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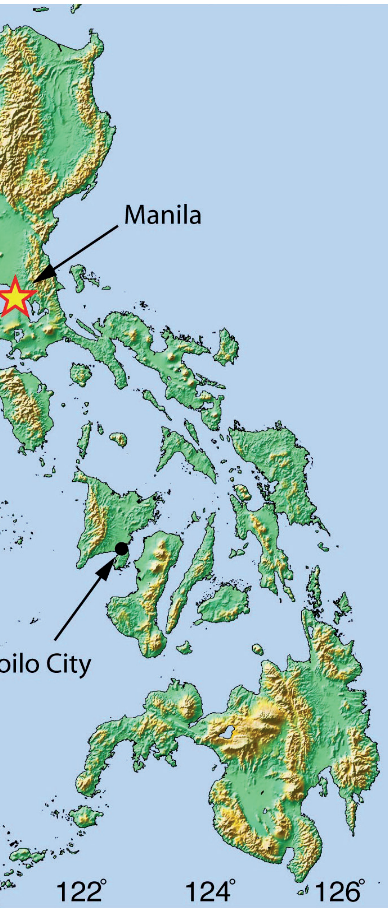

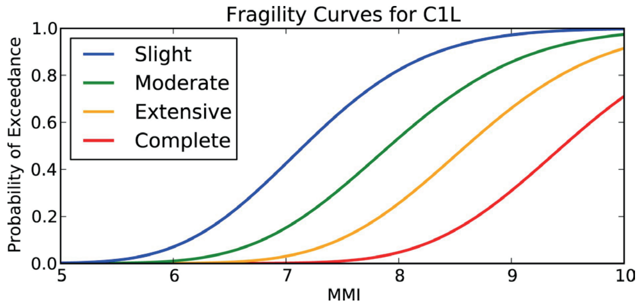

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Strengthening natural hazard risk assessment capacity in the Philippines:

An earthquake impact pilot study for Iloilo City, Western Visayas

Maria Leonila. P. Bautista, Bartolome C. Bautista, Ishmael C. Narag, Angelito G. Lanuza, Janila B. Deocampo, Kathleen L. Papiona, Ramil A. Atando, Renato U. Solidum Jr, Trevor I. Allen, Matthew Jakab, Hyuek Ryu, Mark Edwards, Krishna Nadimpalli, Mark Leonard, and Mark A. Dunford.

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by

PHILIPPINE INSTITUTE OF VOLCANOLOGY AND SEISMOLOGY

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Acknowledgments

The earthquake risk pilot study conducted in Iloilo City represents a large multi-disciplinary initiative over several years in which there were numerous contributions from colleagues, both in the Philippines and in Australia. The contributions were so numerous, it is impossible to identify every individual in this section. Nevertheless, it is appropriate to mention some of the key people and organisations that made this project a success.

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We acknowledge members of the Philippine Institute of Civil Engineers and the Association of the Structural Engineers of the Philippines for their participation in the workshops at Clark and Tagaytay. Many of the participants whom attended these workshops did so on their own time and the authors are very grateful for their contributions. A smaller, but no less committed, group of engineers are thanked for their participation in the final engineering workshop in May 2011, when the preliminary engineering fragility models were presented.

Arising from the outcomes of the engineering workshops, the University of the Philippines Diliman Institute of Civil Engineering (UPD-ICE) agreed to provide their technical expertise to develop a national building typology for the Philippines as well as the earthquake fragility functions that were critical to the success of this project. We particularly acknowledge the contribution of Benito Pacheco, Jaime Hernandez, Ulpiano Ignacio Jr., Eric Tingatinga, Raniel Suiza, William Mata, and Romeo Eliezer. We also acknowledge the critical review of this manuscript by the team at UPD-ICE.

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Executive Summary

The Philippine Institute of Volcanology and Seismology (PHIVOLCS) and Geoscience Australia (GA) have developed a long-term partnership in order to better understand and reduce the risks associated with earthquake hazards in the Philippines. The Project discussed herein was supported by the Australian Agency for International Development (AusAID). Specifically, this partnership was designed to enhance the exposure and damage estimation capabilities of the Rapid Earthquake Damage Assessment System (REDAS), which has been designed and built by PHIVOLCS. Prior to the commencement of this Project, REDAS had the capability to model a range of potential earthquake hazards including ground shaking, tsunami inundation, liquefaction and landslides, as well as providing information about elements at risk (e.g., schools, bridges, etc.) from the aforementioned hazards. The current Project enhances the exposure and vulnerability modules in REDAS and enable it to estimate building damage and fatalities resulting from scenario earthquakes, and to provide critical information to first-responders on the likely impacts of an earthquake in near real-time. To investigate this emergent capability within PHIVOLCS, we have chosen the pilot community of Iloilo City, Western Visayas.

A large component of this project has been the compilation of datasets to develop building exposure models, and subsequently, developing methodologies to make these datasets useful for natural hazard impact assessments. Collection of the exposure data was undertaken at two levels: national and local. The national exposure dataset was gathered from the Philippines National Statistics Office (NSO) and comprises basic information on wall type, roof type, and floor area for residential buildings. The NSO census dataset also comprises crucial information on the population distribution throughout the Philippines. The local exposure dataset gathered from the Iloilo City Assessors Office includes slightly more detailed information on the building type for all buildings (residential, commercial, government, etc.) and appears to provide more accurate information on the floor area. However, the local Iloilo City dataset does not provide any information on the number of people that occupy these buildings. Consequently, in order for the local data to be useful for our purposes, we must merge the population data from the NSO with the local Assessors Office data. Subsequent validation if the Iloilo City exposure database has been conducted through targeted foot-based building inventory surveys and has allowed us to generate statistical models to approximate the distribution of engineering structural systems aggregated at a barangay level using simple wall and roof-type information from the NSO census data.

We present a comparison of the national and local exposure data and discuss how information assembled from the Iloilo City pilot study – and future study areas where detailed exposure assessments are conducted – could be extended to describe the distribution of building stock in other regions of the Philippines using only the first-order national-scale NSO data. We present exposure information gathered for Iloilo City at barangay level in a format that can be readily imported to REDAS for estimating earthquake impact.

In order to meet the project objectives, the PHIVOLCS-GA partnership has engaged with, and encouraged the input of the local Philippine structural engineering community through the Institute of Civil Engineering of the University of the Philippines Diliman (UPD-ICE) with the support of the Philippine Institute of Civil Engineers (PICE) and the Association of the Structural Engineers of the Philippines (ASEP) Through this engagement, we have hosted two successful workshops with the engineering community to focus on the development of a building classification schema and to provide an estimate of multi-hazard (i.e., earthquake and severe wind) vulnerability of the building stock in the Philippines. Through these workshops, the local engineering community agreed to deliver a building classification schema and corresponding macroseismic intensity-based vulnerability models for use in our damage assessment methodologies.

Finally, we present earthquake impact estimates on Iloilo City resulting from two earthquake scenarios. It was determined that a repeat of the 1942 *M* 8.1 Lady Caycay earthquake would result in over 8,500 buildings being in a complete damage state (i.e., those that are collapsed or cannot be repaired), and approximately 1,500 fatalities. A smaller *M* 6.3 earthquake occurring on a blind thrust about 15 km southwest from Iloilo City would result in approximately 2,700 buildings being in a

complete damage state, and approximately 450 fatalities. This new capability in REDAS can be used in two key ways: 1) as a decision support tool for disaster managers during potentially damaging earthquakes, and 2) to target policy makers and local chief executives to use REDAS as a tool for mainstreaming disaster risk reduction into the local development planning process.

Through this partnership, PHIVOLCS are aiming to develop the first national-scale building exposure database for the Philippines for the purposes of estimating natural hazard risk. It will be designed such that it can be readily updated as more detailed information becomes available. PHIVOLCS intends to be custodian of this database, but will allow its use – in the first instance – to other Government of the Philippines agencies. Few countries in the world can boast similar capabilities and the value of this product will likely be demonstrated through its future use in multi-hazard risk assessments and climate change adaptation studies, for example. Much of the work presented herein sets the framework for the Risk Assessment Project for the Greater Metro Manila Area (GMMA), a separate multi-hazard initiative with Government of the Philippines agencies, funded through AusAID. The GMMA Risk Assessment Project was initiated in response to Typhoon Ketsana, which struck the GMMA in 2009.

Glossary and Abbreviations

Barangay:	The smallest administrative division in the Philippines which may occupy an area of a few city blocks, to tens of square kilometres in rural areas. Each barangay has a central hall and elected leader, or barangay captain
DRR:	Disaster risk reduction
GA:	Geoscience Australia
GMICE	Ground-motion to intensity conversion equations
GMPE:	Ground-motion prediction equations
GoP:	Government of the Philippines
LGU:	Local Government Unit
MoA:	Memorandum of Agreement
MMI:	Modified Mercalli Intensity
PAGASA:	Philippine Atmospheric, Geophysical & Astronomical Services Administration
PAGER:	Prompt Assessment of Global Earthquakes for Response
PEIS:	PHIVOLCS Earthquake Intensity Scale
PGA:	Peak ground acceleration
PGV:	Peak ground velocity
PHIVOLCS:	Philippine Institute of Volcanology and Seismology
QuiveR:	Quick inventory and vulnerability evaluation in REDAS
REDAS:	Rapid earthquake damage assessment system
RoU:	Record of Understanding
UPD-ICE:	University of the Philippines Diliman - Institute of Civil Engineering

Introduction

The Philippines is a country beset by a range of natural hazards and experiences frequent, and severe, natural hazard events such as earthquakes, floods, landslides and typhoons. Disaster risk reduction (DRR) is an area of emerging priority within the Philippines. There are many definitions of risk, but in broad terms disaster risk refers to the impact of natural hazards on communities, infrastructure, agricultural lands, economic indicators, etc. For example, maps are frequently produced showing regions of high hazard - regions that are more or less likely to experience earthquakes, floods, typhoons, and so on (e.g., OCHA natural hazard maps). However to really understand the potential impact of a natural disaster on a community, province, or country, it is necessary to move beyond this understanding of hazard to a more comprehensive understanding of the risks posed by natural hazards to its communities. For example, earthquake risk assessments can provide information on which communities are most vulnerable to ground shaking or how many people would be left homeless by an earthquake of any given magnitude.

The key goal of this Project, named the Quick Unified Inventory of Vulnerability and Exposure for REDAS (QuiveR), is to develop a long-term partnership between the Philippine Institute of Volcanology and Seismology (PHIVOLCS) and Geoscience Australia (GA) in order to better understand and reduce the risks associated with earthquake hazards in the Philippines. The Project discussed herein is supported by the Australian Agency for International Development (AusAID). Specifically, this partnership is designed to enhance the damage estimation capabilities of the Rapid Earthquake Damage Assessment System (REDAS), which has been designed and built by PHIVOLCS. REDAS currently models a range of potential earthquake hazards including ground shaking, tsunami inundation, liquefaction and landslides.

The REDAS tool was initially designed as a decision support tool for emergency responders located outside an earthquake disaster zone to provide an indication of the areas most likely to be affected following an event. This use is particularly important, since lines of communication and transportation networks can often be cut to the most-affected communities for several days (and possibly weeks) following a major earthquake. REDAS is now being routinely used by municipal planners for developing hazard-based land use plans and for long term disaster preparedness and mitigation.

The study presented herein, is intended to enhance the damage estimation modules in REDAS so that it can compute impact to a suite of building types for an expected input ground-motion, as either a plausible earthquake scenario, or in response to future earthquakes. An important underpinning component required to compute earthquake impact is a reliable building inventory. Through this Project, PHIVOLCS have developed a user-friendly REDAS module and the necessary training to allow Local Government Units (LGU's) to provide the comprehensive building inventories necessary for detailed risk assessments. In summary, this Project has:

1. Undertaken a process of reviewing and validating existing models and methodologies;
2. Modified existing models, in particular exposure and building vulnerability models;
3. Selected a community for a pilot earthquake impact study;
4. Developed a detailed exposure database for the pilot community, which can be translated nationally;
5. Engaged with experts from the Philippine structural engineering community to develop a national building typology and earthquake vulnerability functions for the different structural types;
6. Implemented final models into REDAS for initial use in a pilot community with the intention of being applied by PHIVOLCS for other communities in the future;
7. Undertaken the pilot study in partnership with the selected LGU's; and
8. Undertaken a community awareness campaign focussing on LGU's in the Iloilo City area.

In order to conduct such a study, a pilot community had to be chosen. The pilot community was selected using the following criteria:

- The community has high earthquake hazard
- The region has high earthquake risk (i.e., moderate-to-high population exposure with vulnerable structures)
- The LGU should be willing to participate in the Pilot study and assist in gathering the building inventory data
- The Pilot region should have a variety of structure types of different ages
- Region is politically stable and peaceful
- Availability of high-resolution aerial photography

Following a systematic approach to ranking several regions, the community of Iloilo City, Western Visayas, was chosen to undertake the pilot earthquake impact study.

The present report provides a large volume of electronic material. Appendix I outlines the directory structure of the attached electronic material.

THE NATURAL HAZARD IMPACT FRAMEWORK

Any natural hazard impact assessment requires an understanding of the resilience of the human population, or building portfolio, exposed to a given *hazard* that will have a given severity (Fig. 1). For earthquakes, the impact is typically measured by the vulnerability of buildings to ground-shaking intensity. The building *vulnerability* can then be translated into human casualties owing to the collapse, or partial collapse of structures. In the natural hazard risk framework, both human population and the building stock are commonly referred to as *exposure*.

In natural hazard risk assessments, the hazard is typically defined as an event that has a specified impact footprint. In the case of hazard for a scenario earthquake, this footprint would represent the spatial area that experiences a given severity of ground-shaking, determined by the earthquake magnitude and the distance between the earthquake source and the location of interest.

The *impact* or *loss* resulting from a hazard event is defined as the convolution of the hazard, exposure and vulnerability (Fig. 1).

Figure 1: *The natural hazard risk (or impact) framework, showing the three key elements necessary to derive the impact of a natural hazard event; hazard, exposure and vulnerability. While it is often impossible to reduce the hazard from any given event (i.e., earthquake ground-shaking), this simple framework demonstrates that by reducing the elements exposed to the hazard, and reducing the vulnerability of the exposure can result in a reduction of the risk (or impact) to communities.*

THE RAPID EARTHQUAKE DAMAGE ASSESSMENT SYSTEM (REDAS)

The Rapid Earthquake Damage Assessment System (REDAS) has been designed and built by PHIVOLCS to model a range of potential earthquake-related hazards including ground shaking, tsunami inundation, liquefaction and earthquake-triggered landslides, as well as providing information about elements at risk (e.g., schools, bridges, etc.) from the aforementioned hazards. The software aims to provide quick and near real-time simulated earthquake hazard map information as a decision support tool for disaster managers during potentially damaging earthquakes. The software also targets policy makers and to use REDAS as a tool for mainstreaming disaster risk reduction into the local development planning process (Fig. 2).

Inputs required to model hazards are basic earthquake source and finite-fault parameters. In addition, the software also has the capability of superimposing output from other hazard assessments (e.g., flood, landslide and lahar susceptibility, hydrometeorological maps) to visualise community resilience for land use planning and DRR activities. Its potential to be multi-hazard risk assessment tool is being enhanced by the inclusion of building inventory and vulnerability modules and enhancing its modelling capability to address other natural hazards.

As part of its community outreach and education program, PHIVOLCS hosts regular training sessions to Local Government Units (LGUs) across the Philippines. Participants in these training sessions are instructed how to build their own database of elements at risk using GPS and aerial imagery. The software is being continuously improved through feedback and input from users to further customise it to their needs (Bautista *et al*., 2011). To date, a total of 24 Philippine provinces, 175 towns and six government institutions have been trained and PHIVOLCS-DOST is determined to disseminate widely the use of this software to local government units (Bautista *et al*., 2011).

***Figure 2:** REDAS ground shaking hazard module page*

The main mapping tool used is the Generic Mapping Tool (GMT) (Wessel and Smith, 1991). The GMT software provides an open source collection of approximately 60 tools for manipulating geographic and Cartesian data sets and produces Encapsulated PostScript File (EPS) illustrations ranging from simple x-y plots via contour maps to artificially illuminated surfaces and 3-D perspective views. Visual basic is used both to wrap the GMT commands, and because of its convenient graphic user interface, database searching and sorting capabilities. To view the maps, REDAS uses freeware image processing and viewing packages, Ghostscipt and Imagemagik. Other freeware used are Programmer's File Editor (PFE) as text editor to input data and bitmap digitizer for map digitization.

The motivation for developing a freeware tool such as REDAS, which functions like a Geographic Information System (GIS), stems from the need to assist LGU planners have a tool that they can easily manipulate and has functions to meet their needs for land use planning and development of disaster mitigation strategies. Most LGUs do not have a GIS capability because most systems use proprietary software, which are prohibitively expensive to purchase and maintain. In addition, some LGUs are deterred by the steep learning curve of GIS.

Hence, PHIVOLCS initiated the development of the REDAS platform to assist LGUs learn concepts of hazard assessment and disaster risk reduction. The overarching goal of REDAS is to encourage these hazard and risk concepts to be mainstreamed into local development planning process to mitigate the impacts of future hazard events.

The objective of this Project is to enhance the functionality of REDAS to provide the ability to:

1. incorporate more detailed building exposure datasets;
2. apply building-specific vulnerability models to estimate impact to a portfolio of buildings;
3. evaluate damage at a point based on ground motion, exposure and selected damage model; and
4. aggregate and summarise impact estimates to barangay or city level.

STAKEHOLDER WORKSHOPS

An important component of this Project was the engagement of the local Philippine structural engineering community. In order to meet the project objectives, the PHIVOLCS-GA partnership actively engaged with, and encouraged the input of the local Philippine structural engineering community with the support of the Association of the Structural Engineers of the Philippines (ASEP). Through this engagement, two successful workshops were hosted to focus on the development of a building classification schema and to provide an estimate of multi-hazard (i.e., earthquake and severe wind) vulnerability for the building stock in the Philippines (Fig. 3).

The first workshop (WS1), the Philippine Earthquake Exposure and Vulnerability Workshop, was held at Clark Air Force Base from 14-15 November 2009 (Appendices II and III). This workshop was held to discuss the need for developing exposure and impact models to support disaster risk reduction in the Philippines. The objective of WS1 was to engage the local Filipino structural engineering community on disaster risk reduction issues and to develop a standardised classification schema for different building types. The workshop discussion was targeted to advance the following PHIVOLCS-GA project objectives to:

- develop a uniform classification schema for the Philippines building stock;
- develop an approach for evaluating vulnerability models for key building types;
- anticipate the applicability of the classification schema to other major hazards such as floods, severe wind, and landslides

Through this workshop, working relationships between PHIVOLCS, GA and the engineering were enhanced. Subsequently, the engineering group agreed that they would develop a National Building Classification Schema for the Philippines.

The second workshop (WS2), held in Tagaytay 12-13 March 2010 (Appendix IV), was scheduled to expand on principles introduced in WS1. This workshop also focused more heavily on flood and wind risk methods. Given the extended scope, this workshop was co-hosted by the Philippine agency responsible for meteorological and flood monitoring, the Philippine Atmospheric, Geophysical & Astronomical Services Administration (PAGASA). The primary outcome of WS2 was to further reinforce to local governments, the engineering community and to other partners the importance of exposure as a critical input to natural hazard risk assessments.

Figure 3: *Participants from the Philippine Earthquake Exposure and Vulnerability Workshop (WS1), held at Clark Air Force Base from 14-15 November 2009. See Appendix II for a full list of participants.*

Subsequent to the stakeholder workshops, PHIVOLCS signed a Memorandum of Agreement (MoA) with the University of the Philippines Diliman Institute of Civil Engineering (UPD-ICE) to formalise the delivery of the building classification schema to be used as a reference for the QuiveR project (Appendix I). The MoA also specified the engagement of UPD-ICE to develop a suite of vulnerability curves appropriate for the building stock in the Philippines. These vulnerability curves relate the probability of being in a given damage state for a given level of ground-shaking for a given structure type. The overarching goal is to incorporate these models into the REDAS impact assessment module.

The final workshop was held on 17 May 2011 at the PHIVOLCS headquarters in Quezon City. The purpose of the workshop was for the consortium of UPD-ICE engineers to summarise the newly developed building typology and present preliminary vulnerability and fragility functions for typical buildings in the Philippines. The preliminary functions were presented to a focus group from the Association of the Structural Engineers of the Philippines and were generally well received by this group of local experts. The primary outcome from this workshop was for the UPD-ICE group to verify the results from their study and finalise the fragility functions. The work undertaken by UPD-ICE is documented further herein.

ENGAGEMENT AND PARTICIPATION OF THE LGU

A key motivation for the choice of Iloilo City as the location of the pilot study was the willingness of the LGU to participate and their appreciation of DRR principles and its application. The LGU suffered significant impacts following Typhoon Frank which struck the city in 2008, inundating thousands of dwellings and resulting in up to 500 fatalities (Carrcellar *et al.*, 2011). Subsequently, the city is cognisant of the role DRR can play to mitigate impacts of natural hazard events.

Because of the LGU's high level of interest, they played a major role in helping capture building data during the QuiveR project field surveys in Iloilo City. More than twenty participants from the LGU worked with the QuiveR team to gather the field data that was used to validate and calibrate first-order exposure datasets based on census and taxation data.

Earthquake Hazard

WHAT IS EARTHQUAKE HAZARD?

Earthquake hazard is often referred to as the probability of a given level of earthquake ground-shaking being exceeded within a given time period. For example, most national (Petersen *et al.*, 2008) or global (Giardini *et al.*, 1999) earthquake hazard assessments provide maps of peak ground accelerations (PGA) that are likely to be exceeded in a 475 year return period (or 10% chance of exceedance in 50 years), for example. The term “hazard” is often referred to in a probabilistic sense when it is necessary to assess the likely maximum ground-motions that a site or structure might be subjected to in its lifetime. Using this information, land use plans can be developed such that high-hazard regions are identified and building codes are applied accordingly.

It is also useful to think of hazard as a deterministic or scenario earthquake. That is, the likely ground-motion to be experienced by a “characteristic” earthquake along a known fault. This approach is also useful as it can provide a credible worst-case ground-shaking scenario at a location near a known fault.

The latter approach is that adopted by PHIVOLCS’ REDAS software as a means to provide community awareness regarding potential earthquake hazards to a given region. Consequently, the earthquake impacts presented in this study will be based upon scenario earthquakes. The candidate scenarios are described below.

HISTORICAL EARTHQUAKES IN WESTERN VISAYAS REGION

The Philippine archipelago represents a complex system of microplates that are being compressed between two convergent plate margins that bound the nation: the Philippine Sea to the east and Eurasian plates to the west. Because of its tectonic setting, the Philippines experiences frequent damaging earthquakes. The island of Panay, Western Visayas, is located partly in a collision zone and the northern extent of the Negros Trench to its south. The area is seismically active and is host to many damaging historical earthquakes such as in 1621, 1787, 1887 and the 1948 earthquake (Fig. 4).

The Magnitude M_S 8.2 Lady Caycay Earthquake and Tsunami of January 25, 1948 in west-central Philippines is the second biggest earthquake in the 500-year Philippines earthquake history (Bautista and Oike, 2000; Bautista *et al.*, 2011). According to archives, 55 Spanish-era churches in Panay Island were damaged, 17 of which totally collapsed. Recent field investigation showed that the earthquake caused the collapse of the churches of Igbaras, San Miguel, Oton and Maasin and the bell towers of San Joaquin (Fig. 5), Alimodian, Tigbaua, Duenas, Dumangas, Guimbal, Lambunao and the Iloilo City districts churches in Jaro, Molo and Arevalo (Jaro archives, 1948; Maza, 1987 citing Fr. Juan Fernandez). The earthquake also severely damaged the church and convent of the town of Santa Barbara. The temporary belfry also collapsed. Less severe damage was incurred by the UNESCO-heritage church of Miagao (Jaro archives, 1948). Damage estimate for the Tigbauan Church was P50,000 at that time (Manila Times, January 27, 1948). A tsunami was reported from the shores of San Joaquin to Oton, killing two persons.

At the time of the Lady Caycay Earthquake, World War II just ended and most communities were just starting to recover from the disastrous effects of the war. Reports were quite sparse and damages due to war and earthquake were difficult to differentiate. Using existing reports, there appears to be an incompatibility between intensity distribution and epicentre location and magnitude. Recently, new archival documents have been unearthed that can be used to re-evaluate intensities and consequently re-estimate magnitude.

A review of original documents to examine the extent of damaging intensities as a means to constrain the epicentral location raised more questions that provided answers (Bautista *et al.*, 2011). The earthquake's less serious effects in the epicentral towns of Anini-y and Dao bring the earthquake’s documented location into question. It should be acknowledged that earthquake locations at the time of the 1948 earthquake were notoriously poor owing to the sparse global networks. The actual epicentre of this earthquake could be up to 100 km in any direction from the documented location.

