibility Mapping for Selected Areas in the Philippines Severely Affected by Super Typhoon Haiyan. Open-File Reports. Project NOAH. https://center.noah.up.edu.ph/shallow-landslide-susceptibility-mapping-for-selected-areas-in-the-philippines-severely-affected-by-super-typhoon-haiyan-3/ Accessed June 10, 2018

Rees, J., Loughlin, S., Tappin, D., England, P., Petley, D., Barclay, J., & John McCloskey. (2012). Anticipation of Geophysical Hazards. Government Office of Science

ReliefWeb (2017). Philippines: NDRRMC Scales Up Preps for Magnitude 7.2 Earthquake. https://reliefweb.int/report/philippines/philippines-ndrrmc-scales-preps-magnitude-72-earthquake June 9, 2018

Sabornido, LR. (2015). Top 10 Strongest Earthquakes to hot the Philippines. https://faq.ph/top-10-strongest-earthquakes-to-hit-the-philippines/ Accessed June 3, 2018

Salasar-Quitalig, R and Orale, RL. (2016). Comprehensive Land Use Planning Capacity of Local Government Units in Samar Philippines. Countryside Development Research Journal, 4(1).

ThinkHazard (nd). Tsunami – Samar. http://thinkhazard.org/en/report/24261-philippines-region-viii-eastern-visayas-samar/TS Accessed March 10, 2018

Thompson Reuters Foundation (2017). Timeline: World's 14 Deadliest Earthquakes of Last Decade. Compiled by Guilbert, K. Ed. Goldsmith, B. https://www.preventionweb.net/risk/hazard Accessed June 3, 2018

Tsunami Mapper (nd). Tsunami Siumulator. http://tsunami-maps.com/index.html Accessed June 3, 2018

UNICEF, 2017. Philippines -Disaster Risk Reduction. United Nations International Children's Emergency Fund https://www.unicef.org/philippines/risk.html#.XBW8r80RWUk Accessed February 4, 2018.

UNESCO ITIC (nd). Tsunami Risk Zones. Am I in danger? UNESCO-Tsunami Risk Zones. International Tsunami Information Center. http://itic.ioc-unesco.org/index.php?option=com_content&view=category&layout=blog&id=1166&Itemid=1166 Accessed June 1, 2018

USGS (nd). What was the Biggest Landslide in the World? United States Geological Survey – Natural Hazards. https://www.usgs.gov/faqs/what-was-biggest-landslide-world?qt-news_science_products=0#qt-news_science_products Accessed November 3, 2018.

USGS b (nd). What is the Relationship Between Fault and Earthquakes? What Happens to a Fault When an Earthquake Occurs? https://www.usgs.gov/faqs/what-relationship-between-faults-and-earthquakes-what-happens-a-fault-when-earthquake-occurs?qt-news_science_products=0#qt-news_science_products Accessed June 2, 2017

USGS c (nd). At What Magnitude Does Damage Begin to Occur in an Earthquake. https://www.usgs.gov/faqs/what-magnitude-does-damage-begin-occur-earthquake?qt-news_science_products=0#qt-news_science_products Accessed June 3, 2017

Vashchilov, Y.Y. & Kalinina, L.Y. J. (2008). Deep-seated Faults and Lineaments, and the Location of Earthquake Epicenters in the Russian Northeast on Land. Journal of Volcanology and Seismology 2(3).

Volcano Live. (nd). Taal Volcano – John Search. http://www.volcanolive.com/taal.html Accessed June 2, 2018.

Wei-Haas, M. (2018). Why Indonesia's Volcano Tsunami' Gave Little to no Warning. National Geographic. https://www.nationalgeographic.com/science/2018/12/indonesia-volcano-tsunami-surprise-explained-anak-krakatau/ Accessed December 23, 2018

William, R., & Rutland, R. (1967). A Tectonic Study of Part of the Philippine Fault Zone. Quarterly Journal of the Geological Society, 124(1-4).

World Atlas (nd). Deadliest landslides in Recorded History. https://www.worldatlas.com/articles/deadliest-landslides-in-recorded-history.html Accessed June 2, 2018