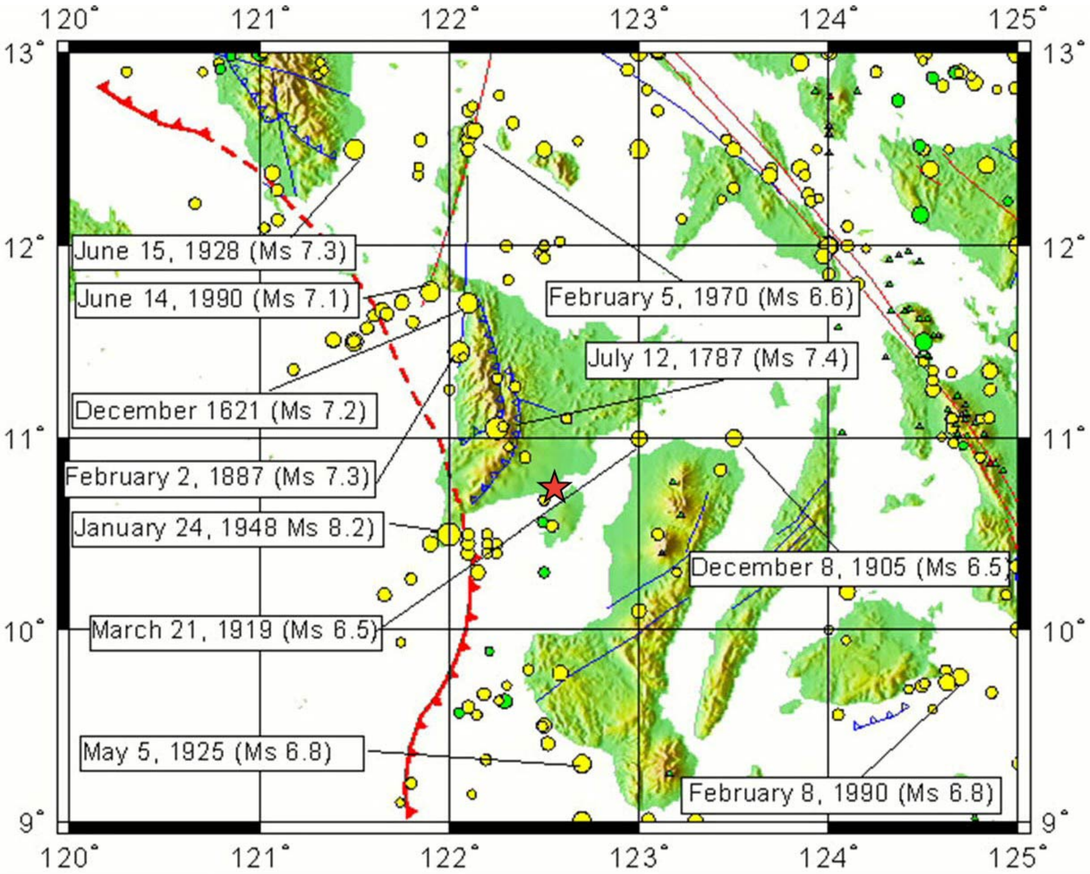

Figure 4: *Historical earthquakes to have been documented in the Western Visayas region. Approximate geometry of known active faults are indicated as either thick red lines. Note the documented location of the 1948 Ms 8.2 Lady Caycay earthquake on the southern tip of Panay. The red star indicates the location of Iloilo City.*

Figure 5: *The photograph on the left is the 16th-century San Joaquin Church showing affects of the 1948 Lady Caycay Earthquake where the belfry collapsed. The photo on the right is the current-day San Joaquin Church after the belfry has been repaired.*

Using the REDAS software, the estimated intensities were modelled. Figure 6 shows the estimated distribution of intensity using original earthquake parameters. Comparing these with the observed intensities, we observe less severe intensities than were observed in the inland towns of Panay Island, especially Iloilo province. The epicentral location of Gutenberg and Richter for the 1948 event appears to be inconsistent with the intensity actual distribution. In the epicentral area between Anini-y (Antique) and San Joaquin (Iloilo), damages were not as intense as compared to the town of Igbaras which is located in the inner part of island in the mountain region. The so-called Antique Range, is a fault-bounded range which could potentially be the source of the 1948 earthquake. Placing the earthquake source along this fault zone could help explain the observed intensity distribution. The sense of motion of these faults is difficult to ascertain as the area is largely inaccessible and outcrops are poor. There is also lack of focal mechanism solutions in the epicentral area in the global catalogue.

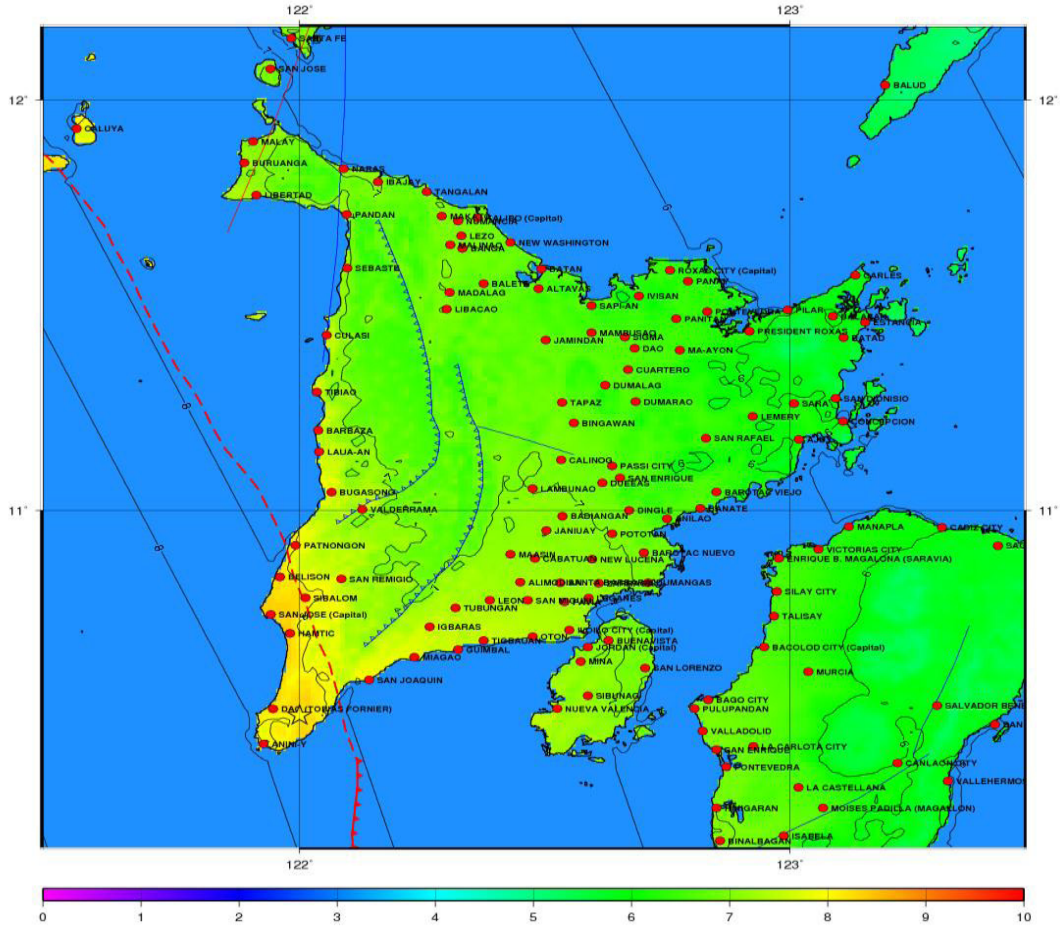

Figure 6: *Modelling of the ground shaking from the 1948 January 25, 1948 Lady Caycay Earthquake. Yellow star in the southwest area of Panay Island (the biggest island in the figure) shows the original location of the epicentre as determined by Gutenberg and Richter (1954). Intensities, in PHIVOLCS Earthquake Intensity Scale of I to X, are colour coded and delineated as isoseismal lines. Modelling this event using the original earthquake parameters would fail to explain the intensity distribution.*

Meanwhile, by relocating the epicentre in the meisoseismal area, could a submarine landslide be able to explain the occurrence of a small tsunami? An offshore epicentre to account for the tsunami should have caused structural damages in the island province of Guimaras, but none have so far been encountered. A corollary question is if indeed the epicentre was on land, is there still evidence of ground rupture that could be validated now? Finally, how much impact did local site conditions coupled with level of construction have on level of damages? The absence of a high-quality epicentre for the earthquake as well as no information of recent fault rupture cannot rule out the original Gutenberg and Richter (1954).

GROUND-MOTION ESTIMATION METHODS

The REDAS software is able to compute earthquake hazard using different metrics of ground-shaking: peak ground acceleration (PGA), peak ground velocity (PGV), response spectral acceleration (RSA) at different shaking periods and macroseismic intensity (both Modified Mercalli Intensity and PHIVOLCS Earthquake Intensity Scale). PGA, PGV and RSA ground-motion values are commonly estimated using ground-motion prediction equations (GMPEs).

Equations exist that can predict macroseismic intensities directly (e.g., Atkinson and Wald, 2007; Allen *et al.*, in press). However, in earthquake hazard applications, macroseismic intensity is usually computed by first using GMPEs to compute PGA or PGV and then use ground-motion to intensity conversion equations (GMICEs) to estimate macroseismic intensity (e.g., Wald *et al.*, 1999; Atkinson and Kaka, 2007). The advantage of the latter approach is that site effects can implicitly be considered within the GMPE module, whereas direct intensity prediction techniques often lack site amplification factors.

In the existing Project we want to compute macroseismic intensities so that they can be used to compute damage probabilities for particular building types common in the Philippines. One of the primary drivers for using macroseismic ground-shaking metrics in estimating structural vulnerability is that earthquake damage functions derived from physical properties of structures and experimental data – like those from HAZUS methodologies (National Institute of Building Sciences and Federal Emergency Management Agency [NIBS-FEMA], 2011) – are not uniformly available for all global structure types, particularly in the developing world. Even if common structure types do exist between different geographic regions, it does not necessarily follow that these structures will be designed and constructed to the same level of rigor. Consequently, comparatively abundant macroseismic intensity observations from historical earthquakes are often the only means we have to relate ground-motion to damage and to subsequently evaluate the vulnerability of different structure types in many regions of the world (e.g., Jaiswal and Wald, 2008; Porter *et al.*, 2008; Sengara *et al.*, 2010). Furthermore, earthquake ground-shaking intensity is conceptually simpler for non-expert users to understand; such as those users of REDAS at local municipal levels in the Philippines.

CONSIDERATION OF SITE EFFECTS

Knowledge of seismic site-conditions is an important factor in estimating ground motion amplification potential at a given location. In site-specific surveys for large engineering projects, detailed geotechnical studies can be undertaken to model the likely response of the building foundations to strong ground-shaking. However, for regional hazard studies, detailed knowledge of the subsurface foundations is rarely available. Consequently, many hazard studies now rely on proxy site-conditions information determined from maps based on geology and other geomorphic and geotechnical indicators (Wills *et al.*, 2000; Matsuoka *et al.*, 2005; Wald and Allen, 2007).

Commonly, these site-condition maps have been based on surficial geology maps, which generally assign a constant site response term to a given geological unit. This type of site class mapping often leads to sharp transitions in amplification factors between geological units.

Wald and Allen (2007) presented a method for mapping uniform global seismic site conditions, or the average shear velocity to 30 m depth (V_{S30}), from the Shuttle Radar Topography Mission (SRTM) 30 arc-second (approximately 1 km resolution at the equator) digital elevation model (Farr and Kobrick, 2000). The basic premise of Wald and Allen's (2007) technique is that topographic gradient can be diagnostic of seismic site-conditions, or V_{S30}, because more competent (high-velocity) materials are more likely to maintain a steep slope, whereas deep (low-velocity) basin sediments are deposited primarily in environments with low gradients. Unlike geology-based maps, the topographic approach allows for variable V_{S30} across a geologic unit by characterizing the presumed change particle size with slope (the transition between alluvial fans and plains, for example). Though this approach is no replacement for detailed site-condition assessments, topographic gradient has been found to be a reliable predictor of V_{S30} in the absence of geologically and geotechnically-based site-condition maps (Allen and Wald, 2007; Wills and Gutierrez, 2008; Silva *et al.*, 2011; Thompson *et al.*, 2011).

PHIVOLCS previously used a digitized map of surficial geology to infer site amplification factors in REDAS following the recommendations of Fukushima and Tanaka (1990). Through this project PHIVOLCS have first trialled, and then adopted a topographically-based site condition map based on the approach of Wald and Allen (2007) as an optional method for computing ground-motion amplification (Fig. 7).

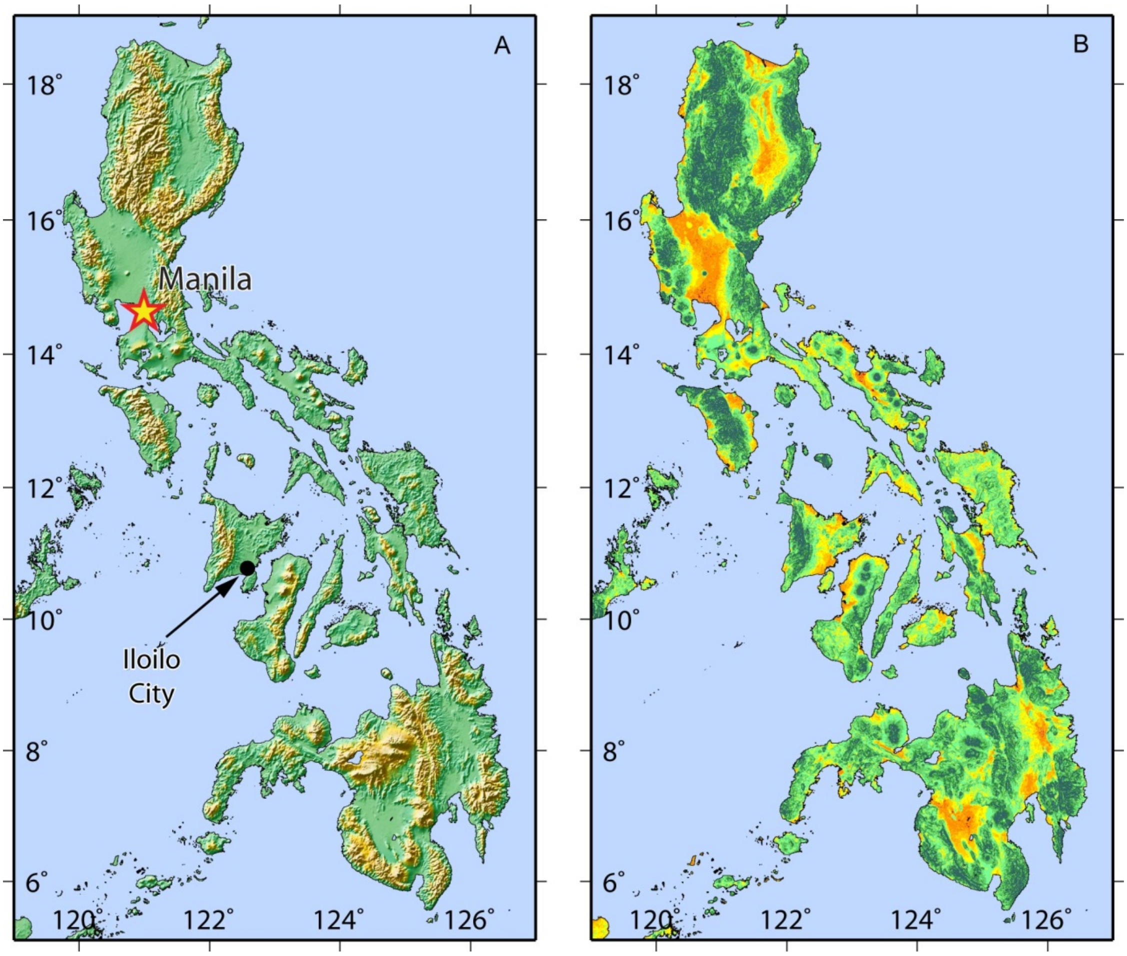

Figure 7: *(a) Topographic map of the Philippines. (b) Site-condition map derived from topographic gradient.*

REVIEW OF GROUND-SHAKING MODELS

Prior to undertaking earthquake impact assessments, it is first important to understand the ground-shaking hazard that is appropriate for the Philippines. Because there are relatively few strong-motion observations from Philippine earthquakes with which to develop a Philippine-specific GMPE, we must apply GMPEs from different geographic regions with abundant strong-motion records (e.g., Japan or California). Preferably, these regions will have similar characteristics in terms of earthquake sources and ground-motion attenuation (often assumed based on similarities in geology). Recently, some researchers have suggested that regional differences in attenuation observed between regions may be more a function of limitations in datasets used to develop the GMPEs, particularly at near source distances (e.g., Douglas, 2007; Allen and Wald, 2009). Since there is presently no GMPE developed specifically for the Philippines, PHIVOLCS often employ the GMPE of Fukushima and Tanaka (1990) – developed for Japan – in the REDAS software. To estimate macroseismic intensity, the REDAS software employs the Gutenberg and Richter (1942) ground-motion to intensity conversion equation (GMICE). Below, we test the utility of the Fukushima and Tanaka (1990) GMPE as well as the Gutenberg and Richter (1942) GMICE for use in the Philippines.

Review of PGA prediction models (GMPEs)

Since there are very few Philippine ground-motion records that can be used to evaluate the performance of GMPEs, we employ a global dataset of PGA data compiled through the US Geological Survey's Prompt Assessment of Global Earthquakes for Response (PAGER) program (Allen and Wald, 2009) to evaluate the Fukushima and Tanaka (1990) GMPE (hereafter referred to as FT90). For each PGA record in this global dataset, we calculate PGA using FT90 at magnitude and distance pairs equivalent to that record. We also apply site correction factors as prescribed by the GMPE using topographically-based estimates of seismic site conditions (V_{S30}). Figure 8 illustrates the median PGA residuals for shallow crustal earthquakes, windowed by magnitude range and binned at 10-km increments. Figure 9 shows the same information, but employing only data from subduction zone earthquakes. In general, we find that the FT90 GMPE generally performs well when tested against global earthquake data for both shallow crustal and subduction zone earthquakes. Whilst this does not demonstrate the GMPE is directly applicable to the Philippines, it does show that the FT90 relationship is generally appropriate for average global conditions.

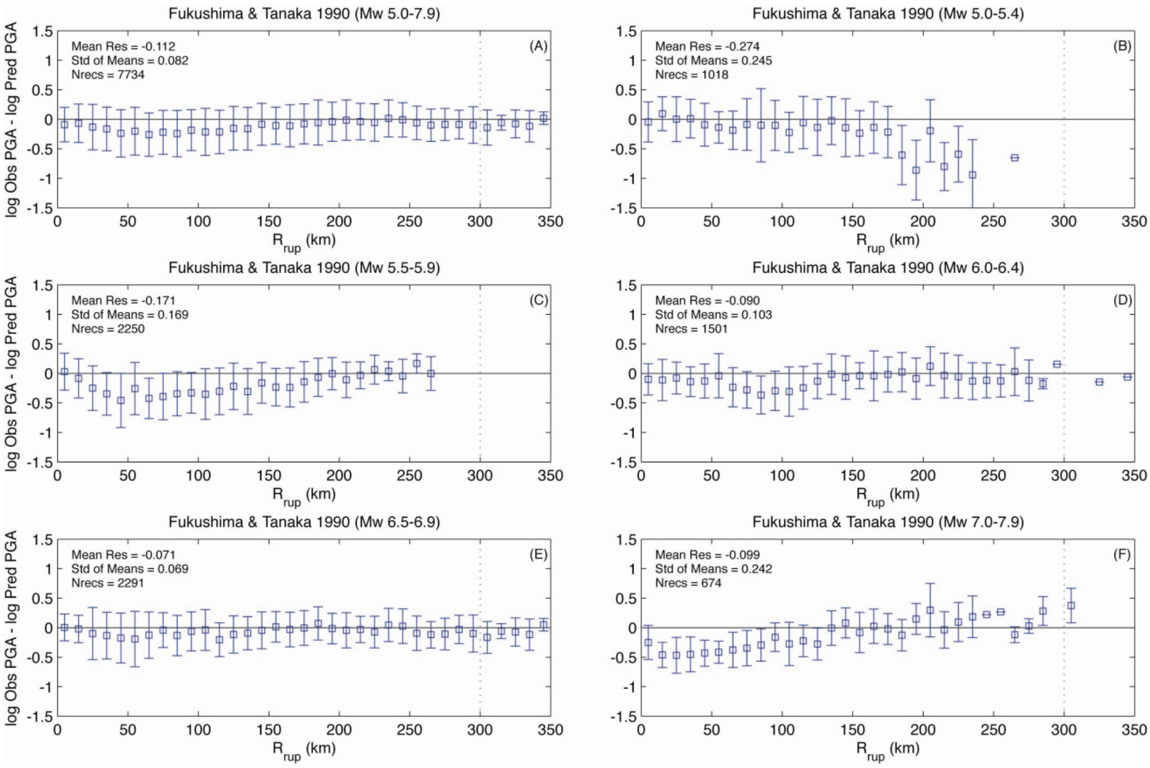

Figure 8: *PGA residuals for the Fukushima and Tanaka (1990) GMPE for shallow active crust against the global dataset from Allen and Wald (2009). Each subplot indicates the discrete magnitude window, and residuals are binned in 10-kilometre windows and the median residual is plotted. The standard deviation of the residuals is indicated. Vertical dashed lines indicate the maximum distance of usage as indicated in Fukushima and Tanaka (1990).*

Review of PGA to Intensity Models (GMICEs)

Equations that relate peak ground motions to macroseismic intensity observations are an important component in U.S. Geological Survey's ShakeMap and PAGER applications (Wald *et al.*, 1999). In generating a REDAS ground-shaking intensity map, peak ground accelerations (PGAs) are first calculated over the spatial extent of the map using a GMPE. Once the peak ground motions are estimated, they are then converted to macroseismic intensity using ground-motion-to-intensity conversion equations (GMICEs) to produce a map of shaking intensity.

We examine the use of five candidate equations for converting peak ground motions to macroseismic intensity: Gutenberg and Richter (1942), Atkinson and Sonley (2000), Atkinson and Kaka (2007), Tselentis and Danciu (2008), and Faenza and Michelini (2011). Each of these equations relate macroseismic intensity to both PGA and PGV, and the authors generally recommend the use of PGV as the most reliable predictor of intensity, particularly at higher ground-shaking levels. These GMICEs are tested for both shallow active crust and subduction-zone regions.

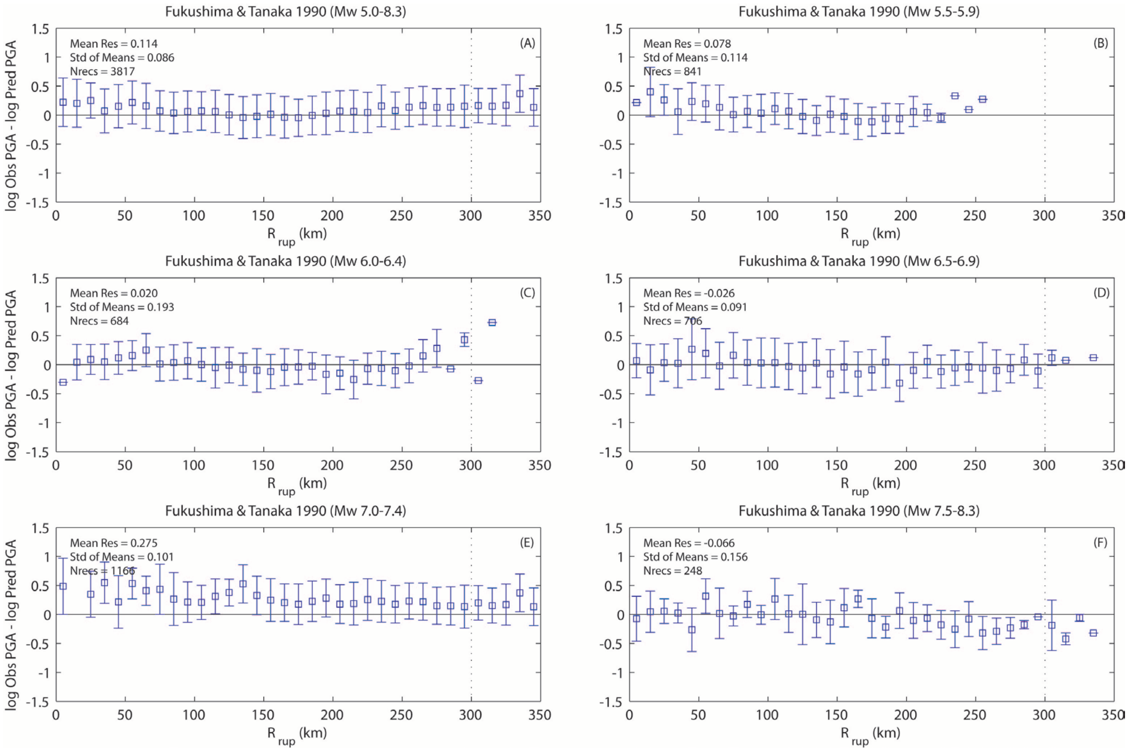

Figure 9: *PGA residuals for the Fukushima and Tanaka (1990) GMPE for subduction zone data against the global dataset from Allen and Wald (2009). Each subplot indicates the discrete magnitude window, and residuals are binned in 10-kilometre windows and the median residual is plotted. The standard deviation of the residuals is indicated. Vertical dashed lines indicate the maximum distance of usage as indicated in Fukushima and Tanaka (1990).*

In order to test the applicability of each of these intensity conversion equations for active shallow crustal regions, we compile a dataset of Philippine macroseismic data from historical earthquakes (see Appendix V). Earthquake magnitude and location information was taken from PAGER-CAT (Allen *et al.*, 2009). Source-to-site distances used to predict ground-motion intensity were calculated based on the earthquake hypocentres. Where finite-faults were defined in the Atlas of ShakeMaps (Allen *et al.*, 2009), these were used to compute the closest distance to rupture as the preferred distance metric.

The intensity observations compiled for this study were a mix of Rossi–Forel (RF), Modified Mercalli Intensity (MMI), and PHIVOLCS Earthquake Intensity Scale (PEIS). Whilst there are some differences across these intensity scales, Musson *et al.* (2009) indicated that macroseismic intensity assignments across a range of scales were remarkably consistent, except perhaps at extreme shaking levels. Furthermore, Musson *et al.* (2009) conclude that differences in the practice of assigning intensities between seismologists and engineers often outweighs the descriptive differences between the scales themselves. Consequently, we assume equivalency between macroseismic scales, and herein we make no attempt to justify this assumption. For more information on the comparison of macroseismic intensity scales, see Trifunac and Brady (1975) and Musson *et al.* (2009).

To test the candidate GMICEs, we first estimate PGA using the FT90 GMPE for the magnitude and distance pairs equivalent to those of the macroseismic intensity observations. For each intensity observation in the Philippine intensity dataset for active crustal regions, we obtain a topographically-based estimate of seismic site conditions (V_{S30}) from the approach of Wald and Allen (2007). We then apply seismic site corrections as prescribed by FT90 based on these V_{S30} estimates.

Once the site-affected PGA is determined, we use these values to estimate shaking intensity at each observation point using the candidate GMICEs. The residual of the observed and predicted intensities are subsequently calculated for Philippine-specific macroseismic intensity data. The median residuals, binned in 10-km windows for shallow crustal earthquakes are plotted in Figure 10. Since we use FT90 for both active crust and subduction zone events, residuals for the complete intensity dataset are indicated in Figure 11. PHIVOLCS' preferred GMICE is Gutenberg and Richter (1942). In our comparisons, it appears that Gutenberg and Richter does perform quite well in the intermediate-distance range (approximately 100-200 km). However, this equation appears to overestimate intensity at near-source distances (less than 100 km). This phenomenon, particularly for large-magnitude earthquakes was recognised by the authors. Of the other candidate GMICEs, two other models appear to provide small residuals using intensity data from Philippine earthquakes across the distance range of interest: Atkinson and Kaka (2007) and Tselentis and Danciu (2008). The other candidate GMICEs appear to indicate a bias in intensity residuals with distance when they are combined with the FT90 GMPE.

Since PHIVOLCS generally observe the Gutenberg and Richter (1942) equation to work well for routine ground-shaking estimation in response to local earthquakes, it was decided to preserve it as the preferred GMICE for the earthquake scenarios presented herein. However, given the differences in intensity residuals between the candidate GMICEs, other models will be considered for implementation in REDAS in the future.

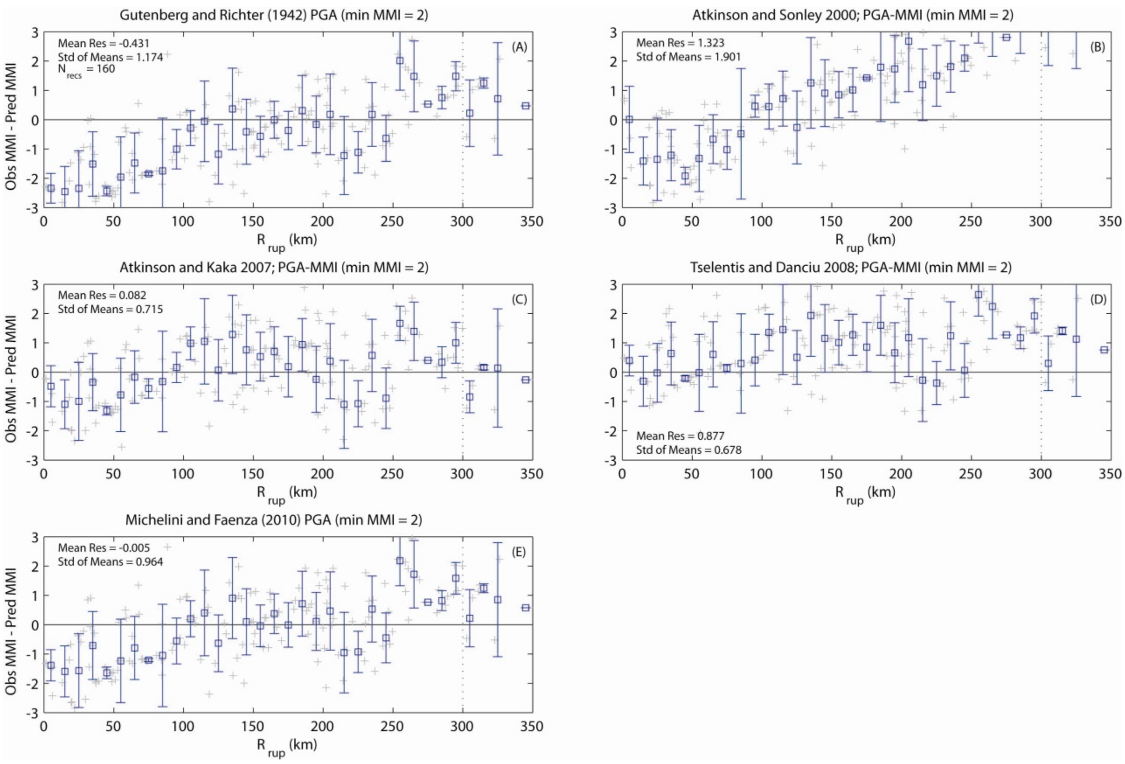

Figure 10: *Residuals for the ground-motion-to-intensity conversion equations (GMICE) for active crustal intensity data from Philippine earthquakes. PGA is first calculated using the Fukushima and Tanaka (1990) GMPE at magnitude and distance pairs consistent with the macroseismic intensity observations. Earthquake mechanism and topographically-based V_{S30} values at each intensity observation point is also considered in evaluating the peak ground-motion. Predicted instrumental ground motions, calculated using the aforementioned GMPE, are converted to intensity using the candidate GMICE and the intensity residual calculated. Residuals are binned in 10-kilometre windows and the median residual is plotted and the standard deviation of the residuals is indicated. Vertical dotted lines indicate the maximum distance of usage as recommend for the Fukushima and Tanaka (1990) GMPE. Grey crosses indicate individual residuals.*

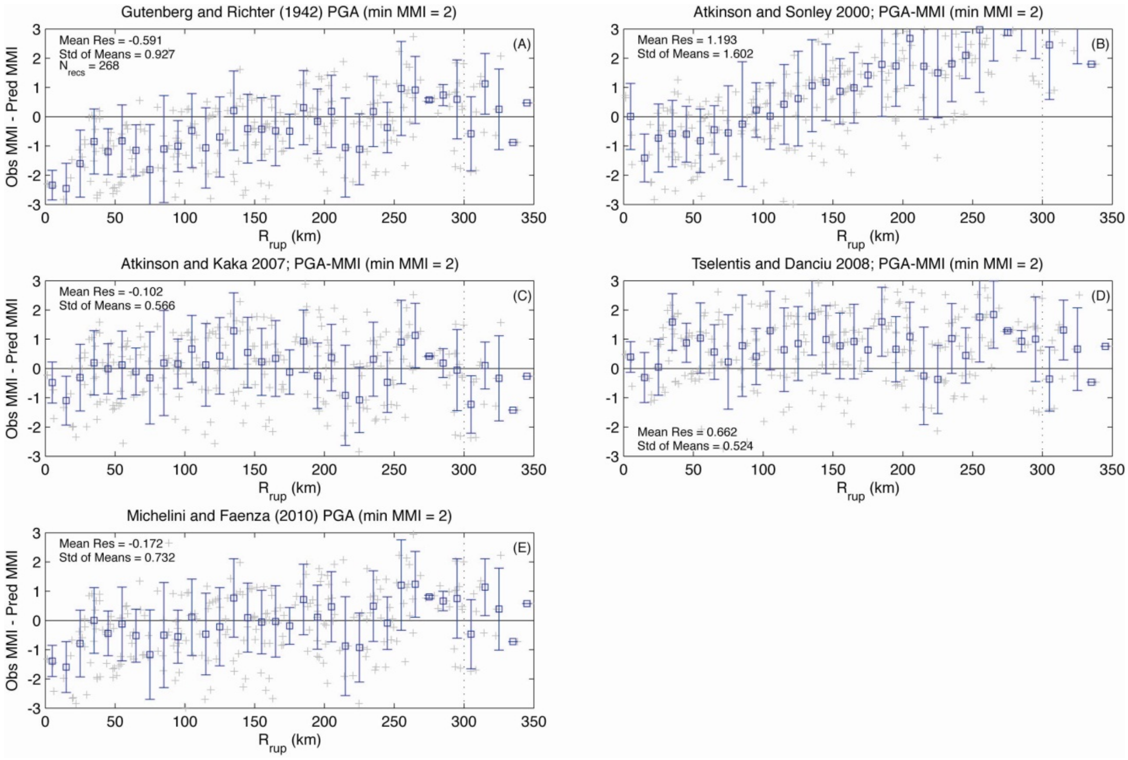

Figure 11: *Residuals for the ground-motion-to-intensity conversion equations (GMICE) for combined active crustal and subduction zone intensity data from Philippine earthquakes. PGA is first calculated using the Fukushima and Tanaka (1990) GMPE at magnitude and distance pairs consistent with the macroseismic intensity observations. See Figure 10 caption for a detailed explanation of the current figure.*

HAZARD MODELS USED IN EARTHQUAKE IMPACT SCENARIOS

In undertaking impact assessments for Iloilo City, it was decided to test two different earthquake scenarios. One impact scenario is a reassessment of the 1948 M_W 8.1 Lady Caycay earthquake. Another scenario is of a smaller, potentially more likely, M_W 6.3 earthquake located near Iloilo City. The latter scenario was deliberately chosen as a direct comparison of the 21 February 2011 earthquake beneath Christchurch in New Zealand. Below we describe the earthquake sources and provide the estimates of shaking intensity.

Scenario 1: M_W 6.3 Earthquake 15 km Southwest of Iloilo City

While a repeat of the 1942 M_W 8.1 Lady Caycay would likely have devastating impacts on the City of Iloilo, there may be other earthquakes of smaller magnitude that may have similar consequences in terms of damage to the built environment and socioeconomic impacts. This could be the case for a moderate magnitude earthquake of between M_W 6.0 to 6.5 occurring on a previously unknown buried fault near the town centre, for example. The 22 February 2011 M_W 6.3 Christchurch earthquake is a recent example of this.

For our first scenario, we model a M_W 6.3 occurring on a blind thrust fault, approximately 15 km west of the Iloilo City town centre with an epicentre of 122.45°E and 10.66°N at a depth of 36 km. Figure 12 shows the ground shaking distribution in terms of MMI for Scenario 1, as calculated in REDAS. This scenario suggests that severe ground shaking of degree MMI VII could be observed in Iloilo City.

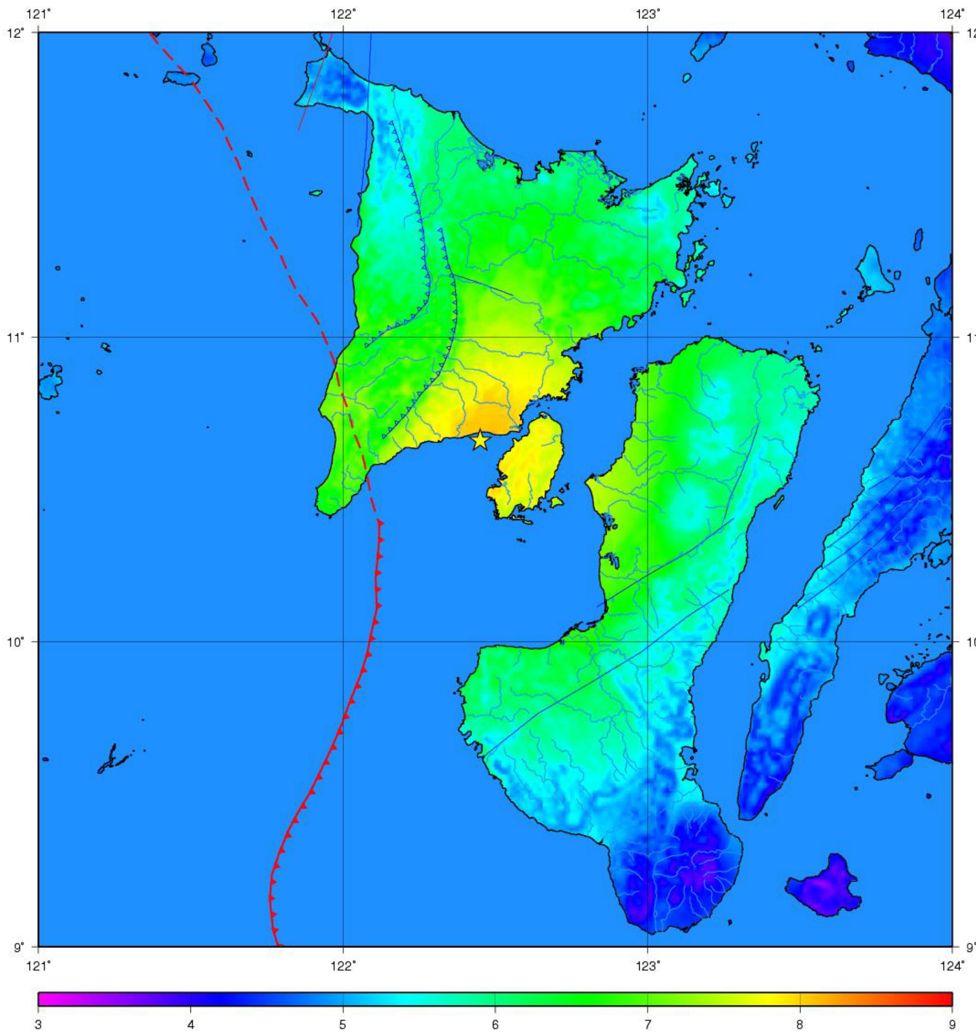

Figure 12: *The spatial distribution of Modified Mercalli Intensity (MMI) estimated using REDAS from a scenario M_W 6.3 blind thrust earthquake, 15 km west of Iloilo City.*

Scenario 2: M_W 8.1 Earthquake on the West Panay Fault

Whilst the epicentre of the 1948 M_S 8.2 Lady Caycay earthquake is located offshore (Gutenberg and Richter, 1954), the relatively small tsunami that was observed from this earthquake, in addition to the distribution of damage documented at churches throughout the Island of Panay (Bautista *et al.*, 2011) suggests that the earthquake may have originated onshore along the Panay Fault system. The Panay Fault is an arcuate system that generally strikes north-south on the western margin of Panay Island. The fault has the potential to host large earthquakes that could pose significant risk to communities on Panay, including the City of Iloilo. Consequently, Scenario 2 uses the Panay Fault as the source of the 1948 earthquake. Because the magnitude of the 1948 earthquake is estimated as M_W 8.1 (Engdahl and Villaseñor, 2002), we preserve this magnitude when modelling ground motions from the Panay Fault source. Figure 13 shows the ground shaking distribution in terms of MMI for Scenario 1, as calculated in REDAS. This model suggests that severe ground shaking of degree MMI VIII could be observed in Iloilo City.

While this scenario may not be a direct reproduction of the 1948 Lady Caycay earthquake in terms of magnitude or fault source given the uncertainties of accurately locating earthquakes at the time, it does represent a plausible scenario that may affect the City of Iloilo in the future.

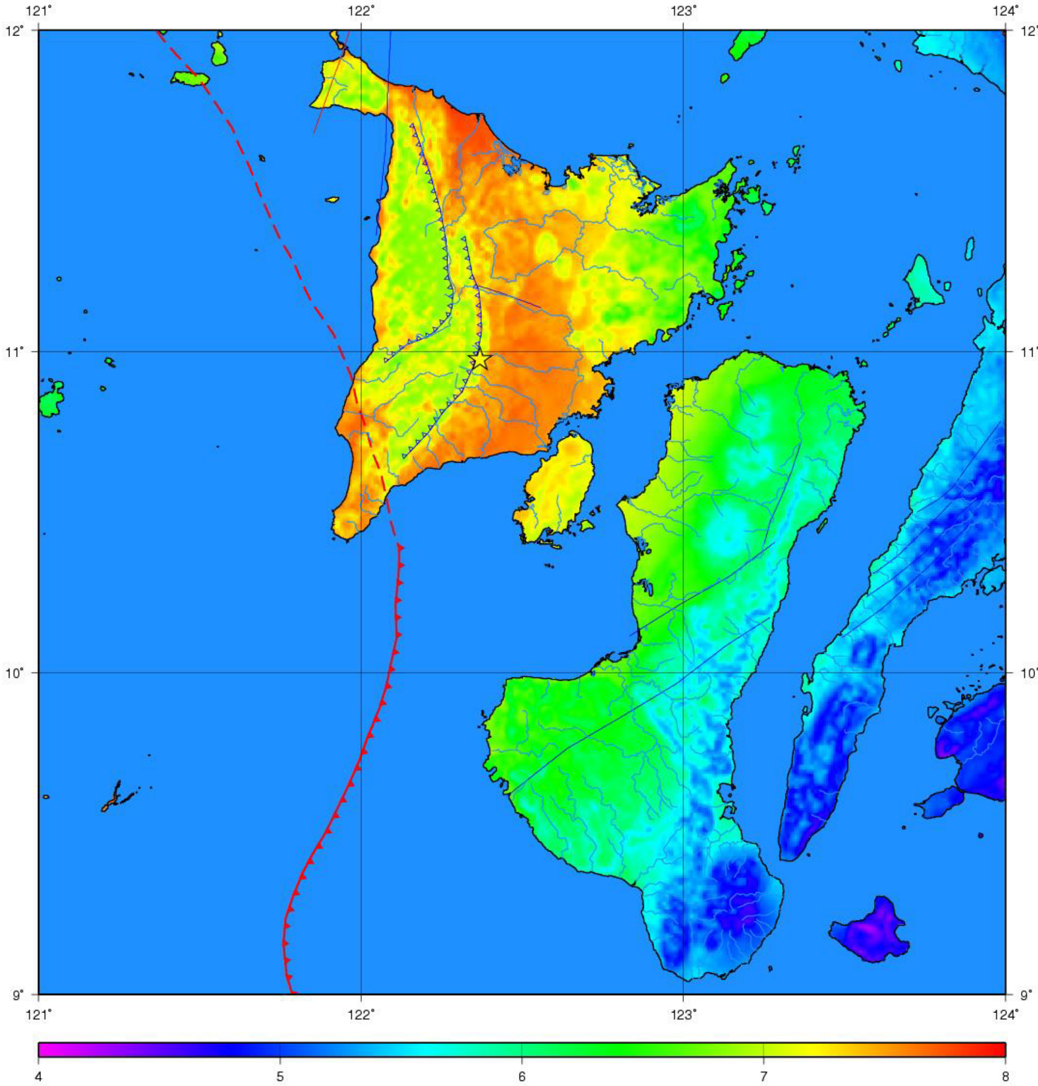

Figure 13: *The spatial distribution of Modified Mercalli Intensity (MMI) estimated using REDAS from a scenario M_W 8.1 earthquake on the West Panay fault.*

Building and Population Exposure Datasets

WHAT IS EXPOSURE?

Exposure refers to the “elements at risk” that may be affected by a hazard. These elements include buildings, people, economic activity, essential services and infrastructure. There is no single source and simple formula to collect and develop exposure database. Some exposure attribute information is usually available in an aggregated level for standard geographic areas like barangay. The currency of the census data is another major issue to estimate the current exposure. The different datasets contribute unique attributes that can be used to infer the nature and vulnerability of the exposure at a given location. It is important to note that exposure databases can often be composed of datasets at different resolution: from local, national to global scales. The resolution of a given exposure database can also vary spatially.

A comprehensive exposure module contains information on the:

- spatial location of people and structures (including residential, business, emergency services and infrastructure);
- structural information including construction type (e.g., wall and roof type), number of stories and building standards associated with age;
- replacement value of structures and contents;
- demographics (e.g., gender, age, socioeconomic status) of the people in the region of interest.

Not all of this information is always available in public access and is often difficult to obtain and maintain in a systematic manner. Consequently, this Project adopted a systematic approach that develops a core of essential information that can be enhanced over time.

There are two common approaches to develop exposure data. The most accurate, although most resource intensive approach, is to manually survey individual structures. The alternative is a statistical approach which is to combine available national- and regional-scale data including census data, statistical surveys, and land use information to develop an approximate and statistically representative exposure dataset. The statistical approach uses the best available data already captured and maintained by other agencies, and is easily repeatable. However, the currency and accuracy at the individual feature level will vary. The statistical approach is a powerful method of modelling exposure when data are aggregated at a predefined municipal level (e.g., census tract, barangay, LGU). However, it is not suitable for building level analysis. This approach will generally provide information that is appropriate for understanding impacts and risks at a municipal level. The overarching vision for QuiveR is to empower LGUs in the Philippines to develop and update their own exposure datasets, which they can then apply to a myriad of applications, from land use planning for DRR and in response to hazard events.

Below is the logic for developing an exposure database for Iloilo City that can be applied to multi-hazard events:

1. Gather data on the nature of the building stock at a range of scales: national and local;
2. Design inventory database schema and employ user friendly tools for development of a detailed LGU-level inventory using open source software (e.g., mySQL) and additional tools for exporting to REDAS input format;
3. Train selected LGU representative(s) to use aforementioned database and data management tools;
4. Gather field data on the nature of the building stock in Iloilo City;
5. Develop generic statistical models that can translate National Statistics Office and Assessors Office data to be consistent with field observations; and
6. Design software to generate a statistical distribution of inventory based on local Assessors Office and national-scale census data.

AVAILABLE DATA SOURCES

There were two main data sources were used to extract information about population and building exposure for the Iloilo City earthquake impact pilot study. The properties of each of the data sources are described, including the data format and the utility of these data sources in the development of our exposure database. A major data inventory or field mapping exercise was undertaken in order to validate the key data sources. Since it is unrealistic to classify and map each individual building for the entire Iloilo city, a representative sample of buildings and related field data obtained from the Philippines National Statistics Office and the Iloilo City Assessors Office. Empirical relationships were developed to translate these datasets to obtain a statistical approximation of the characteristics of the building stock in Iloilo City.

National Statistics Office (NSO) Data

The Philippines National Statistics Office (NSO) has collected the national census in year 2001 and a supplementary survey at barangay level in 2008. The national census dataset has been sourced from the NSO which comprises basic information on wall type, roof type, and floor area for residential buildings. NSO releases the census data aggregated to barangay level, so no building-specific data is available. The NSO census data templates were used to set-up nationally consistent information on the building types and population distribution throughout the Philippines. For examples NSO forms used to gather national census data are provided in Appendix VI. There is no information on commercial or industrial buildings in the NSO data sets. Consequently, the NSO data was supplemented with additional data sources.

Iloilo City Assessors Office (AO) Data

Iloilo City Assessors Office (AO) collects the property data for taxation and revenue. This information is at property level. In general one building has many properties in residential space and one property has many buildings in other cases. The local exposure dataset gathered from the AO includes slightly more detailed information on the street address, barangay name, building usage type (residential, commercial, government, etc.), provides more accurate information on the floor area and building value at property level. However, the local Iloilo City dataset does not provide any information on the number of people which occupy these buildings. Consequently, in order for the local data to be useful for the purpose., we merged the population data from the NSO with the local Assessors Office data. Street address and barangay information is available for each record. However, since there is no standard process to geocode street addresses in the Philippines, all properties in the AO database are spatially related to barangays. There are some inconsistencies discovered in the AO database (i.e., specific fields not consistently classified) therefore data cleaning and massaging was done before mapping the building stock in Iloilo City. This process is explained in more detail in Appendices VII and VIII.

Because the AO dataset comprised all taxable building stock in Iloilo City, it was a key resource for calibrating and validating the final exposure database. The key uses of the AO dataset were:

- Drawing comparisons between total floor area for residential buildings between NSO and survey data;
- Evaluation of the ratio between residential and non-residential buildings between barangays to determine level of urbanization (dense urban, suburban, or rural).

Development of Philippines Building Classification Schema

Critical to understanding earthquake risk in the Philippines is having a reliable understanding of the composition of the building stock. To better inform earthquake impact assessments in the QuiveR project, PHIVOLCS engaged with the local Filipino structural engineering community to develop a building classification schema appropriate for buildings in the Philippines. Initial discussions towards developing this schema were held at the aforementioned workshops in Clark and Tagaytay. Following these discussions, PHIVOLCS entered into a Momorandum of Agreement (MoA) with the University of the Philippines Diliman – Institute of Civil Engineers (UPD-ICE) with the endorsement of the Association of the Structural Engineers of the Philippines (ASEP) and the Philippine Institute of Civil Engineers (PICE) (see Appendix I for MoA).

THE UPD-ICE BUILDING TYPOLOGY

The MoA between PHIVOLCS and UPD-ICE specified that, through consultation with the broader structural engineering community in the Philippines, UPD-ICE would deliver a building typology that was specific to buildings in the Philippines. The final building classification was based upon the building classification of HAZUS-MH (NIBS-FEMA, 2003), with modification due to local construction practices and building materials. The final building typology, as outlined in the report prepared by UPD-ICE (Pacheco *et al.*, 2011), has more sub-types than HAZUS-MH owing to more variability in construction observed in the Filipino building stock (Table 1). The primary attributes upon which the Philippine building typology is based are:

- material: wood (W), masonry (M), concrete (C), steel (S)
- structure (frame, shear walls, etc.)
- building height: low rise (L), medium rise (M), high rise (H), very-high rise (V), extremely-high rise (E), super-high rise (S)
- vintage (pre-1972, 1972-1992, post-1992)

One important attribute listed above is the building vintage, which represents the different regulatory periods of the National Structural Code of the Philippines (Association of Structural Engineers of the Philippines, 2010). A summary of the different vintages for the national building previsions is listed below:

- Pre – 1972: no existing code for the Philippines
- 1992 – 1972: first code developed in the 1970’s as an answer to the need of setting the requirements for construction
- Post – 1992: changes in the ductility requirements from the previous versions of the code

A full description of the Philippine building typology, as developed by UPD-ICE is found in their final technical report (Pacheco *et al.*, 2011).

LINKING THE UPD-ICE AND ILOILO CITY BUILDING TYPOLOGIES

The Iloilo City Assessor’s Office (AO) possesses a database of taxable assets in Iloilo, which assigns a building type. This classification system has four major types according to construction material (i.e., reinforced concrete, semi-concrete, strong and light materials). These types are further classified into sub-types according to its structural characteristics. Specific details of the AO building classification system, as provided by the City of Iloilo, is provided in the electronic supplement accompanying this report (see Appendix I). This classification system is summarised in Table 2. Table 3 summarises the sub-types in the AO typology and their equivalent sub-types in the UPD-ICE typology.

Table 1: *Key building types of the Philippines according to number of floors and year of construction (after Pacheco et al., 2011)*

MATERIAL	TYPE	SUB-TYPE	DESCRIPTION	YEAR OF CONSTRUCTION		
				PRE-1972	1972-1992	POST-1992
Wood	W1*	W1-L	Wood Frame with Area ≤ 500 sq. m (1-2 storeys)	√		
	W2*	W2-L	Wood Frame with Area > 500 sq. m (1-2 storeys)	√		
	W3	W3-L	Bamboo (1-2 storeys)	√		
	N	N-L	Makeshift (1-2 storeys)	√		
Masonry	CHB		Concrete Hollow Blocks (1-2 storeys)	√		
	URA		Adobe (1-2 storeys)	√		
	URM*		Brick (1-2 storeys)	√		
	RM1*		Flexible Diaphragm (1-2 storeys)	√		
	RM2*	RM2-L	Rigid Diaphragm (1-2 storeys)	√		
		RM2-M	Rigid Diaphragm (3-7 storeys)	√		
	MWS		Half-Masonry/Half-Wood/Metal (1-2 storeys)	√		
Concrete	CWS		Half-RC Frame/Half-Wood/Metal (1-2 storeys)	√		
	C1*	C1-L	Moment Frame (1-2 storeys)	√		
		C1-M	Moment Frame (3-7 storeys)	√	√	√
		C1-H	Moment Frame (8-15 storeys)	√	√	√
	C2*	C2-L	Shear Walls (1-2 storeys)	√		
		C2-M	Shear Walls (3-7 storeys)	√	√	√
		C2-H	Shear Walls (8-15 storeys)	√	√	√
		C2-V	Shear Walls (16-25 storeys)	√		
		C2-E	Shear Walls (26-35 storeys)	√		
		C2-S	Shear Walls (36+ storeys)	√		
	C4	C4-M	Shear Walls and Frames (3-7 storeys)	√	√	√
		C4-H	Shear Walls and Frames (8-15 storeys)	√	√	√
	PC1*	PC1-L	Precast Tilt-up (1-2 storeys)	√	√	√
	PC2*	PC2-L	Precast Frame (1-2 storeys)	?	?	√
		PC2-M	Precast Frame (3-7 storeys)	?	?	√
Steel	S1*	S1-L	Moment Frame (1-2 storeys)	√	√	√
		S1-M	Moment Frame (3-7 storeys)	√	√	√
		S1-H	Moment Frame (8-15 storeys)	√	√	√
	S2*	S2-L	Braced Frame (1-2 storeys)	√	√	√
		S2-M	Braced Frame (3-7 storeys)	√	√	√
		S2-H	Braced Frame (8-15 storeys)	√	√	√
		S2-V	Braced Frame (16-25 storeys)	√	√	√
		S2-E	Braced Frame (26-35 storeys)	√	√	√
		S2-S	Braced Frame (36+ storeys)	√	√	√
	S3*	S3-L	Light Metal (1-2 storeys)	√		
	S4*	S4-L	Frame w/ Cast-in-place Shear Wall (1-2 storeys)			√
		S4-M	Frame w/ Cast-in-place Shear Wall (3-7 storeys)			√
		S4-H	Frame w/ Cast-in-place Shear Wall (8-15 storeys)			√
		S4-V	Frame w/ Cast-in-place Shear Wall (16-25 storeys)			√
		S4-E	Frame w/ Cast-in-place Shear Wall (26-35 storeys)			√
		S4-S	Frame w/ Cast-in-place Shear Wall (36+ storeys)			√

* similar to a HAZUS-MH Model Building Type with the same label

Table 2: *Building typology according to IloiloCity Assessor's Office (after Pacheco et al., 2011)*

Material	Type	Sub-Type	Structural Components							
			Columns	Beams	Walls	Flooring	Roof Frame	Roofing	Upper Storey	
									Wall	Floor
Reinforced Concrete	Type I	I-A	RC	RC	RC	RC	RC	RC	-	-
		I-B	RC	RC	CHB	RC	RC	RC	-	-
		I-C	RC	RC	CHB	RC	Steel	G.I. Sheet	-	-
Semi-Concrete	Type II	II-A	RC	RC	CHB	RC	Wood	G.I. Sheet	CHB	RC
		II-B	RC	RC	CHB	RC	Wood	G.I. Sheet	CHB	Wood
		II-C	RC	Wood	CHB	RC	Wood	G.I. Sheet	Wood	Wood
		II-D	RC	Wood	Wood on Zocalo	RC	Wood	G.I. Sheet	Wood	Wood
Strong Materials	Type III	III-A	1st Group Wood	1st Group Wood	Wood on Zocalo	RC	Wood	G.I. Sheet	Wood	Wood
		III-B	1st Group Wood	1st Group Wood	1st Group Wood	RC	Wood	G.I. Sheet	3rd Group Wood	3rd Group Wood
		III-C	1st Group Wood	1st Group Wood	1st Group Wood	1st Group Wood	Wood	G.I. Sheet	Wood	Wood
		III-D	3rd Group Wood	3rd Group Wood	3rd Group Wood	3rd Group Wood	Wood	G.I. Sheet	Wood	Wood
		III-E	3rd Group Wood	3rd Group Wood	3rd Group Wood	3rd Group Wood	Wood	G.I. Sheet	Wood	Wood
Light Materials	Type IV	IV	Makeshift/Improvised Materials							

RC: *Reinforced Concrete*
CHB: *Concrete Hollow Blocks*
G.I. Sheet: *Galvanized Iron Sheet*
1st Group Wood: *Local building materials: Ipil-ipil, Molave, Tindalo, Narra, Yacal*

Table 3: *Equivalent sub-classification of Iloilo Assessor's Office typological system compared with UPD-ICE typological system (after Pacheco et al, 2011).*

Typology (Assessor's Office, Iloilo)		KeyBuilding Type (UPD-ICE)
Material	Sub-Type	Sub-Type(s)
Reinforced Concrete	I-A	C2*
	I-B	C1*
	I-C	C1*
Semi-Concrete	II-A	C1*
	II-B	C1*
	II-C	CWS
	II-D	W1*
Strong Materials	III-A	W2*
	III-B	W2*
	III-C	W1*
	III-D	W1*
	III-E	W1*
Light Materials	IV	N

Field Data Capture

PURPOSE OF FIELD SURVEYS

A field survey of buildings in Iloilo City was undertaken as part of this Project. The main purpose of the survey was to:

- Validate available data sources with actual building information
- Collect data that could be used to determine correlations between NSO and AO data relative to the building inventory on the ground
- Collect data useful for multi-hazard applications
- Enable the local community to gather useful data that can be used to improve future risk assessments

The validation of available data sources was an attempt to correlate the data available from sources such as the 2007 Census of Population and Housing (collected by the NSO) and the Iloilo City Assessor's Office. The survey also served as a first-pass attempt to capture building attributes useful for a multi-hazard risk assessment. In addition to the Iloilo City earthquake risk pilot study, this capability has been developed in preparation for further risk assessment work in the "Enhancing Risk Analysis Capacities for Flood, Tropical Cyclone Severe Wind and Earthquake for Greater Metro Manila Area – Component 5 of the Post-Ketsana Recovery and Reconstruction Program" activity.

The information gathered will be used to inform statistical assumptions of exposure from first-order datasets (i.e., how a buildings footprint relates to its height). Electronic forms were developed for simple data capture and reduction of transcription errors from paper forms. Through the field surveys, we aimed to achieve 100% building coverage across several barangays. The barangays were chosen based on their size, diversity of building construction types, and mix of usage (i.e., residential, commercial, government, etc.). From the two survey missions, the QuiveR team, with support from the LGU, surveyed 1077 individual buildings and obtained complete coverage of seven barangays in the district of Jaro. Although this is a relatively small sample at a national scale, information collected from the door-to-door surveys can be used to relate to information contained in both the NSO and AO datasets. Further building surveys in other areas of the Philippines will no doubt help lower the uncertainties in the usage of these algorithms.

The survey was carried out in two phases. The first phase of the survey data capture was completed in September 2010 and the second phase commenced in January 2011 and was completed in late February 2011. Data collection focussed on the Jaro district in Iloilo City, and barangays close to the commercial centre of Jaro were chosen for survey in consultation with the Iloilo LGU (Fig. 14). The survey teams comprised members participants from PHIVOLCS, GA, UPD-ICE, DOST-Region VI, OCD-Region VI and several agencies from the Iloilo City LGU (Fig. 15). The survey procedure and the tools used are described below.

DEVELOPMENT OF FIELD SURVEY DATA SCHEMA

Prior to the development of the forms, advice was sought from structural engineers on the range of attributes that would be useful for undertaking a multi-hazard risk assessment for buildings typically found in the Philippines. This advice resulted in comprehensive set of attributes that would enable each building to be assessed for its response to ground shaking, in addition to other natural hazards (e.g., severe wind and flood inundation). Further consultation with PHIVOLCS and UPD-ICE prior to the first survey resulted in the addition of extra fields to permit the classification of buildings in the Iloilo City Assessor's Office and the UPD-ICE classification system. A summary of building attributes used to prepare survey fields (arranged into themes) is available in Table 4. A domain (list) of values for particular attribute types was prepared. The values provided by "GA/PHIVOLCS decision" were developed during discussions at the PHIVOLCS headquarters in Manila and from some reconnaissance of the urban areas in the Jaro district in the days prior to the survey. During this reconnaissance, typical features of buildings were noted and included in the domains. Values that include “LGU recommendations” were developed with input from Iloilo City survey team members during the survey. More detailed information on these survey forms can be found in Appendix IX. A field survey manual in the form of a small booklet was prepared to assist surveyors in classifying buildings in the field. This booklet is provided in Appendix X.

Feedback received from the LGU at the conclusion of the survey included the desire to record information about critical facilities. These facilities would include significant sites supporting institutional or essential service functions, as well as some infrastructure features.

In preparation for the second survey, forms for the capture of Schools and Hospitals were prepared for the PDA. These forms were based on a template developed by PHIVOLCS following discussions at the end of the first survey. Domains of values were developed in the weeks leading up to the second survey and cosmetic changes were made shortly before deployment to the field in January 2011.

During the first survey, a review of the effectiveness of the survey equipment, techniques and forms was undertaken at the end of each day’s activities. Following completion of the survey, all suggestions were collated and discussed between GA and PHIVOLCS staff. The recommendations yielded the addition of new fields to the survey form template.

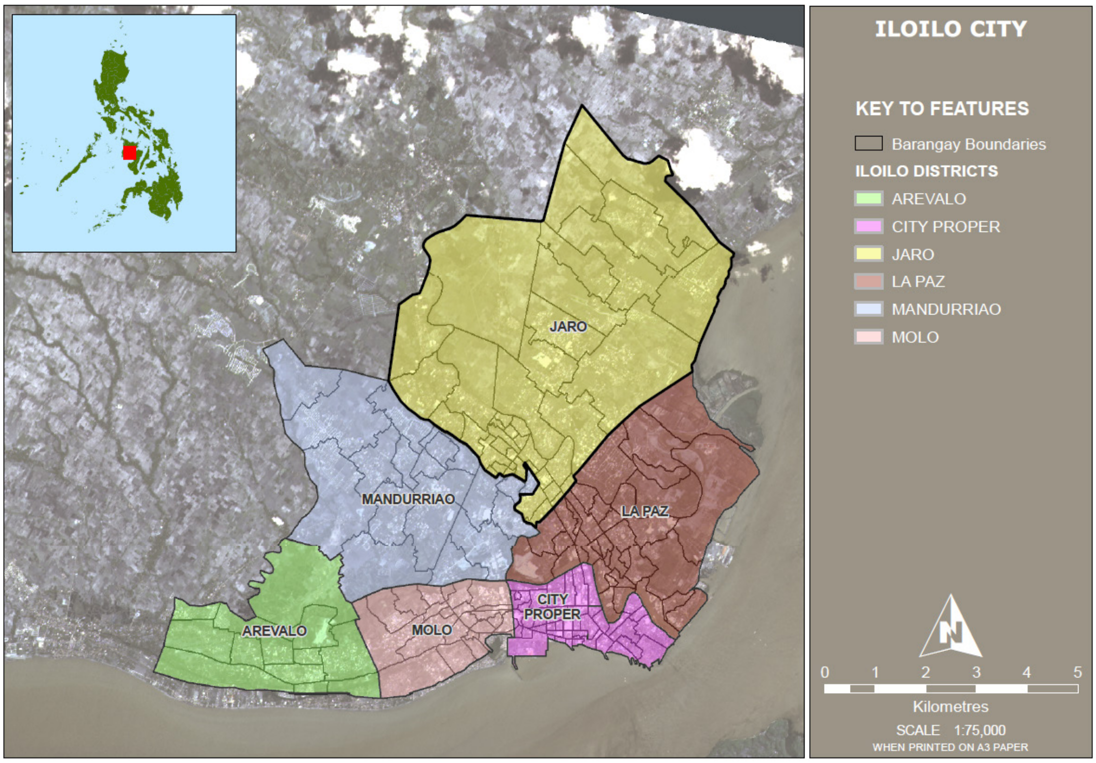

Figure 14: *Map indicating the location of the Jaro district with respect to the other districts in Iloilo.*

Figure 15: *Participants of the Iloilo field surveys undertaken in September 2010.*

Table 4: *Attributes captured during building surveys. Superscript codes indicate the source of the attribute. Metadata are provided in Appendix IX*

ATTRIBUTE	THEME	DESCRIPTION
Latitude	Geography	Latitude of the building location
Longitude	Geography	Longitude of the building location
Building Name	Geography	Name of the building (if known)
Street Number	Geography	Street number of the building (if known)
Street Name	Geography	Name of the street on which building is addressed (if known)
Barangay [1]	Geography	Name of the barangay
District [2]	Geography	Name of the District
City [3]	Geography	Name of the City
Province [4]	Geography	Name of the Province
Estimate of Year Built – Range [5]	Structural System	Range of years in which building was constructed
Year Built - Actual	Structural System	Actual year of construction of building (if known)
Building Type (Assessor's Office) [6]	Structural System	Use of building as per Iloilo City Assessor's Office building use classification
Structural System (Assessor's Office) [6]	Structural System	Structural system of building as per Iloilo City Assessor's Office structural classification system
Structural Classification (UPD-ICE) [5]	Structural System	Structural system of building as per University of Philippines Institute of Civil Engineering structural classification system
Vertical and Horizontal Plan Shapes [7]	Structural System	Dominant and sub-dominant vertical and horizontal plan shape of building
Estimate of Building Width and Depth [8]	Structural System	Estimate of width and depth ranges of the building referenced to the street frontage or main frontage
Overall Building Condition [8]	Structural System	Condition of the building at time of survey
Seismic Separation [8]	Structural System	Estimate of distance range between subject building and building immediately to the left and right (as seen from street or main frontage)
Primary/Secondary/Other Use [9]	Building Use	Dominant, sub-dominant and other use(s) of the

ATTRIBUTE	THEME	DESCRIPTION
		building
Percentage values (various) [8]	Building Use	Estimate of the overall percentage of each use of the building
Estimate of Number of People [8]	Building Use	Estimate of the number of people associated with each use of the building
Primary/Secondary Roof Attachments [8]	Roof System	Dominant and sub-dominant attachment to roof surface
Roof Attachment Heights [8]	Roof System	Range of estimated maximum height of roof attachment(s)
Roof Pitch [8]	Roof System	Classification of slope of roof or system of slope types
Primary/Secondary Roof Material Types [10]	Roof System	Dominant and sub-dominant roof cladding material type
Roof Decorations [8]	Roof System	Decorations at or around lowest portions of roof area
Primary/Secondary Wall Material Types [11]	Wall System	Dominant and sub-dominant external wall material type
Lower/Upper Level of Wall Type [8]	Wall System	Lower and upper storey of dominant (and sub-dominant) external wall material type
Primary/Secondary Wall Attachments [12]	Wall System	Dominant and sub-dominant attachment to exterior walls
Floor System [7]	Floor System	Placement of lowest floor on or above ground
Floor Material Type [8]	Floor System	Type of material used for the lowest floor
Lowest Floor Elevation from Street [8]	Floor System	Estimate of difference in elevation between lowest floor and street level
Sub-Floor Void Percentage [8]	Floor System	Estimate of percentage of sub-floor void (if partially or wholly elevated above ground)
Primary Sub-Floor Void Use [8]	Floor System	Dominant use of the sub-floor void (if applicable)
Basement Presence [8]	Floor System	Presence or otherwise of a basement
Slope of underlying terrain [8]	Floor System	Slope of the terrain underlying the building
Soil Foundation type [13]	Floor System	Type of foundation below building as per Table 1615 Site Class Definitions (2000 International Building Code)
Primary/Secondary Façade Types [14]	Façade	Dominant and sub-dominant façade type of building
Primary Window Type [12]	Façade	Dominant type of external windows around building
Comments	Survey Details	Additional comments about building
Survey Team [8]	Survey Details	Name of organisation responsible for survey
PDA Unit Name [15]	Survey Details	Name of data collection device
Date of Survey	Survey Details	Date of survey of building
Confidence of Responses [8]	Survey Details	Assessment of confidence in the survey
Photograph 1	Photos	File path of Photo 1 of building
Photograph 2	Photos	File path of Photo 2 of building
Photograph 3	Photos	File path of Photo 3 of building
Photograph 4	Photos	File path of Photo 4 of building
Time of Survey [8 #]	Survey Details	Time of entry of survey into database
Maximum Flood Level [8 #]	Survey Details	Maximum known flood level
Critical Facility ID [8 #]	Survey Details	Identification number of Critical Facility (if applicable)
Critical Facility Name [8 #]	Survey Details	Name of Critical Facility (if applicable)
Taxable Status [8 #]	Survey Details	Local taxation status of building
Attic Presence [8 #]	Roof System	Indication of presence of an attic

ATTRIBUTE	THEME	DESCRIPTION
Bracing Material [8 #]	Structural System	Material of the bracing system
Roof Frame Material [8 #]	Structural System	Material of the roof frame system
Beam Material [8 #]	Structural System	Material of the beam system
Column Material [8 #]	Structural System	Material of the column system
Floor Material [8 #]	Structural System	Material of the intermediate floor frame

1 Iloilo Barangay names
2 Iloilo District names
3 Iloilo City names
4 Western Visayas Province names
5 UPD-ICE building classification schema
6 Iloilo City Tax Ordinance and LGU recommendations
7 GA recommendations
8 GA/PHIVOLCS decision
9 NSO building use classification schema
10 NSO roof classification schema
11 NSO wall classification schema
12 GA/PHIVOLCS/LGU recommendations
13 GA recommendations based on Table 1615 Site Class Definitions (2000 International Building Code)
14 GA recommendations (based on Australian CBD surveys)
15 Naming of GA and PHIVOLCS units

FIELD SURVEY EQUIPMENT

The first survey was undertaken using six Getac PDAs enabled with ESRI ArcPad mobile GIS software. Four PDAs were provided to PHIVOLCS, using funds obtained from AusAID, prior to the commencement of the survey and two PDAs owned by GA were used to provide extra field capability.

The Getac PDAs are a rugged device designed for use in the field (Fig. 16). These PDAs have a number of useful features for field data collection:

- Windows Mobile 6 as the operating system
- ESRI ArcPad Mobile GIS software
- Colour touch-sensitive screen
- Weather sealed for use in wet weather
- Built-in single frequency GPS receiver
- Built-in 3 megapixel camera and LED flash
- Built-in voice recorder
- Rugged design for use in the field

The second survey was carried out with these same devices, plus eight laptops loaded with a PC-based data capture tool developed by PHIVOLCS. The development of these tools is discussed in more detail below.

Figure 16: *A Getac PDA showing a typical ESRI ArcPad interface.*

FIELD SURVEY BACKGROUND INFORMATION

Since the digital survey tools used in Iloilo use a map interface for the display and creation of spatial data, existing spatially referenced data can be used as a reference for locating new features. Typically this involves the use of aerial imagery and other datasets such as administrative or cadastral boundaries, road centrelines and other useful references where available.

Aerial Imagery

In the lead-up to the survey, the best openly available ortho-rectified aerial imagery was pan-sharpened imagery from the Sentinel Asia sensor (Fig. 17). The available Sentinel Asia imagery was loaded into the PDAs to provide a backdrop to the other spatial data.

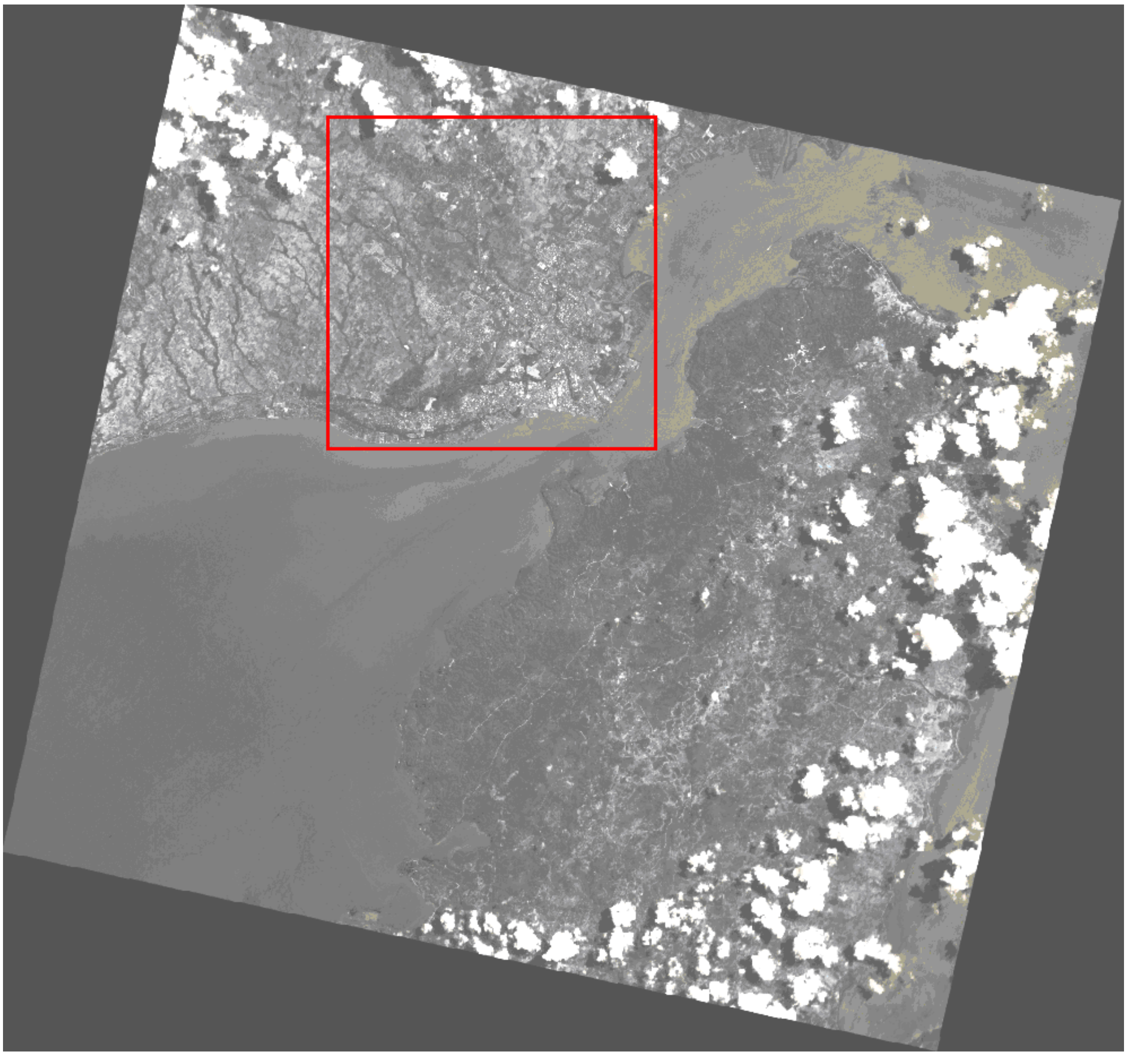

Figure 17: *Sentinel imagery for Iloilo City (Source of imagery: https://sentinel.tksc.jaxa.jp). The red polygon represents the spatial extents of Iloilo City.*

Road Centrelines

As a majority of the survey would be conducted from existing roads, a georeferenced road centreline network was considered to be important for providing additional context to the displayed imagery and GPS position. The Open Street Map website (http://www.openstreetmap.org/) permits spatial data to be created by users around the world, and is freely available for use. The data is licensed under Creative Commons Attribution-Share Alike 2.0. Data for Iloilo City was downloaded from the Open Street Map site and converted to ESRI™ shapefile format. Additional road centrelines in areas likely to be surveyed were captured from interpretation of Sentinel Asia imagery.

Barangay Boundaries

Spatial data for the boundaries of barangays in the Iloilo City area was supplied by the NSO. These data features were subsequently added to the backdrop of the PDAs and displayed with each polygon labelled with the barangay name.

DEVELOPMENT OF SURVEY FORMS IN ARCPAD STUDIO

In the first phase of the field survey, ESRI ArcPad Studio 8 software was used for the preparation of a survey form. The survey form consisted of multiple pages arranged into themes of building attributes according to Table 4. The intention of the form was to provide an opportunity for a PDA operator to rapidly locate and record exposure information for buildings in a foot survey (Fig. 18). A list of the unique building attributes arranged by each page of the survey form is listed in Appendix IX.

Figure 18: *An example of the data capture forms created in ArcPad Studio 8 for the capture of building data in Iloilo City.*

ArcPad Studio 8 permits the development of forms that can be associated with an existing ESRI shapefile or AXF (ArcPad feature dataset), and allows domains of values for each attribute to be sourced from an associated database file (DBF). ArcPad Studio 8 allows a GIS operator to prepare the forms in a Graphical User Interface (GUI) environment or as an editable extensible Mark-Up Language (XML) file.

Format for First Phase

For the first survey, forms were developed using a pre-defined ESRI™ shapefile that comprised the building attributes described in Table 4. The forms were saved as an APL file that accompanies the shapefile. The APL is the simplest method for ArcPad form development, since shapefiles are relatively uncomplicated in their data structure. The APL can incorporate a number of customisations, and the following basic examples were applied to the form:

- Restricting various entries to a dropdown list (domain)
- Specifying mandatory fields that required data entry before proceeding to next page

An additional customisation was added to automatically transfer the latitude and longitude of a feature into the attribute table upon completion of the survey of that feature.

Format for Second Phase

In preparation for the second phase of the survey, forms were developed within the structure of AXF files for ArcPad. AXF files were introduced to ArcPad version 8 as an alternative to shapefiles. The vision for this format change was to introduce a more flexibility data structure. AXF files are unique to ArcPad and behave more like a file-based geodatabase rather than a single shapefile. They are created by mimicking an existing ESRI File Geodatabase. An AXF file can contain many feature classes, each of which may store either point, polyline or polygon features. For each feature class, the XML code for a survey form is stored with the feature class and applies uniquely to that feature class. The AXF file system also permits enhanced management of surveyed data (such as tracking of features already returned to the parent File Geodatabase).

DEVELOPMENT OF SURVEY FORMS IN MYSQL

The compilation of a detailed building inventory would require years to develop for a moderate-sized Philippine city, let alone on a national scale. To hasten this database development, a strategy was employed to involve as many stakeholders/organizations as possible and equip them with a standardized tool for data collection and management. The preferred organizations to engage are the local government units (LGUs) since they have better knowledge of their respective area of responsibilities and have a greater interest in the use of such a database.

We have described the development of the survey forms using the ESRI ArcPad framework on Windows Mobile PDA devices. Although these devices are appropriate for our purpose of validating the building stock in Iloilo City, they have limited utility for providing a city-scale building-specific inventory because the instruments and software required are prohibitively expensive for many LGUs in the Philippines. Consequently, PHIVOLCS have now developed an inexpensive building data capture system that can run on ordinary laptops or netbooks (Bautista *et al.*, 2011), with plans to extend this technology to Android tablet devices.

The existing software has been designed to work on Windows devices, such as a common laptop or netbook device that can easily be acquired by LGUs (Fig. 19). The hardware can be connected to a GPS and a digital camera to simultaneously capture images of structures and their location. The system uses an open source database system for encoding the building attributes and parameters. A user-friendly GUI with a simplified drop-down menu, containing the building classification schema described above is adopted in the system (Fig. 20). The resulting data capture is integrated by PHIVOLCS-DOST and will form part of the REDAS hazard simulation tool that is also made freely available to partner local government units.

Figure 19: *Setup of PHIVOLCS exposure capture system Hardware setup consists of a netbook PC, a webcam, a Garmin GPS connected to the PC thru USB cable or a wireless Bluetooth GPS receiver and USB extension cables in case there is a need to put the webcam or Garmin GPS at a position away from the netbook PC. The power inverter, not shown in the picture, may be required over long period surveys. Shown on the right side of the figure are surveyors undertaking the building survey on foot.*

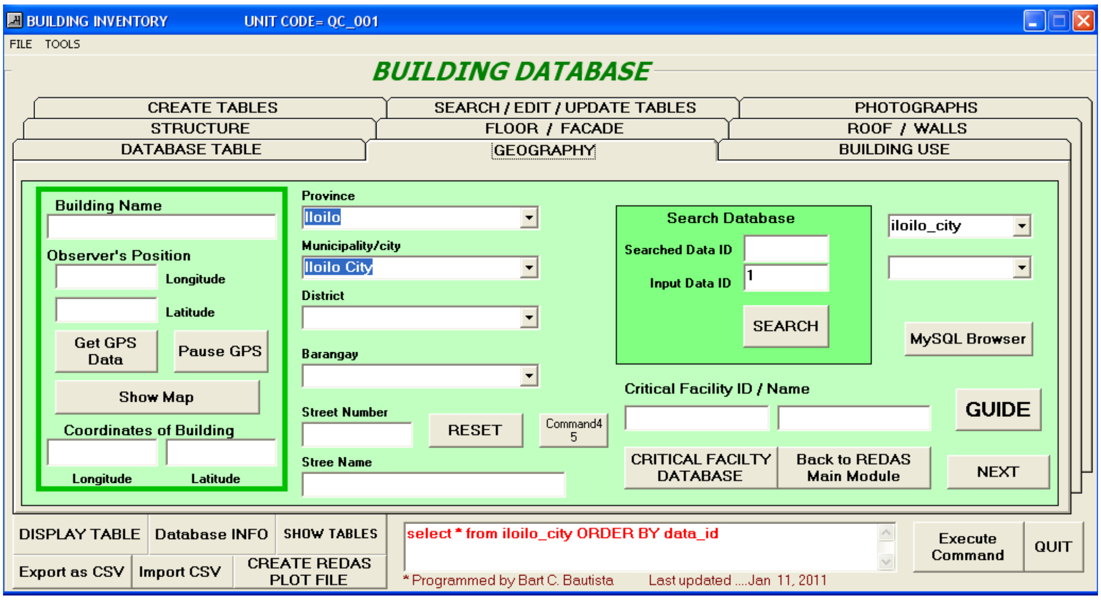

Figure 20: *Screen capture of the REDAS Building Database software showing the Geography page and its corresponding attributes that are observed and filled up in the survey.*

FIELD SURVEY APPROACH

Selection of Barangays – First Phase

Prior to the commencement of the data capture, barangays were selected for survey based on their size, likely number of buildings and proximity to the centre of Jaro (the focus of the survey operation). It was decided that a number of barangays should be completely surveyed to enable a direct comparison between NSO, Assessor's Office and the surveyed data. The barangays selected for the first phase survey were Burgos Seminario, Luna, Libertad and Maria Christiana.

Selection of Barangays – Second Phase

The second phase of the survey was discussed in detail prior to commencement. The issue of building profiles in different barangays was explored, since it was understood that the density and style of buildings would vary across the district of Jaro. It was acknowledged that large areas of some barangays would contain subdivisions. These subdivisions would predominately contain relatively new free-standing dwellings, and there would be wide spacing between adjacent buildings. The style of buildings would be quite different to those in the more well-established barangays in Jaro. Two barangays that were identified in this category were Cubay and Tabuc Suba.

Given limitations in the portability with laptops, it was decided that barangays with a lower density of buildings would be surveyed using the laptop tools to allow operation from the comfort of the support vehicles. In contrast, barangays close to the centre of Jaro (San Jose, Javellana and Our Lady of Fatima) were surveyed using PDAs because of the higher density of building distribution and generally busier roads.

Survey of Buildings - PDA

Before commencement of fieldwork on each day, the PDAs were all switched on, ArcPad was opened and the relevant data collection file was opened. The first task for the survey of a building is to locate the building using the current GPS position and the backdrop imagery. Once the location of the building is identified, the user digitises a point at the centre of the building, which creates a new record in the database. The position is marked with a symbol and the survey form for that building is launched. The user then begins to fill out the details about the location, structural characteristics, use(s), roof, wall(s), floor and façade of the building. At the completion of the survey, the user has the opportunity to provide additional comments about the building and finalises the survey with information about the date, name of unit, the user's organisation name and the level of confidence they have in the quality of the survey. The user is then able to capture up to four photographs of the exterior of the building using either the in-built camera on the PDA, or webcam attached to the laptop PC. Upon completion of the survey, the record is populated with all responses, filenames of the photos and geographic coordinates of the digitised point.

DATA MANAGEMENT PROCEDURE

In the first survey, each PDA was uploaded with an empty shapefile prior to the first day for the storage of survey data. At the conclusion for the first day, shapefiles containing survey data were transferred from all PDAs into backup directories on a laptop and an external hard drive. All photos captured in the field were also transferred from the PDAs and archived. The six unique shapefiles were then merged into a single file, and this file was returned to each PDA. Building points in this shapefile were displayed in a different colour to the active shapefile, so that survey teams would easily identify buildings that had already been surveyed. An empty shapefile was returned to the PDAs in preparation for the next day's survey. This process was repeated at the conclusion of each day of survey.

In the second survey, a similar approach for the PDAs was developed to the first survey, though the ability to check data in to the original database allowed the merging of data to be performed in a more rapidly. This merged dataset was also transferred back to each PDA to indicate buildings already surveyed. The AXF data files on each PDA unit were retained on the units throughout the survey, so that surveyed points accumulated within the AXF file during the survey.

The data captured using the laptop devices was aggregated using similar methods described above to the PDAs. The laptop approach populated a MySQL database, which had the ability to export the data in a comma separated value (CSV) file. The CSV files were exported from each laptop daily and imported into a MySQL database. These data and accompanying photographs were subsequently backed up on an external storage device. The merged data were subsequently reloaded onto each laptop device at the commencement of work each morning to ensure no duplication in subsequent surveys.

QUALITY CHECKING OF FIELD DATA

Since no survey is ever completely accurate, a review of the survey data was conducted to ensure the highest possible quality assurance of the survey. After the completion of the first survey, significant time was spent reviewing the locations of buildings and the attributes recorded in the field. This involved checking and, if required, correcting errors related to:

- building point placement;
- membership of administrative area (mainly barangays);
- disparities between Year Built Range and actual Year Built (where entered);
- Horizontal Plan Shape when compared with aerial imagery;
- disparities between Number of Storeys and highest wall type classification;
- disparities in total percentages of Use 1, Use 2 and Use 3 of building;
- disparities in total percentages of Roof 1 and Roof 2 of building;
- disparities in Wall 1 and Wall 2 level classifications;
- classification of Floor System and subsequent Sub-Floor percentage and Sub-Floor Use

For any record where one or more changes were made to the original field data, an entry of 'Y' in the EDIT_BY_GA field was made. Additional fields were added to the attribute table to facilitate post-processing and analysis of the data. The new fields are listed in Table 5).

Table 5: *Building attributes appended to survey data for post-processing and analysis..*

FIELD NAME	FIELD TYPE	DESCRIPTION
EDIT_BY_GA	Text	Register if record had been edited by GA
WIDTH_NUM	Double	For conversion from Width range to number
DEPTH_NUM	Double	For conversion from Depth range to number
FOOTPRINT	Double	Calculated building footprint area
FLOOR_AREA	Double	First-pass building floor area
FOOT_SCALE	Double	Scale factor for reducing floor area for irregular buildings
FLAREA_FIN	Double	Final floor area (after scaling)

ESTIMATION OF BUILDING FOOTPRINT AREA AND FLOOR AREA

Estimation of building floor area from the survey data is the key element used for the earthquake impact assessment. Consequently, it is important to obtain the most reliable estimate of building floor area from either the NSO or AO datasets. The survey data is thus important for validating reported floor areas in the respective city-scale data.

Using the field estimate of building width (along the street frontage) and building depth (away from street frontage) it is possible to estimate the area of building footprint. Since the building width and depth was estimated in the field using a range of values, the following conversion was applied to provide a single value:

0 – 5 metres→ 2.5 metres

5 – 10 metres → 7.5 metres

10 – 15 metres → 12.5 metres

15 – 20 metres → 17.5 metres

20 – 25 metres → 22.5 metres

25 – 50 metres → 37.5 metres

For buildings with one of these values in the WIDTH_M and DEPTH_M fields, the numerical equivalent was placed in the WIDTH_NUM and DEPTH_NUM fields. The following calculation was then made:

$$FOOTPRINT = WIDTH\_NUM \times DEPTH\_NUM$$

For any building that had been attributed with a width and/or depth of >50 metres, footprints were individually captured for those buildings using the georectified aerial imagery. The footprint was subsequently calculated from the resultant shape of the feature and inserted into the FOOTPRINT field.

For all buildings, the first-pass of the floor area was then calculated using the following calculation:

$$FLOOR\_AREA = FOOTPRINT \times NO\_STOREYS$$

CORRECTING FLOOR AREA FOR HORIZONTAL PLAN SHAPE

Since the estimation of building footprint area and floor area in the survey is based on rectangular dimensions, it is possible this technique will overestimate the area for buildings with an irregular shape. For buildings with a horizontal plan shape other than square or rectangular, it is possible to compare a rectangular building extent area with the actual footprint area. For a selection of buildings with horizontal plan shapes of Irregular, L-Shaped, T-Shaped, U-Shaped, X-Cranked and X-Cruciform, the actual footprints were captured, along with an estimation of the rectangular extent. Figure 21 highlights examples of this capture, with actual footprints outlined in yellow and rectangular extents outlined in red.

Figure 21: *Examples of buildings with irregular horizontal plan shapes. A correction factor was derived for irregular buildings by finding the ratio of the rectangular (red polygons) and actual (yellow polygons) footprint areas.*

The areas were calculated for selected buildings and the difference was calculated as a percentage of the rectangular extent. The mean percentage differences were calculated for each type. The overall mean was calculated as 66.8%, with a standard deviation of 12.3%. Since the overall footprint mean was close to two-thirds of the rectangular extent, the scale factor of 0.67 was applied to the value for FLOOR_AREA for the irregular buildings, and a scale factor of 1.0 applied to square and rectangular buildings. The final corrected floor area was calculated in the FLAREA_FIN field.

SUMMARY OF DATA CAPTURE

In total, attributes for 1077 individual buildings were captured over the two field surveys using a combination of PDA units and the MySQL forms developed by PHIVOLCS. Furthermore, seven barangays have complete coverage of all buildings in the barangay. Figure 22 shows a map of the buildings from these surveys in the district of Jaro.

Using the building survey data, were able to examine specific characteristics of the building stock in the Jaro district, including the vintage of buildings and the predominant structure type for different vintages (pre-1972, 1972-1992, post-1992), for example. Table 6 shows the number of buildings constructed in each vintage for each building type. This table clearly shows that the predominant building type in the district of Jaro is reinforced concrete moment frame (C1), which becomes more common in recent vintages. The other two building types commonly found in Jaro are those wooden structures with light frames (W1) and buildings with reinforced concrete frames with the upper story made of light materials (CWS). Figure 23 indicates the relative percentage of each construction period for each construction material once the data is aggregated to primary construction material rather than building type as indicated in Table 6. From the Figure 23, it can be seen that most of both concrete and steel buildings were predominantly constructed after 1972, whereas wood and masonry buildings were both common before 1972. This is most likely due to the availability of building materials and/or building construction skills at the time period. The relative abundance of post-1992 wooden buildings is in part due to the increasing number of makeshift construction (N) with time (see Table 6).

Figure 22: *Map of individual buildings surveyed in the district of Jaro (filled circles). Translucent polygons superimposed by the building points indicate the full extent of the barangays for which some building data was captured. Background imagery obtained from Google Earth™.*

Table 6: *Vintage distribution of UPD-ICE engineering classifications from field survey data.*

MATERIAL	TYPE	PRE-1972	1972-1992	POST-1992	TOTAL
Wood	W1	59	66	42	167
	W2	3	1	0	4
	W3	0	0	6	6
	N	7	15	31	53
Masonry	CHB	9	31	26	66
	URA	1	0	0	1
	MWS	5	9	1	14
Concrete	CWS	58	77	31	166
	C1L	52	156	301	509
	C1M	1	7	63	71
	C2L	1	5	5	11
	C2M	0	1	0	1
	C4M	0	0	1	1
Steel	S1L	0	1	3	4
	S3L	0	1	1	2
Total		196	370	511	1077

Figure 23: *Distribution of construction materials with vintage as determined from field survey data.*

Through first-order analysis of the data captured from the field surveys in Jaro, we can obtain a snapshot of the distribution and vintage of different building types in the district. Subsequently, we can use these data to "paintbrush" characteristics of the building stock observed in Jaro, to the remainder of Iloilo City using simple statistical methods and models. The development of these methods will be discussed later. The full database and metadata (i.e., photographs) of the 1077 buildings survey is provided in the electronic supplement accompanying this technical report (see Appendix I).

COMPARISON OF AO AND ENGINEERING CLASSIFICATIONS

The survey data provides an excellent opportunity to cross-reference assigned building classifications from the AO with the UPD-ICE engineering classifications described above. In addition to fields describing the structural attributes of buildings, surveyors were also prompted to provide their final classification according to the AO and engineering classifications. However, during the second field survey, these fields for inputting building classification data were not mandatory. Consequently, either UPD-ICE engineering, AO, or both classifications were missing for some building entries. Following the survey, engineers from UPD-ICE were engaged to validate the assigned UPD-ICE engineering classification and also to enter the classification in case of missing value. Table 3 above illustrates the theoretical mapping of building typologies as provided by UPD-ICE. In Figure 24, we see the correspondence with survey data. Note that the total number of buildings with both UPD-ICE engineering and AO classifications is 665, whereas the total number of surveyed buildings is 1077. In this figure, we observe that there is generally good correspondence between the AO and engineering typologies based on our surveyed data. In a few instances such as I-A, the surveyed results do not directly match the proposed mapping. However, given the ambiguity in providing a one-to-one mapping between the two schemas, the apparent irregularities are consistent with observed building attributes. These data are visually illustrated in Figure 25 in terms of relative percentage of UPD-ICE engineering type given AO type. It is important to note that the mismatch between UPD-ICE engineering and AO types is specific to the survey area; if survey were done for different region, then different mapping between building typologies could be observed.

	I-A	I-B	I-C	II-A	II-B	II-C	II-D	III-A	III-B	III-C	III-D	III-E	IV	Sum
W1	0	2	1	4	9	13	6	10	12	7	9	16	9	98
W2	0	0	0	0	0	0	0	0	1	1	0	0	1	3
W3	0	0	0	0	0	0	0	0	1	0	0	1	3	5
N	0	0	0	1	0	0	0	0	0	1	1	0	26	29
CHB	2	2	1	6	6	5	3	1	0	0	0	0	1	27
URA	0	0	1	0	0	0	0	0	0	0	0	0	0	1
MWS	0	0	0	0	2	0	0	0	0	0	0	0	0	2
CWS	1	1	0	6	41	52	19	5	1	1	0	0	3	130
C1	38	42	86	142	26	8	1	10	0	0	0	1	0	354
C2	1	1	4	4	1	1	0	0	0	0	0	0	0	12
C4	1	0	0	0	0	0	0	0	0	0	0	0	0	1
S1	1	0	0	0	0	0	0	0	0	0	0	0	0	1
S3	0	0	1	0	0	0	0	0	0	0	0	0	1	2
Sum	44	48	94	163	85	79	29	26	15	10	10	18	44	665

Figure 24: *Matrix indicating the number of buildings with AO and UPD-ICE assignments as observed through field surveys. Yellow cells indicate the proposed mapping, and bold italic numbers indicate the maximum number of buildings assigned to engineering classifications given AO type from the survey data.*

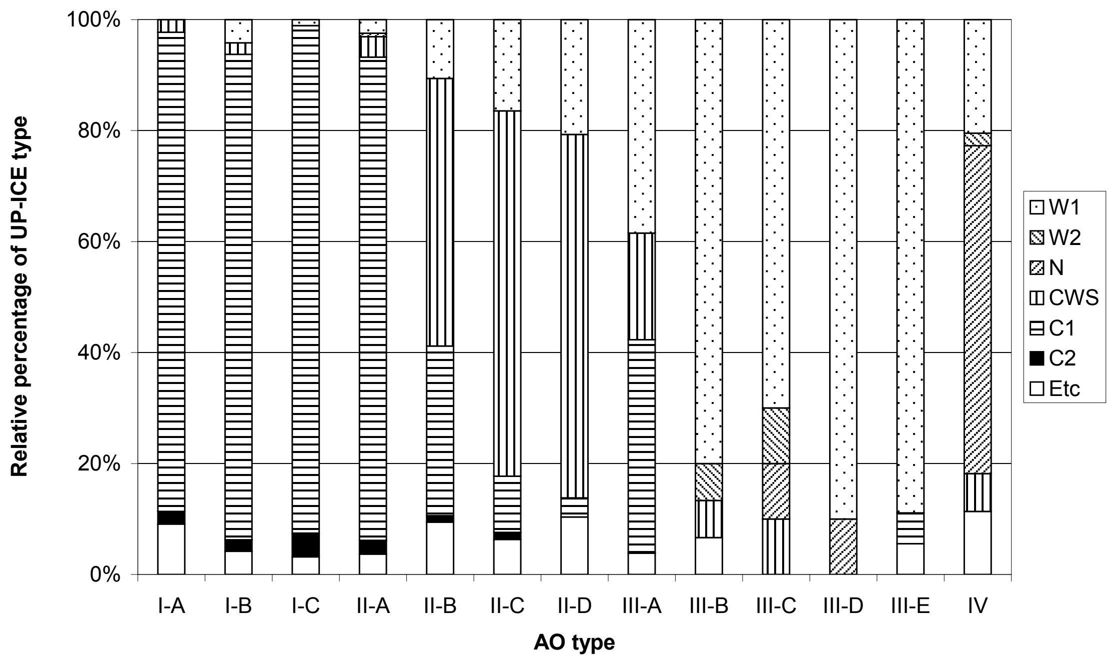

Figure 25: *Composition of UPD-ICE engineering type given AO as observed through field surveys. Those percentages labelled "Etc" represent other types not captured in the six most abundant building types in the district of Jaro.*

COMPARISON AND VALIDATION OF DATA SOURCES

Based on the total floor area of residential structures, we were able to undertake some first order comparisons based between the NSO and AO datasets, of which floor area per barangay is a common attribute. As mentioned previously, the AO dataset combines information for all taxable assets, both residential and non-residential. In contrast, the NSO data only provides information for residential structures.

We compare the total floor area for residential structures for each of the 180 barangays in the Iloilo City region. It is observed that the AO dataset estimates approximately 30% greater floor area per barangay than the NSO for residential structures on average (Fig. 26). These differences may be due to more up-to-date records in regions of increasing urbanisation, which may be present in the AO, but are not reflected in the NSO 2000 census data. Reviewing these comparisons with the 2010 census data, when it becomes publically available would be recommended.

Subsequently, we use our field survey data, which is complete for seven barangays in the Jaro district, to further evaluate the accuracy of both the AO and NSO datasets relative to our field data. Table 7 indicates the total floor area for residential structures obtained from the three data sources for the barangays with complete survey coverage. Generally, the results from the field surveys appear to be more consistent with the NSO data. However, these results should be verified in another city before implementing broad-brush modification to national scale NSO data.

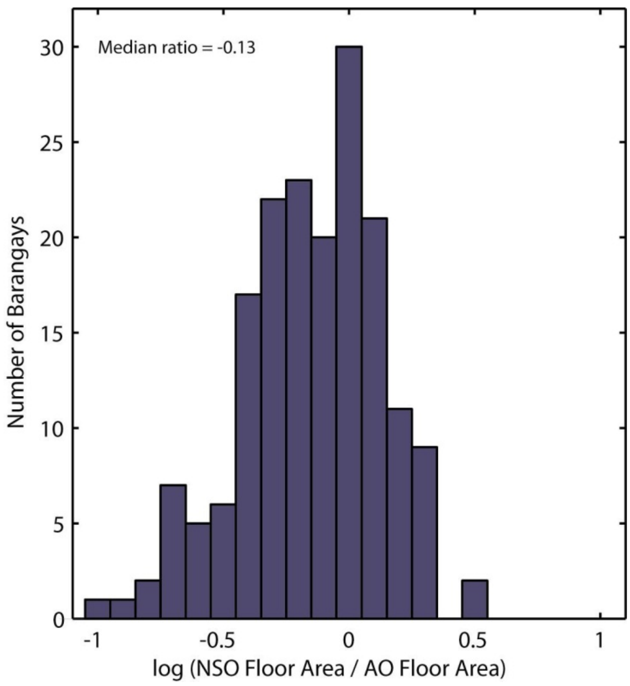

Figure 26: *The logarithm of the ratio of total residential floor area from the NSO database per barangay and the total residential floor area from the AO database. In general we observe that the the AO dataset estimates approximately 30% greater floor area per barangay than the NSO for residential structures.*

Table 7: *A comparison of total floor area for residential structures as recorded in the NSO, AO and field survey datasets.*

BARANGAY	NSO AREA (M^2)	AO AREA (M^2)	SURVEY AREA (M^2)
Benedicto	30135	51120	6358
Burgos Seminario	4285	18179	4365
Claudio Lopez	4295	5672	4973
Fajardo	11070	17431	3456
Our Lady Of Fatima	31790	48026	37402
Javellana	8770	13035	16400
Libertad	11310	17293	11160
Luna	6565	32155	6692
Maria Cristina	18695	16434	20538

RECOMMENDATIONS FOR USING AO DATA

While the AO dataset should be more reliable for determining total floor area in Iloilo City, there are a few key reasons why we prefer the use of the NSO data for development of exposure models in REDAS: 1) the general correspondence of the NSO data with the survey data; 2) the NSO data are nationally consistent, so theoretically, the methods developed for Iloilo City should be applicable anywhere in the Philippines; and 3) the availability of the soon-to-be published 2010 census data, which can be substituted into our exposure framework.

Despite our preference for using the NSO data for the development of the exposure models, the AO data has utility for providing important residential to non-residential scaling factors. Since the NSO data only considers residential buildings, we must apply a scaling factor to the NSO data if we want to consider buildings of other usage in our impact assessments. If data were captured systematically across all building uses, then we should expect the ratio between residential and non-residential floor area to be consistent with true observations. Assuming this to be the case, we apply a “swell factor” to account for those non-residential buildings not captured by the NSO data. The swell factors are determined and applied for each barangay using the following equation:

$$A'_{NSO} = A_{NSO} / (A_{res} / A_{tot})$$

where:

A'_{NSO} is the modified NSO total floor area per barangay;

A_{NSO} is the original NSO total floor area per barangay;

A_{res} is the total floor area of residential buildings per barangay in the AO dataset; and

A_{tot} is the total floor area of residential and non-residential buildings per barangay in the AO dataset.

Whilst there is significant scope to incorporate the AO dataset in a more rigorous manner due to its detailed building classification system, we were not able to take full advantage of these details to develop the exposure dataset for Iloilo City using our current framework. This is partially due to our desire of developing a framework for exposure database development on a national scale. However, these data should be used more constructively in the development of future exposure datasets.

RECOMMENDATIONS FOR MODIFYING NSO DATA

Because the NSO data is consistent at a national level, it provides a very powerful framework for the development of a national building exposure database that can be used for natural hazard risk assessments. As discussed previously, the NSO census data comprises key information regarding the primary wall and roof type of residential buildings. In addition to this information, a building floor area can also be associated with unique residential dwellings. However, because these dwellings cannot be geocoded, we rely on aggregating NSO floor area for barangay to “paintbrush” statistical models determined from field activities across the full city.

In developing a building exposure database for Iloilo City, the floor area for different combinations of NSO wall and roof type were aggregated for each barangay. Using the analysis above, which subdivides UPD-ICE building type as a relative proportion of floor area by NSO wall and roof type combination, a proxy exposure database could be developed using the following steps:

1. Aggregate unique combinations of NSO wall and roof type (e.g., galvanised iron roof combined with concrete hollow block walls and determine total floor area of each combination per barangay
2. Determine residential to non-residential floor area correction (swell) factors using tax ordinance data.
3. Modify NSO floor area per barangay by multiplying by residential to non-residential factors determined from 2
4. Using survey data, for each combination of NSO wall and roof type:
   - subdivide modified floor area by the proportion of UPD-ICE building types determined from the survey data for a given NSO combination
   - obtain total floor area per building type and vintage, per barangay
   - divide the total floor area per barangay by the number of grid cells in the barangay to determine building density

It is acknowledged that this is a very approximate approach to determine a building exposure model. However, in the absence of a detailed building specific survey, the NSO dataset can act as a powerful proxy dataset to estimate natural hazard risk throughout the Philippines.

Application of an Exposure Database in REDAS

Although the field surveys in Iloilo capture building inventory at very high level of detail, it was untenable to complete a door-to-door survey for the full QuiveR study area. As discusses previously, the field data collected were used to validate, and better understand the data gathered from the two aforementioned data sources; the NSO and Iloilo City Assessors Office. It also enabled us to develop simple empirical relationships to extrapolate our field data to the rest of Iloilo City and the Philippines.

The REDAS software uses the Generic Mapping Tools (GMT, Wessel and Smith, 1991) as its main computational engine to produce maps of earthquake ground-shaking. Since REDAS has been designed to be used by LGUs across the Philippines, the advantage of using GMT for this purpose is that it precludes the need to invest in costly commercial GIS software that the LGUs would otherwise not be able to afford.

Because the GMT computational engine is being used in REDAS, the exposure dataset must be converted into a GMT grid file format. In the Philippines, readily accessible information on the specific location of buildings is rare, as it is in the vast majority of countries around the world. Consequently, to develop exposure data that can be used in REDAS, we will assign tabulated data across a spatial grid, delineated by barangay boundaries. The basic logic for generating these grids is listed below:

1. Create a dummy grid across the spatial area of interest at the preferred resolution (e.g., 1 ,3, 9, 30 arc-second)
2. Digitise coastlines and major tributaries and mask cells that are offshore or located within major river systems
3. Use barangay polygons and populate dummy grid-cells located within a given barangay with NSO barangay number
4. **For each building type**, match barangay cell number with tabulated floor area data and uniformly distribute building floor area equally across each cell in the barangay according to the equation below:

Floor Area per Cell = Total Barangay Floor Area / Number of Cells in Barangay

The logic outlined above is undertaken by running the python script *make_brgy_grd.py* (Appendices XI and XII).

MAPPING NSO DATA TO BUILDING CLASSIFICATION SCHEMA

Since vulnerability models for the Philippines-specific buildings were tied to the UPD-ICE engineering classifications, it was necessary to map data from the NSO dataset to the engineering classifications. To do this, simple statistical models were developed that relate NSO definitions of roof and wall material, floor area and number of stories to the engineering classifications. Because our ground-based building survey of the Jaro district captured building characteristics in the NSO data, we could design simple logic to distribute NSO data (which is nationally consistent) to the engineering schema at a barangay level. The logic for developing the exposure data for the 178 barangays in Iloilo City is listed below. For each barangay:

1. Apply residential to non-residential swell factor from AO data to NSO total floor area
2. Disaggregate modified NSO floor area by unique roof and wall combination
3. For each NSO combination of roof and wall type:
   - determine statistical relationships between the of NSO wall and roof combination and engineering building class based on survey data
   - distribute engineering building types to total floor area based on statistics determined in (a)
4. Because multiple NSO combinations may be mapped to a single engineering class, aggregate floor area for a UPD-ICE building type from each of the NSO combinations

Because the vulnerability varies with different construction periods, simple statistical models were developed for the distribution of building vintage given the engineering type. We derived the statistics of construction period for each of the primary construction materials (Table 8). Of the UPD-ICE classes commonly found in Iloilo City, only four are affected by changes in the building code (Pacheco *et al.*, 2011). Given the vast majority of buildings surveyed in the district of Jaro are of structure types that do not need to be compliant with building codes, we did not end up using these statistics for deriving the exposure models in our analysis. Nevertheless, these data are still of interest and may be used for future studies.

Table 8: *Weights corresponding to the construction period for UPD-ICE engineering class.*

UP-ICE ENGINEERING CLASS	PRE-1972	1972-1992	POST-1992
C1M	15%	32%	53%
C2M	15%	32%	53%
C4M	15%	32%	53%
S1L	0%	33%	67%

Statistical Data for Distributing Exposure

As described above, a key part of developing the exposure datasets for the earthquake impact assessments is to determine statistical relationships between each combination of NSO wall and roof material and engineering building class using the survey data. Total floor area for each combination of NSO wall and roof material in each barangay can be determined from the NSO data. The building materials available in the NSO dataset are listed in Table 9. For each building surveyed in the Jaro district, we collected information on the NSO building materials, the total floor area of the building, in addition to the UPD-ICE building classification. With this data, we can find the proportion of surveyed buildings (in terms of total floor area) for the NSO roof and wall material combinations and subdivide them by the UPD-ICE typology. Table 10 provides statistical relationships between the NSO wall and roof material and UPD-ICE engineering building classifications, as determined by our survey data.

Because this is a relatively small sample of buildings (1077 in a city of almost 90,000 buildings), the statistical relationships provided below should not be considered as absolute relations between survey the NSO and survey data. It is important to recognise that these statistics should be considered as first-order relationships and that they will be improved by further reconnaissance in Iloilo City, and other urban centres in the Philippines.

Based of field data from Jaro, the statistical distribution of UPD-ICE building types given the different NSO roof and wall combinations identified in Table 10 above for the three urbanization classes (i.e., residential, commercial and mixed). Whilst we can identify some significant variations in the distribution of some building types with barangay class, the subdivision of the survey data to determine these statistics acts to increase the variance in the data by lowering the number of samples that determine the distribution of building types per barangay class. Consequently, we do not employ these statistics in the development of the building-specific grids to be used by REDAS. It is recommended that more data be captured to quantify these relationships for future risk and impact assessments.

The impact methodology described below classifies damage based on the aggregated floor area for all buildings of a common type. This is useful in order to obtain an estimate of the relative proportion of damage that would be experienced by a given building type. However, this information does not readily translate in to number of buildings. In order to obtain an indication of the actual number of buildings affected, we *normalise* the total floor area impact by the average floor area of one building unit. From our survey data, we are able to get an estimate of the median floor area for a single building in the UPD-ICE dataset (Table 11).

Table 9: *List* of *acrynoms used to define building materials listed in the NSO census data.*

KEY	MATERIAL
A	Asbestos
B	Bamboo
C	Concrete/Brick/Stone
G	Glass
GI	Galvanised Iron
GIC	Galvanised Iron & Concrete
MS	Makeshift
N	Nipa
NO	None
O	Other
T	Tile
W	Wood

Table 10: *Statistical relationships between each combination of NSO wall and roof material and UPD-ICE engineering building classifications using the survey data. The columns beneath "percent floor area" indicate the proportion of engineering types given a particular NSO roof and wall combination. Percentages are shown for the combined survey dataset, in addition to barangays classed as commercial, residential, or mixed as described above.*

NSO COMBINATION		UP BUILDING TYPE	PERCENT FLOOR AREA			
NSO ROOF	NSO WALL		ALL BRGYS	COMMERCIAL	RESIDENTIAL	MIX
A	C	C1L	100.0	0.0	100.0	0.0
N	B	N	42.3	0.0	100.0	78.5
N	B	W1	9.6	0.0	0.0	21.5
N	B	W3	48.1	100.0	0.0	0.0
N	GI	W3	100.0	100.0	0.0	0.0
N	MS	W1	100.0	0.0	0.0	100.0
N	NA	N	100.0	0.0	0.0	100.0
N	W	W1	100.0	0.0	0.0	100.0
GI	A	CWS	100.0	0.0	0.0	100.0
GI	B	CHB	2.5	0.0	9.8	0.0
GI	B	CWS	8.5	0.0	3.1	14.2
GI	B	N	20.3	37.3	19.6	14.2
GI	B	W1	15.3	0.0	38.7	23.9
GI	B	W3	45.8	62.7	28.9	47.7
GI	C	C1L	53.7	34.9	73.7	39.3
GI	C	C1M	16.0	26.9	7.6	21.3
GI	C	C2L	1.0	5.3	0.2	0.6
GI	C	C2M	0.1	1.1	0.0	0.0
GI	C	CHB	5.2	0.0	7.2	4.5
GI	C	CWS	13.4	25.4	4.4	19.0
GI	C	MWS	1.1	0.0	0.0	2.4
GI	C	N	0.5	0.0	0.6	0.5
GI	C	S1L	4.0	5.6	0.3	7.2
GI	C	S3L	0.0	0.0	0.1	0.0
GI	C	URA	0.7	0.0	1.6	0.0
GI	C	W1	4.2	0.7	4.4	5.0
GI	C	W2	0.1	0.0	0.0	0.1
GI	GI	C1L	5.1	0.0	0.0	8.6
GI	GI	CWS	8.5	0.0	0.0	14.3
GI	GI	N	48.6	0.0	58.3	41.9
GI	GI	S3L	4.0	0.0	0.0	6.7
GI	GI	W1	33.9	0.0	41.7	28.6
GI	G	C1L	100.0	100.0	0.0	100.0
GI	MS	N	85.7	0.0	0.0	85.7
GI	MS	W1	14.3	0.0	0.0	14.3
GI	NO	C1L	43.1	0.0	0.0	77.9
GI	NO	N	21.1	100.0	0.0	8.8
GI	NO	W1	35.8	0.0	100.0	13.2
GI	O	N	17.0	0.0	0.0	50.0
GI	O	S1L	17.0	0.0	0.0	50.0
GI	O	W1	66.0	100.0	100.0	0.0
GI	W	C1L	3.4	6.7	0.0	2.6
GI	W	CHB	0.3	0.0	0.0	0.6
GI	W	CWS	19.9	36.6	0.0	16.6
GI	W	MWS	0.5	0.0	0.0	0.9
GI	W	N	5.2	0.0	11.8	6.2
GI	W	W1	66.8	56.7	88.2	65.9

NSO COMBINATION		UP BUILDING TYPE	PERCENT FLOOR AREA			
NSO ROOF	NSO WALL		ALL BRGYS	COMMERCIAL	RESIDENTIAL	MIX
GI	W	W2	3.3	0.0	0.0	6.3
GI	W	W3	0.5	0.0	0.0	0.9
GI	C	C1M	100.0	0.0	100.0	0.0
O	C	C1L	18.0	0.0	12.5	20.7
O	C	C1M	67.8	0.0	87.5	58.4
O	C	CWS	14.2	0.0	0.0	21.0
O	O	C1L	100.0	100.0	0.0	0.0
T	C	C1L	46.9	38.0	59.4	38.0
T	C	C1M	45.9	62.0	36.1	46.3
T	C	C4M	5.3	0.0	0.0	15.7
T	C	W1	1.9	0.0	4.5	0.0
T	G	C1L	100.0	100.0	0.0	0.0
T	NO	C1M	100.0	100.0	0.0	0.0
W	W	N	100.0	0.0	0.0	100.0

Table 11: *The median floor area for each building type from the building surveys in the Jaro District.*

UPD-ICE BUILDING TYPE	FLOOR AREA PER BUILDING (M^2)
C1L	156.3
C1M	625.0
C2L	112.5
C2M	281.3
C4M	1225
CHB	93.8
CWS	175.0
MWS	112.5
N	37.5
S1L	856.2
S3L	53.1
URA	1553.3
W1	112.5
W2	125.0
W3	125.0

Application of Statistical Data for Generating REDAS Grid Files

Implementation of the logic described results in the generation of 16 unique GMT grids, each providing the floor area per grid cell for unique UP building types. This is achieved by running the python scripts *modify_nso.py* and *make_building_grids.py* (Appendices XI and XII, respectively). Figures 27 and 28 show the relative floor area per grid cell of low-rise (C1L) and medium-rise (C1M) reinforced concrete buildings. As can be observed from these two figures, the low-rise reinforced concrete structure is the predominant building type. Floor area per grid cell for reinforced concrete lower and light upper structures (CWS) and light-frame wooden structures (W1) are shown in Figures 29 and 30.

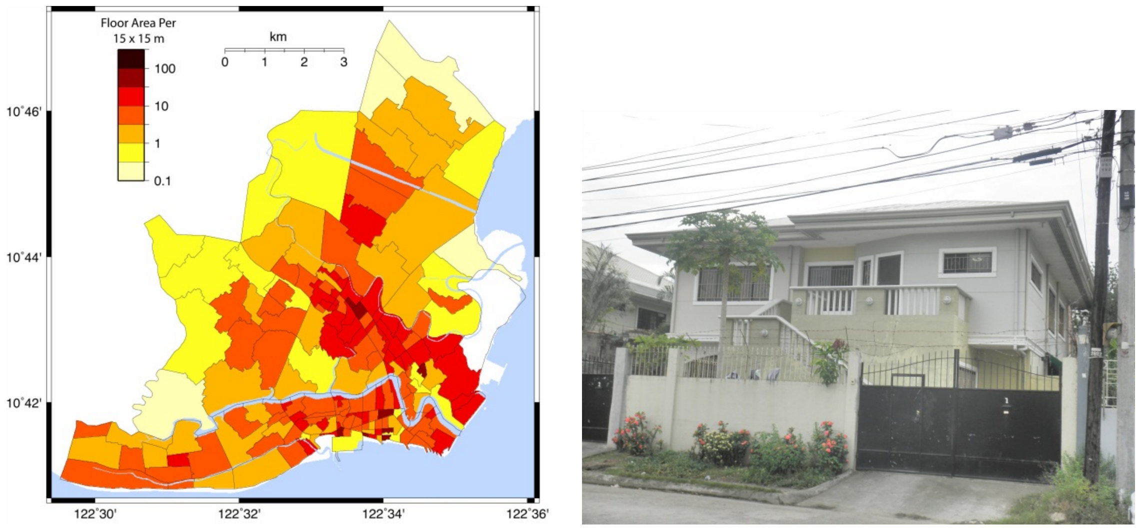

Figure 27: *Gridded exposure showing the relative density of (a) C1L buildings across the city of Iloilo, and (b) an example of this builing type. Map indicates the floor area in metres squared per 225 m^2 land footprint area.*

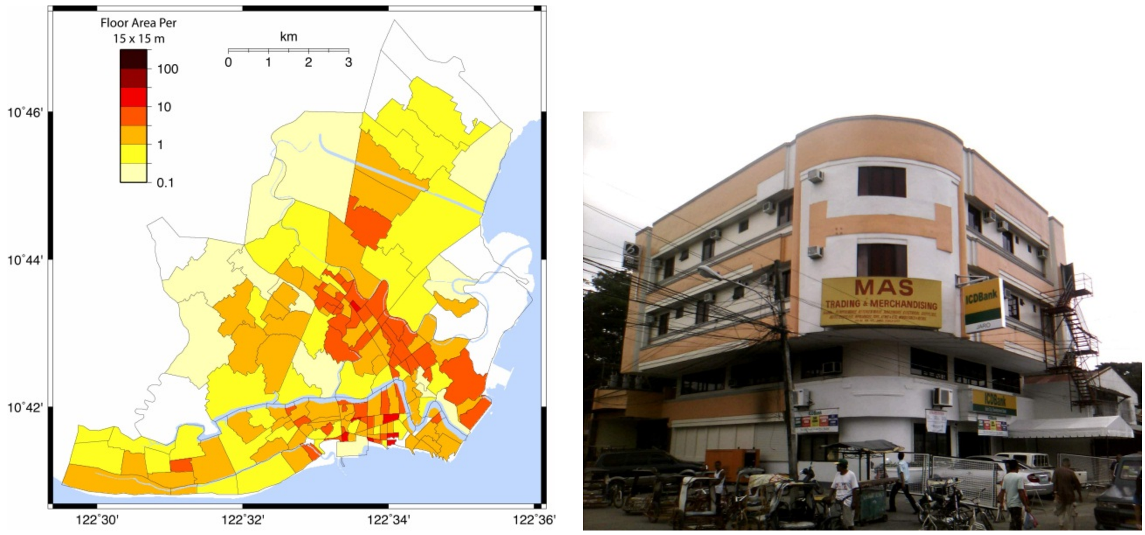

Figure 28: *Gridded exposure showing the relative density of (a) C1M buildings across the city of Iloilo, and (b) an example of this builing type. Map indicates the floor area in metres squared per 225 m^2 land footprint area.*

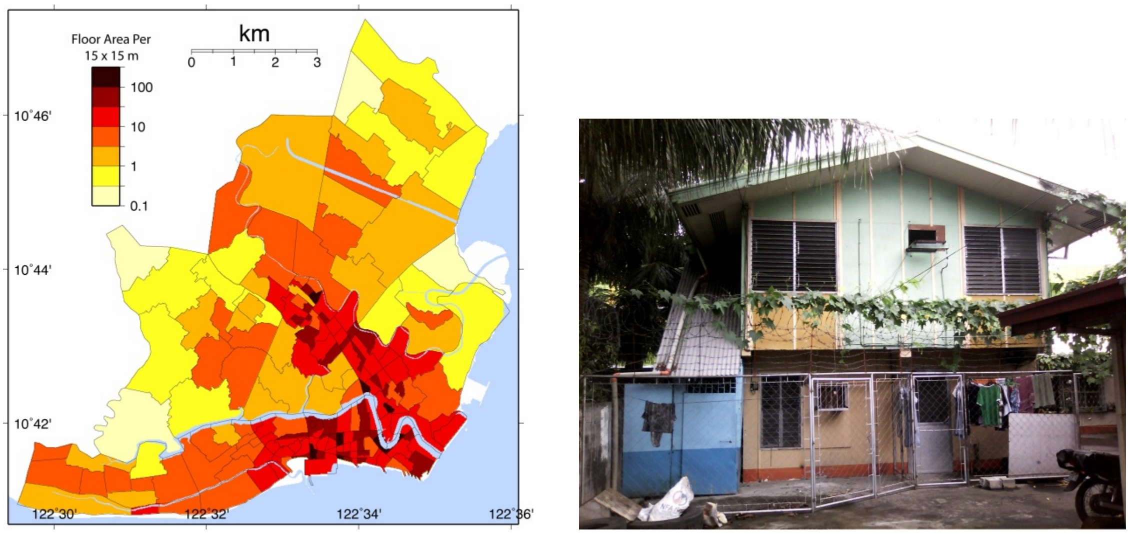

Figure 29: *Gridded exposure showing the relative density of (a) CWS buildings across the city of Iloilo, and (b) an example of this builing type. Map indicates the floor area in metres squared per 225 m^2 land footprint area.*

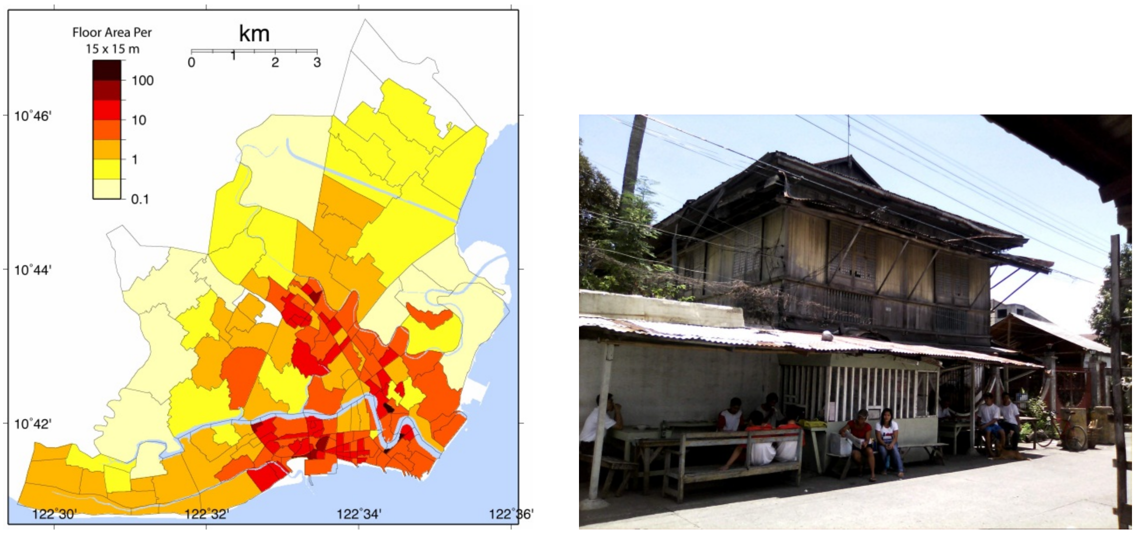

Figure 30: *Gridded exposure showing the relative density of (a) W1 buildings across the city of Iloilo, and (b) an example of this builing type. Map indicates the floor area in metres squared per 225 m^2 land footprint area.*

FUTURE IMPROVEMENTS TO REDAS EXPOSURE METHODOLOGY

It should be acknowledged that by distributing building floor area uniformly across a barangay, we are not accounting for land usage, and the potential that buildings are placed in more hazardous locations within a barangay (i.e., on river banks or steep slopes). This is potentially important for flood, wind or landslide hazards. However, for earthquake, we do not expect that the ground-shaking will vary significantly across the relatively small spatial extent of Iloilo City from a scenario earthquake, let alone across the area the size of a typical urban or suburban barangay.

Because those barangays in rural areas will tend to cover larger spatial extents, the assumption that exposure is distributed uniformly across the barangay is likely to be inadequate, even for earthquake hazards, where the ground-shaking will vary across large areas. Furthermore, seismic site-conditions may vary and are likely to have a significant impact on the overall ground-shaking estimates. The methodologies for incorporating these complexities into the generation of REDAS exposure grids will be a topic for future work. Options to more accurately assign regions of human development in future multi-hazard risk assessments may be to:

1. mask those areas that are reserved for agriculture or parklands
2. mask areas covered by steep slopes that are unlikely to be inhabited (using topographic slope)
3. mask densely forested areas
4. distribute population and building exposure along roadways

The framework for implementing the first recommendation in REDAS already exists. In developing the exposure module plug-in, we allowed for the implementation of a system to mask regions used for aquaculture, which is a primary industry in Iloilo City. Fishponds could be simply digitized in programs such as Google Earth, and subsequently input into the module to make the barangay grid. By undertaking this procedure in our present methodology for distributing buildings across a spatial grid, it effectively increases the floor area per area for those grid cells that are not within the polygons identified as regions of intensive aquaculture (Fig 31). This feature is important for some hazards such as floods where the impact to the built environment is very sensitive to proximity to local river systems, for example. However, in the earthquake impact assessments presented herein, the variation of ground shaking predicted by REDAS over the spatial extent does not change significantly over the small spatial extent of a barangay. Consequently implementation of the aforementioned feature for the current still would be of little overall benefit, since the impact results would not change markedly.

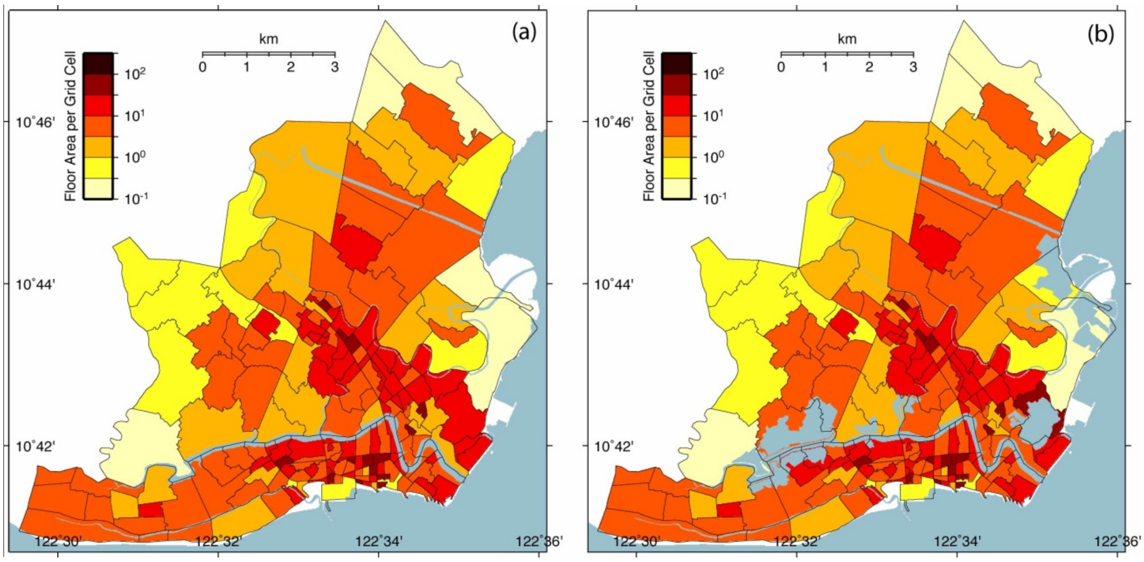

Figure 31: *Gridded exposure map showing the relative density of (a) C1L buildings across the city of Iloilo with no areas masked from the computation area, and (b) C1L buildings with areas covered by fishponds, with no corresponding buildings, masked from the computation area. Note the building density of some barangays with a large proportion of fishponds increases due to the decrease in area that can be used for residential and commercial buildings. Map indicates the floor area in metres squared per 225 m^2 land footprint area.*

Some of the functionality discussed in the previous section could not be incorporated into the REDAS exposure calculation module because of the limitation of data available to make certain assumptions on the distribution of building types. In particular, it was difficult to implement the relative distribution of certain building types in barangays of different classes of urbanisation. This is because of a limitation of the field survey data not consciously targeting barangays that are of different levels of urbanisation: i.e. urban, sub-urban and rural. If we were to attempt to develop these factors, it would reduce the sample size of buildings surveyed for each barangay class, thus increasing the uncertainty in any subsequent model. Consequently, it was chosen to use uniform statistics to distribute the building types based on the NSO combination of wall and roof-type data. Furthermore, sub-dividing the exposure data by specifying barangay class would result in an additional dimension in the exposure and loss calculation modules that would increase the computation time

Vulnerability Model Development

WHAT IS EARTHQUAKE VULNERABILITY?

Vulnerability to natural hazards is an integral factor in understanding the true extent of risk. Although there is no single definition for vulnerability, it generally refers to the resilience of people, infrastructure and the economy to cope with the onset of a natural hazard.

Earthquake induced deaths primarily result from the structural collapse of buildings in the affected area (e.g., Coburn and Spence, 1992). The damage incurred from the collapse of buildings, and subsequent human casualties (i.e., fatalities and injuries), depends upon the type of structural system, the number of stories, and several other factors (Jaiswal and Wald, 2010). Consequently, it is important to recognize how vulnerable different structural systems are, and estimate their likely response to strong ground-shaking. A review of available literature documenting earthquake damage was undertaken (Appendix XIII).

Because of the limited information on the Philippine building stock and its subsequent collapse fragility, the QuiveR Project engaged with key members of the Philippine structural engineering community to provide estimates of collapse fragility for specific earthquake loads. Through this engagement the Philippine structural engineering community, led by the UPD-ICE team, embarked on a process to develop earthquake fragilities for Philippine building types. As such, the second key objective of the MoA agreed to between UPD-ICE and PHIVOLCS was to:

> *"To develop a basic suite of vulnerability curves of key building types in the Philippines which can be used in earthquake impact assessments and potentially for wind and flood risk assessment".*

The work described below is analogous to those currently being pursued in other global studies, such as the joint World Housing Encyclopedia (WHE) – PAGER project (D'Ayala *et al.*, 2010; Jaiswal *et al.*, 2011) and the joint Australian-Indonesian study following the 2009 Padang earthquake (Sengara *et al.*, 2010).

DEVOLOPMENT OF PHILIPPINES-SPECIFIC VULNERABILITY MODELS

Building fragilities for the QuiveR Project were developed through a combination of analytical and expert judgment processes. Seismic vulnerability and fragility curves are used to assess the performance of a structure subjected to an earthquake. Seismic fragility curves are used to describe the performance of an engineering component or system subjected to earthquake excitations in probabilistic terms. They represent the probability of exceeding different damage states given the ground shaking intensity (Pacheco *et al.*, 2011). Damage is usually categorised into discrete damage states: namely, Slight, Moderate, Extensive and Complete (NIBS-FEMA, 2011).

The seismic fragility curve is approximated by a lognormal cumulative distribution function shown in equation:

$$P[ds \mid S_d] = \Phi\left[\frac{1}{\beta_{ds}} \ln\left(\frac{S_d}{\bar{S}_{d,ds}}\right)\right],$$

where:

$P[ds \mid S_d]$ is the probability that a damage state *ds* is reached or exceeded for a given spectral displacement S_d;

Φ is the standard normal cumulative distribution function

β_{ds} is the standard deviation of the natural logarithm of damage state, *ds*; and

$S_{d,}ds$ is the median value of spectral displacement at which the building reaches the threshold of the damage state, *ds*.

Rather than using spectral displacement, S_d, as the ground-motion metric, the fragility curves developed by UPD-ICE were converted to macroseismic intensity so that they could be seamlessly integrated into REDAS. The details of the development of Philippine-specific earthquake fragility curves are presented in Pacheco *et al.*, (2011). The lognormal parameters for fragility curves derived analytically are provided in Table 12. Fragilities for those buildings derived heuristically through expert judgement are given in Table 13. With results in Tables 12 and 13, given the shaking intensity in MMI, one may estimate the probability a building type of interest being in a given damage state, for use in REDAS to combine hazard, exposure, vulnerability information.

Table 12: *Lognormal parameters for fragility curves derived analytically and converted from PGA to MMI using the Gutenberg and Richter (1942) intensity conversion equation (source Pacheco et al., 2011). The original lognormal parameters for fragility curves in terms of PGA can be found in Pacheco et al. (2011).*

Material	Type	Sub-type	Slight		Moderate		Extensive		Complete	
			Median	Beta	Median	Beta	Median	Beta	Median	Beta
Concrete	CWS	CWS-L	8.22	0.14	8.58	0.15	9.16	0.14	10.21	0.15
	C1	C1-L	7.16	0.12	7.92	0.12	8.60	0.11	9.46	0.10
		C1-M (Pre-code)	7.70	0.12	8.07	0.11	8.77	0.11	9.18	0.10
		C1-M (Low-code)	7.72	0.12	8.13	0.11	8.81	0.10	9.22	0.10
		C1-M (High-code)	7.71	0.12	8.01	0.12	8.93	0.10	9.86	0.09
	C4	C4-H (Pre-code)	6.60	0.16	6.77	0.16	7.43	0.14	8.26	0.12
		C4-H (Low-code)	6.99	0.14	7.30	0.13	7.83	0.12	8.61	0.11
		C4-H (High-code)	7.21	0.13	7.92	0.11	8.60	0.11	9.46	0.10
Steel	S1	S1-L (Pre-code)	7.70	0.14	7.92	0.14	8.93	0.11	9.41	0.11
		S1-L (Low-code)	7.79	0.12	8.13	0.13	8.88	0.13	9.37	0.11
		S1-L (High-code)	8.17	0.13	8.63	0.12	9.08	0.11	9.65	0.10
		S1-M (Pre-code)	7.41	0.12	8.28	0.11	9.04	0.10	9.54	0.09
		S1-M (Low-code)	7.74	0.12	8.45	0.11	9.35	0.10	9.73	0.09
		S1-M (High-code)	8.15	0.11	8.96	0.10	9.27	0.10	10.06	0.09

Table 13: *Lognormal parameters for fragility curves derived in terms of MMI using heuristic expert opinion (source Pacheco et al., 2011).*

Type	Sub-type	Slight		Moderate		Extensive		Complete	
		Median	Beta	Median	Beta	Median	Beta	Median	Beta
W1	W1-L	8.85	0.09	9.27	0.09	9.70	0.09	10.16	0.09
W3	W3-L	8.93	0.09	9.35	0.09	9.79	0.09	10.25	0.09
N	N-L	8.57	0.09	8.94	0.09	9.34	0.09	9.76	0.09
CHB	CHB-L	5.50	0.16	6.30	0.17	7.10	0.15	7.40	0.14
MWS	MWS-L	5.50	0.16	6.30	0.17	7.10	0.15	7.40	0.14

CASUALTY MODELLING APPROACHES

Whilst the primary aim of the study in Iloilo City was to determine the impact to the built environment, a key concern in disaster management in any earthquake impact assessment is provision of an estimate of the human impact in terms of the number of casualties (fatalities and injuries). Recently, simple models have become available that estimate the probable number of fatalities from earthquakes anywhere in the word (e.g., Jaiswal and Wald, 2010). These simple models empirically relate the number of people exposed to different levels of strong ground shaking to the number of fatalities observed from historical events. However, because we implement a framework for computing building damage that calculate the probability of a building being in a given damage state, we are able to undertake more sophisticated analyses to estimate the number of fatalities resulting from scenario earthquakes using the HAZUS framework (NIBS-FEMA, 2011).

The primary cause of fatalities in earthquakes is due to the collapse of buildings. HAZUS prescribes a complex logic to estimate casualties from earthquakes, which considers factors such as building occupancy with time of day, building collapse rates for a given building type in a complete damage state, and the probability of being in a given casualty severity state, given the damage state of the building. HAZUS defines four casualty severity levels ranging from minor injuries to death.

In our framework, we only calculate direct fatalities (casualty severity level 4) resulting from the earthquake. Each building type has specific fatality rates for a given level of building damage (slight, moderate, extensive and complete). Additionally, buildings in the complete damage state are further subdivided into collapse and non-collapse. Collapse rates, given a building is in a complete damage state, are given in Table 14. Given a particular damage state for any building type, we assume the fatality rates as given in Table 15. Figure 32 indicates the probability of exceedance curves to given damage states for several of the key building types in Iloilo City.

Table 14: *The percentage of buildings with complete damage expected to be collapsed for UPD-ICE building types in Iloilo City. Collapse rates for most building types are taken directly from HAZUS-MH (NIBS-FEMA, 2011). Collapse rates for those building types that are not represented in HAZUS-MH are infered from buildings of similar contruction and vulnerability (e.g., CHB uses URM collapse rate). Building types using inferred collapse rates are indicated with an asterix (*).*

UPD-ICE BUILDING TYPE	COLLAPSE RATE (%)
C1L	13
C1M	10
C2M	10
C4M	10*
CHB	15*
CWS	13*
MWS	15*
N	3*
S1L	8
S3L	3
URA	15*
W1	3
W2	3
W3	3

Table 15: *Indoor fatality rates for a given state of structural damage (after HAZUS-MH).*

DAMAGE STATE	FATALITY RATE (%)
Slight	0.0
Moderate	0.0
Extensive	0.001
Complete (Non-collapse)	0.01
Complete (Collapse)	10.0

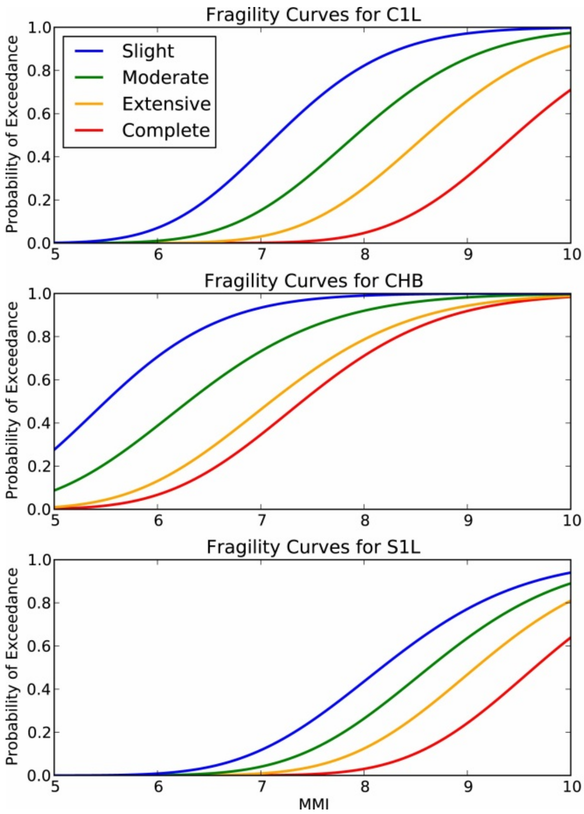

Figure 32: *An example suite of high-code fragility curves for key building types in Iloilo as developed by Pacheco et al, (2011), plotted for intensities MMI V-X.*

COMBINING HAZARD, EXPOSURE AND VULNERABILITY IN REDAS

Using the exposure module and the fragility functions discussed above, the QuiveR Project has developed an earthquake impact computation framework to evaluate that damage to structures and associated fatalities. The procedure for estimating impact from the earthquake scenario is outlined below. ***For each gridded floor area for a given building type***, the following steps are undertaken:

1. Extract the observed shaking level at each grid cell
2. Given the shaking intensity, find the probability of the building type of interest being in a given damage state
3. Correlate the damage probabilities with the floor area for each grid cell
4. For each barangay, aggregate total building floor area being in each damage state
5. Given the average floor area from the survey data for each building type (see Table 11), estimate the number of buildings in each damage state

Damage estimates using this framework are subsequently output as comma separated value (CSV) files. These files provide the total floor area of each building type being in a particular damage state, subdivided by barangay. These data provide valuable information as to the extent of building damage across a spatial area and can give an estimate of the potential cost of repair.

In addition to providing an estimate of the impact to the built environment, it is also important to provide an estimate of the potential human impact in any earthquake scenario. To do this, we again adopt a computational framework similar to that of HAZUS-MH. However, as described above, we only implement the calculation of direct fatalities, and not casualties with varying levels of injury. In this calculation, we assume that building occupancy is proportional to total floor area. Therefore, population distribution in Iloilo City is determined by dividing the total population in each barangay by the total floor area (of combined building types) per barangay. The total population of the city was taken from the NSO 2007 Census of Population. Thus the total number of fatalities *Y* can be approximated by the following functional form:

$$Y(F|D) = \sum_{i=1}^{n} A_i * \left[D_{slight} * F_{slight} + D_{\mathrm{mod}} * F_{\mathrm{mod}} + D_{ext} * F_{ext} + D_{comp} * \left(D_{col} * F_{col} + D_{non-col} * F_{non-col}\right)\right]$$

where *F* is the conditional probability of fatalities given the probability if being in a given damage state, *D*, A_i is the total population of the i^{th} grid cell and *n* is the total number of cells in the grid. The probability of being in a given damage state is itself conditional upon the level of ground-shaking experienced at the grid cell. Assuming uniform occupancy proportional to floor area, the total number of fatalities is finally estimated by building type using the UPD-ICE fragilities and collapse rates given complete damage.

The implementation of the building damage calculation for REDAS is provided in the Python code in the electronic supplement (see Appendix I).

Iloilo Earthquake Impact Assessment

IMPACT FROM SCENARIO EVENTS

This section outlines the outcomes from the two earthquake scenarios undertaken for Iloilo City: 1) the M_W 6.3 earthquake on a buried fault 15 km from Iloilo City, and; 2) the M_W 8.1 earthquake on the West Panay Fault. For each scenario, we estimate the approximate number of buildings being in a given damage state for each barangay. We also estimate the number of fatalities resulting from each event given the methodology above.

M_W 6.3 Scenario, 15 km from Iloilo City

The ground-shaking in Iloilo City for the M_W 6.3 scenario is approximately of degree MMI VIII. Table 16 below gives the total number of buildings being in a complete damage state based on the UPD-ICE fragility functions for the scenario. Whilst not all of these buildings will have collapsed during the earthquake, these are the estimated number of buildings that are beyond repair and will need to be demolished. The total number of buildings in each of the damage states is illustrated for the pre- and high-code scenarios in Figures 33 and 34 respectively. The relative breakdown of buildings in each damage state for the high-code scenario is documented in Table 17. Losses are considered for both pre-code and high-code scenarios. It can be seen that for some of the most common building types that fragilities do not change with building vintage, except for some specific building types (e.g., C1M). Consequently, the overall contribution to the impact assessments of comparing pre-code and high-code is relatively small. Figure 35 shows the mapped distribution of buildings in a complete damage state using high-code fragilities. It is observed that the damage distribution generally mimics the building density distribution. This is because the ground-shaking intensity for the M_W 6.3 scenario does not vary significantly across Iloilo City. Consequently, it should be expected that the damage is consistent with building density.

Table 16: *The estimated number of buildings estimated to be in a complete damage state following the M_W 6.3 scenario. Results are approximate only.*

UP BUILDING TYPE	NO. BUILDINGS COMPLETE DAMAGE (PRE-CODE)	NO. BUILDINGS COMPLETE DAMAGE (HIGH-CODE)	ESTIMATED BUILDINGS IN ILOILO CITY	RATE OF BUILDINGS IN COMPLETE DAMAGE STATE (HIGH-CODE)
C1L	585	585	9029	6.5%
C1M	77	11	688	1.6%
C4M	1	0	3	0.0%
CHB	1134	1134	1517	75%
CWS	672	672	10665	6.3%
MWS	213	213	285	75%
N	72	72	3250	2.2%
S1L	11	5	118	4.2%
W1	42	42	6341	0.7%
W3	3	3	605	0.5%

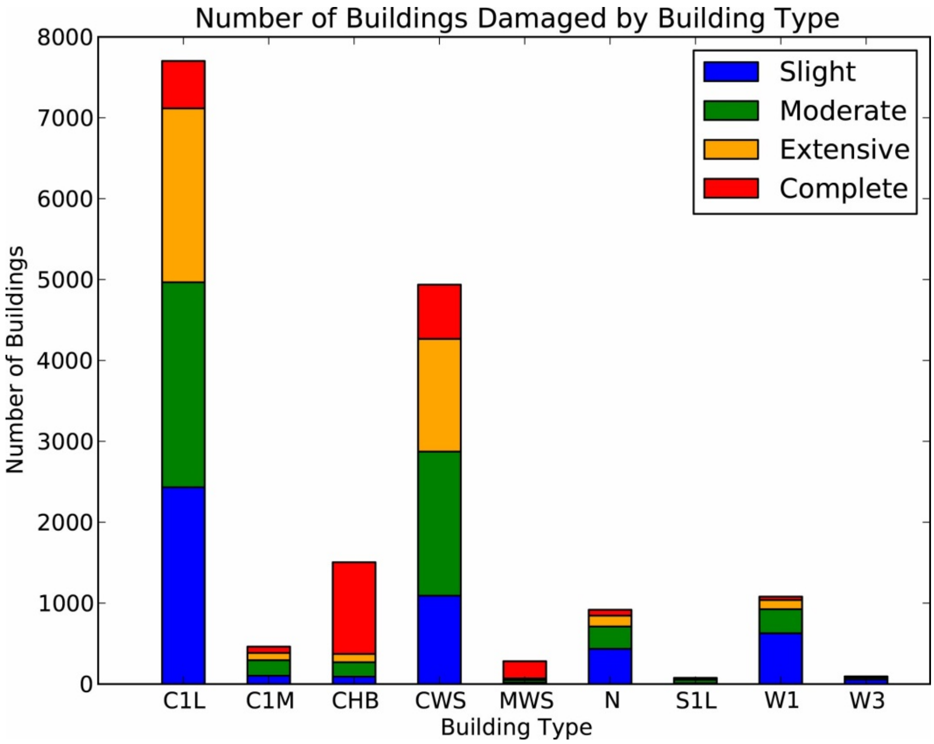

Figure 33: *Total number of buildings in each damage state for the pre-code M_W 6.3 scenario.*

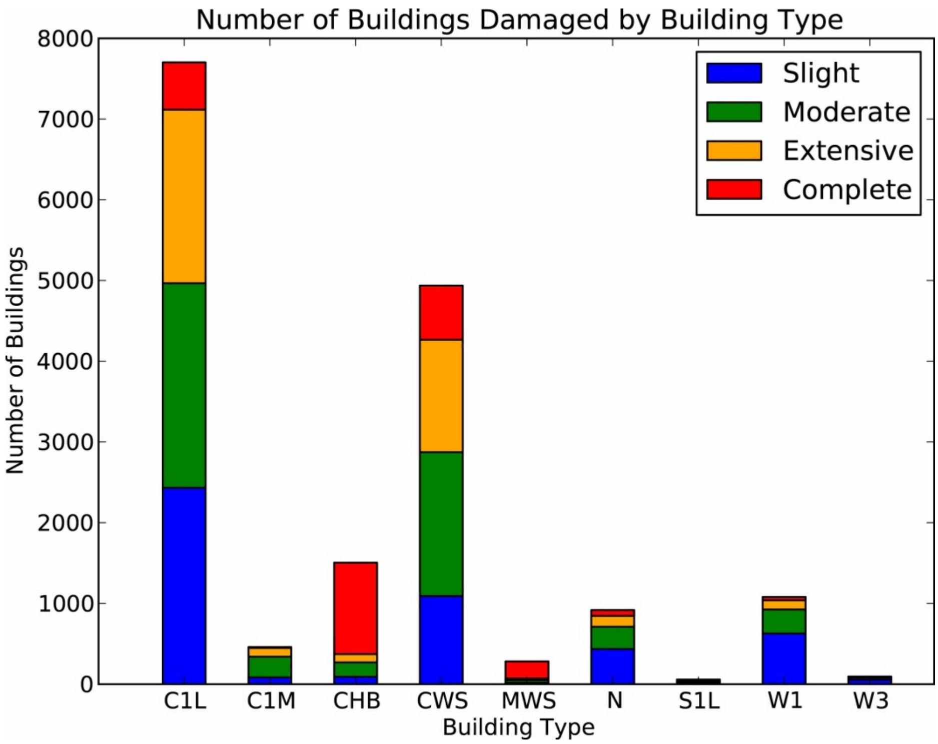

Figure 34: *Total number of buildings in each damage state for the high-code M_W 6.3 scenario. Note that the only building types to have differing fragility functions from the pre-code scenario are C1M and S1L.*

__Table 17:__ The number of buildings estimated to be in a slight, moderate, extensive, or complete damage state following the M_W 6.3 scenario. Results are approximate only and use the UPD-ICE high-code fragility functions.

UP BUILDING TYPE	BUILDINGS WITH SLIGHT DAMAGE	BUILDINGS WITH MODERATE DAMAGE	BUILDINGS WITH EXTENSIVE DAMAGE	BUILDINGS WITH COMPLETE DAMAGE	ESTIMATED BUILDINGS IN ILOILO CITY
C1L	2432	2534	2151	585	9029
C1M	83	257	108	11	688
C4M	1	1	1	0	3
CHB	91	178	103	1134	1517
CWS	1091	1783	1392	672	10665
MWS	17	33	19	213	285
N	435	276	135	72	3250
S1L	21	18	13	5	118
W1	628	297	114	42	6341
W3	55	26	10	3	605

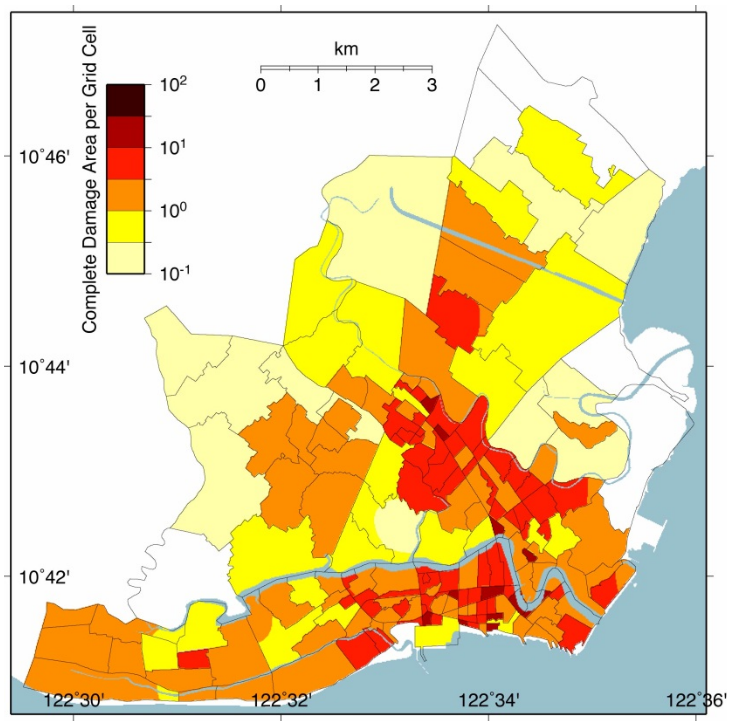

__Figure 35:__ The distribution of buildings in a complete damage state for the M_W 6.3 high-code scenario. The colour scaling indicates the total floor area of all building types in a complete damage state for a 225 m^2 grid cell. Minor fluctuations in damage across some barangays reflect changes in shaking intensity.

For the M_W 6.3 scenario, we observe approximately 8.5% of the total building stock in Iloilo City (i.e., combined building types) to be in a complete damage state. In contrast, approximately 50% of the buildings will sustain no structural damage from this scenario, depending on building type. However, it should be noted that the relative proportion of vulnerable building types – such as CHB and MWS – in a complete damage state contribute significantly to the total building damage and final humanitarian impacts, The number of fatalities for the M_W 6.3 scenario are also estimated. Table 18 shows the estimated number of fatalities by building type, in addition to the total number. **Depending on the code level used, we estimate approximately 440-470 fatalities in Iloilo City from direct earthquake impacts for the M_W 6.3 scenario.**

Table 18: *Estimated number of fatalities by building type from the M_W 6.3 scenario.*

UPD-ICE BUILDING TYPE	FATALITIES (PRE-CODE)	FATALITIES (HIGH-CODE)
C1L	103	103
C1M	41	6
C4M	1	0
CHB	137	137
CWS	152	152
MWS	31	31
N	1	1
S1L	6	3
W1	1	1
W3	0	0
Total	**474**	**435**

M_W 8.1 Scenario on the West Panay Fault

As discussed in the Earthquake Hazard section, the second largest earthquake to have affected the Philippines in historical times is the 1948 M_W 8.1 Lady Caycay earthquake. While the precise location and magnitude are not well known for this earthquake, recent assessment of shaking intensity from this earthquake suggest the West Panay Fault to be a possible source. The ground-shaking in Iloilo City from our scenario earthquake is approximately of degree MMI IX.

Since we did not observe significant differences in earthquake impact between the pre-code and high-code scenarios for the M_W 6.3 scenario, we only show results for the high-code scenario below (Fig. 36). Table 19 gives the total number of buildings being in a complete damage state using the UPD-ICE fragility functions for the M_W 8.1 scenario. The total number of buildings in each of the damage states is given in Table 20. Figure 37 shows the mapped distribution of buildings in a complete damage state using high-code fragilities for the M_W 8.1 scenario earthquake on the West Panay fault.

For the M_W 8.1 scenario, we generally observe approximately 26% of the building stock to be in a complete damage state (based on the estimated number of buildings) and about 20% of buildings will sustain no structural damage. Again, vulnerable building types such as CHB and MWS will sustain very high levels of damage, and will contribute significantly to the number of human casualties. Table 21 shows the estimated number of fatalities for the M_W 8.1 scenario by building type, in addition to the total number. **Based on the UPD-ICE high-code fragilities, we estimate approximately 1,500 fatalities in Iloilo City from direct earthquake impacts for the M_W 8.1 scenario.**

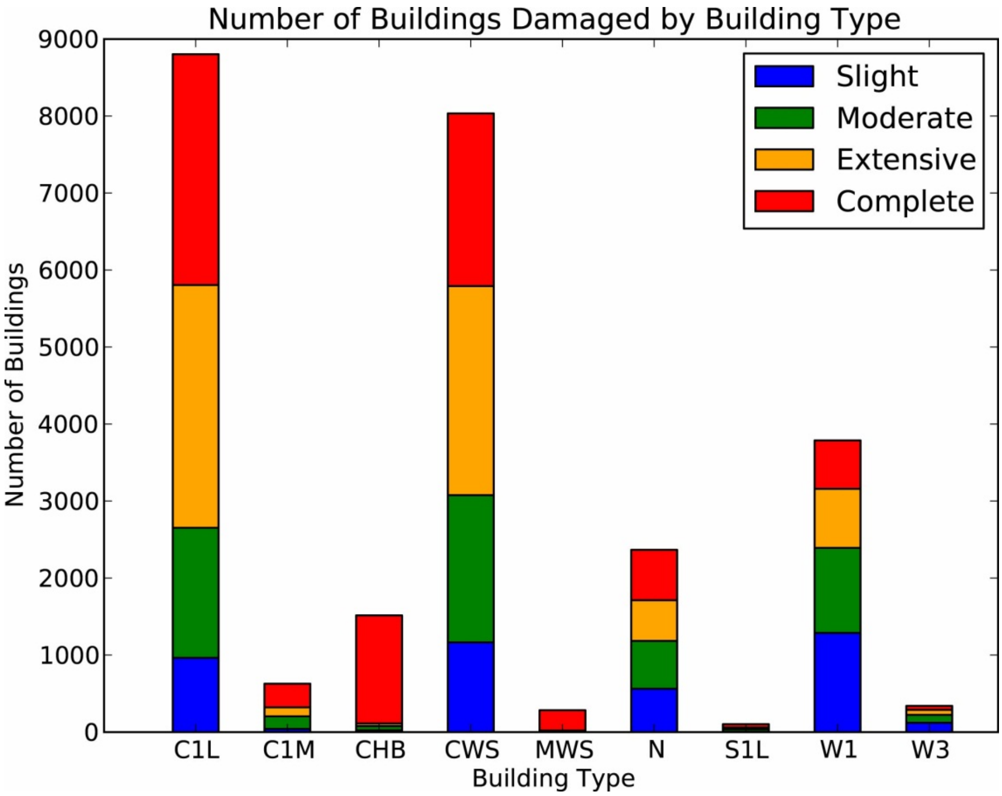

Figure 36: *Total number of buildings in each damage state for the high-code M_W 8.1 scenario.*

Table 19: *The number of buildings estimated to be in a complete damage state following the M_W 8.1 scenario. Results are approximate only.*

UP BUILDING TYPE	NO. BUILDINGS COMPLETE DAMAGE (HIGH-CODE)	TOTAL BUILDINGS IN ILOILO CITY	RATE OF BUILDINGS IN COMPLETE DAMAGE STATE (HIGH-CODE)
C1L	2997	9029	33%
C1M	307	688	45%
C4M	2	3	67%
CHB	1404	1517	93%
CWS	2243	10665	21%
MWS	264	285	93%
N	655	3250	20%
S1L	43	118	36%
W1	629	6341	10%
W3	51	605	8.4%

Table 20: *The number of buildings estimated to be in a slight, moderate, extensive, or complete damage state following the M_W 8.1 scenario. Results are approximate only and use the UPD-ICE high-code fragility functions.*

UP BUILDING TYPE	BUILDINGS WITH SLIGHT DAMAGE	BUILDINGS WITH MODERATE DAMAGE	BUILDINGS WITH EXTENSIVE DAMAGE	BUILDINGS WITH COMPLETE DAMAGE	TOTAL BUILDINGS IN ILOILO CITY
C1L	964	1689	3153	2997	9029
C1M	41	164	116	307	688
C4M	0	0	0	2	3
CHB	23	55	34	1404	1517
CWS	1166	1910	2716	2243	10665
MWS	4	10	6	264	285
N	563	621	528	655	3250
S1L	5	33	22	43	118
W1	1288	1104	767	629	6341
W3	121	102	66	51	605

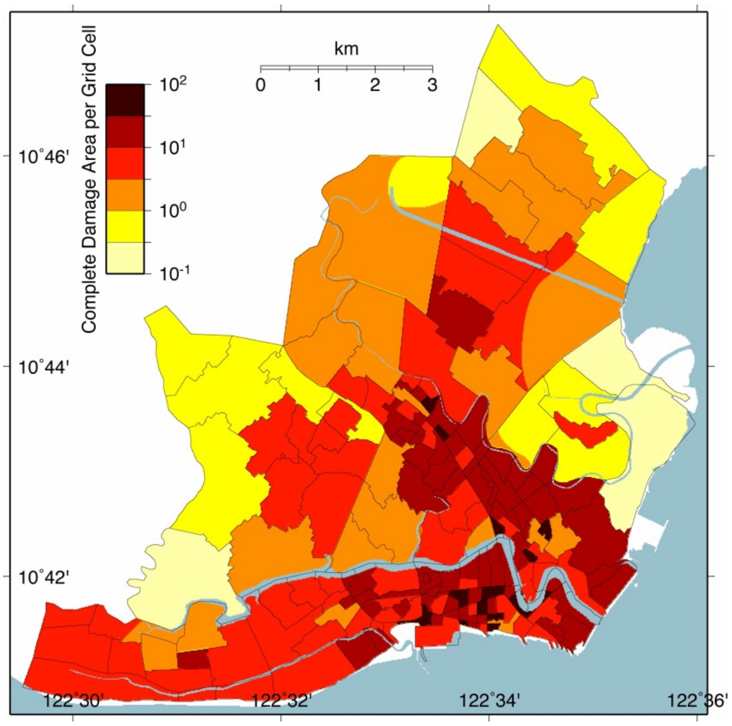

Figure 37: *The distribution of buildings in a complete damage state for the M_W 8.1 high-code scenario. The colour scaling indicates the total floor area of all building types in a complete damage state for a 225 m^2 grid cell. Minor fluctuations in damage across some barangays reflect changes in shaking intensity.*

Table 21: *Estimated number of fatalities by building type from the M_W 8.1 scenario earthquake.*

UPD-ICE BUILDING TYPE	FATALITIES (HIGH-CODE)
C1L	525
C1M	166
C4M	2
CHB	170
CWS	508
MWS	38
N	7
S1L	25
W1	19
W3	2
Total	**1,461**

DISCUSSION OF IMPACT RESULTS

The earthquake impact results presented above indicate that should a large earthquake occur near Iloilo City, there will be widespread damage and casualties across the city. However, these results are sensitive to the full range of input models, from ground-motion estimation, the assumed exposure module, and the engineering fragility functions. As discussed in the Earthquake Hazard Section of this report, PHIVOLCS' preferred ground-motion to intensity conversion is that of Gutenberg and Richter (1942). First-order assessment of this conversion presented above suggests that it may overestimate intensity by up to 2 intensity units for large earthquakes at near-source distances. If this observation holds true in reality, it will have a significant impact on losses from scenario events. For example, if we apply a uniform reduction of one intensity unit across Iloilo City area for the M_W 6.3 scenario (high-code), the total number of buildings in a complete damage state is 2.5% of the total estimated building stock, as opposed to 8.5% from the best-estimate above. Furthermore, the number of fatalities is approximately 25% of the total value given in Table 18. This result clearly demonstrates the sensitivity of the impact results to uncertainties in ground-motion estimates.

While the CHB and MWS building types comprise only about 5% of the building stock in Iloilo City, they contribute to approximately 20% of the total damage. These are unreinforced masonry structures that are most prolific in the lower socioeconomic regions of Iloilo City and the Philippines in general. Consequently, these results clearly demonstrate that strategies to discourage the construction of these buildings, possibly through education and training programs, should be considered to mitigate the risks associated with vulnerable structures like CHB and MWS.

It is important to note the fatality estimates provided above are for indoor casualties only. Furthermore, the estimates assume a worst case scenario that the total population of Iloilo City is occupying a dwelling or non-residential building at the time of the earthquake, which is extremely unlikely. However, since we do not have detailed models to describe the population distribution as a function of time, we distribute population uniformly across all building types and usages. As observed for the M_W 6.3 scenario, the vintage of the building does not significantly influence the damages observed for the building stock in Iloilo City. This is because the fragilities of the most prolific building types in the city (e.g., C1L, CHB, CWS, N, and W1) are not controlled by the Philippine building code (Pacheco *et al.*, 2011). While a similar result might be expected in other provincial cities in the Philippines, we would expect that the change in building code would influence the potential impacts from earthquakes in Metro Manila, for example, where medium- to high-rise buildings are more common.

While we do not provide the uncertainties associated with fatality modelling, recent studies suggest that any fatality estimate can only be considered a first-order approximation and should be expected to vary at least be half an order of magnitude (approximately a factor of three) to the values presented herein (Jaiswal and Wald, 2010).

RECOMMENDATIONS FROM THE ILOILO CITY INFORMATION, EDUCATION AND COMMUNICATION CAMPAIGN

On 16th June 2011, an Information, Education and Communication (IEC) campaign was held with the in Iloilo with key members from the LGU and academics from local universities. The purpose of the IEC was to provide a high-level overview of the work that has been undertaken under the QuiveR Project, and to discuss option for preparing and responding to earthquake disasters in the city. The program for the IEC is provided in Appendix XIV. Overall the work undertaken in the QuiveR program was well received by the Iloilo LGU, and the community was enthusiastic to continue the work in developing a database of buildings to improve their own understanding of natural hazard risk to the city. Moreover, civil engineering academics from local universities identify the importance of these assessments and plan to incorporate building classification as part of the structural engineering syllabus. Lessons learned from these activities will help community planners develop mitigation strategies for future natural hazard events. Some of the key recommendations from the IEC plenary sessions were to:

- enlist local university engineering students to complete the building surveys of Iloilo City
- involve local structural engineers to assist with building assessments for both inventory surveys and post-disaster assessments
- prioritise areas for emergency response and evacuation
- undertake geotechnical surveys to determine the potential for liquefaction in Iloilo City
- assess the risk to Iloilo City's heritage buildings given their importance to tourism and the local economy
- consider multi-hazard scenario in contingency planning
- continue PHIVOLCS' development of an Android-based exposure data capture tool and offer Iloilo City an advanced REDAS training course to ensure continuity of building data capture

Discussion

The earthquake pilot study in Iloilo City has introduced new tools and methods to develop exposure and vulnerability information for the Philippines. The application of these methods has subsequently strengthened the capacity of Philippine technical agencies to undertake risk assessments for local communities. Better understanding the risk to Philippine communities enhances disaster preparedness which can deliver faster, more effective responses to humanitarian crises. It is recognised by international aid agencies that the resilience of developing countries to natural disasters can be enhanced by investing in science and technology to improve the anticipation of these catastrophic events (Australian Agency for International Development, 2011). Consequently, projects such as QuiveR play a major role in raising awareness of the risks associated with natural hazards and provide a mandate for local decision makers to implement strategies which reduce the risk to safeguard their communities. Below we list some of the specific lessons learned for disaster risk reduction in Iloilo City, as well as lessons to take forward into the Greater Metro Manila Area Risk Assessment Project.

LESSONS FOR DISASTER RISK REDUCTION IN ILOILO CITY

From the Iloilo City risk pilot study, we were able to obtain first-order assessments of impact from two earthquake scenarios in the Western Visayas region. As discussed above, the impacts estimated from these scenarios result in significant damages to the building stock in Iloilo City. Through these assessments, we have demonstrated the potential vulnerability of Iloilo City, should a large-magnitude earthquake occur in the future. Armed with this information, it is hoped that city officials and town planners will implement strategies to minimise the impact of future natural hazards, in particular earthquakes. Activities that reduce the impact of natural disasters often strengthen a community’s ability to respond and cope in the aftermath of a disaster.

Through the development of the first-order building exposure database, it was demonstrated how the collection of such data was important to quantify the risk to Iloilo City. However, the database gathered in the present study was limited by the small number of buildings surveyed relative to the complete building stock of Iloilo City. The LGU recognise this limitation and are committed to continue to develop the building exposure database, which will further improve the assessments of risk to the community from potential natural hazards.

To date the impact assessments are largely unvalidated. In particular, the vulnerability models are based on physical models or engineering judgement. These functions would benefit being validated from detailed building surveys following future damaging earthquakes in the Philippines. Consequently, strategies to prepare and rapidly respond to future earthquakes should be developed such that building damage information is gathered and can be used to either validate or update existing earthquake fragility models developed by UPD-ICE through the QuiveR project.

LESSONS LEARNED FOR THE GREATER METRO MANILA AREA RISK ASSESSMENT PROJECT

The earthquake impact pilot study has resulted in many achievements for both PHIVOLCS and researchers at UPD-ICE. Following the Iloilo City project, AusAID Manila has committed to supporting additional disaster risk reduction activities for the Greater Metro Manila Area. Below we list some of the key lessons learned from the Iloilo City pilot study that can be used to inform the Greater Metro Manila Area (GMMA) risk assessment project.

Hazard

Above we have presented comparisons of several intensity prediction techniques against available Philippine macroseismic intensity data. The general philosophy for estimating ground shaking intensity in the REDAS software is to first estimate peak ground motions using a ground-motion prediction equation, then convert these ground motions to intensity using published conversion equations. As tested above, the preferred intensity conversion equation used by PHIVOLCS (Gutenberg and Richter, 1942) performs well in the intermediate-distance range (approximately 100-200 km). However, this equation does appear to overestimate intensity at near-source distances (less than 100 km). This phenomenon, particularly for large-magnitude earthquakes was recognised by the authors. In light of these results, it is recommended that PHIVOLCS investigate the use of alternative intensity conversions to be used in the Philippines for earthquake impact assessments such as those discussed herein.

Exposure

The development of the building exposure database for the Iloilo City was by far the largest and most time consuming component of the earthquake risk pilot study. Consequently, this component also introduced the largest challenges of the project. Despite the size of the task, the project successfully compiled an exposure database which aggregated data at different resolutions into a dataset that could be used to estimate the level of building damage for earthquake scenarios in Iloilo City. However, since this project is the first to develop an exposure methodology outside of Metro Manila and to implement methods that can theoretically be used anywhere in the Philippines, there are many limitations in this work and many potential improvements that could be undertaken. In particular, methods for dealing with informal settlements, improved identification of barangay usage (i.e., residential, commercial, industrial, or rural), and population growth and urban expansion should be addressed.

Informal settlements are presently not handled well in the existing QuiveR methodology because we were not able to obtain suitable data to support the development of exposure models in these areas. It was impractical to undertake building surveys in these areas because of the likelihood of personal security and safety issues. Improved methods to estimate the density of the buildings and the likely number of residents in each dwelling should be introduced for future risk assessment work in the Philippines. These methods should use high-resolution aerial photography to identify and map areas of informal settlements as well as providing estimates of the density of buildings. These remote techniques could subsequently be followed up with limited ground reconnaissance to validate remotely-derived exposure models.

The exposure methodology presented herein relied heavily on the 2000 NSO household census data. Databases such as the NSO data provide a snapshot in time and as such, they only provide an accurate representation of population and building exposure for the time period captured by the census. Basic population growth rates, such as those produced by the United Nations (2006) can be used to modify population to “present-day” numbers. This method is suitable for regional or national-scale assessments. However, when undertaking natural hazard risk assessments at a city level, more detailed information regarding the growth of urban regions, particularly for those barangays which are expanding into zones previously dominated by rural land use. Consequently, better methods need to be developed to examine the spatial and temporal varying nature of communities to estimate such that we can estimate present day or projected exposure for communities in the Philippines. These models will need to consider the dominant use of barangays, such as those which are dominated by commercial, residential, industrial or rural land use.

Data gathered from the field survey component was critical for the development of the building typology as well as for the development of the statistical coefficients to map high-level NSO data to a form that could be used for the impact assessments based on the UPD-ICE engineering schema. Since field survey data capture can be challenging on many fronts, the use of existing information wherever possible is crucial to the success of the survey. Information that is useful during the planning of a survey includes:

- accurate spatial datasets depicting the barangay boundaries and road network;
- recent aerial imagery of the area to be surveyed;
- building locations or footprints (if available);
- existing building data (from LGUs or others); and
- other spatially referenced information that assists in locating buildings in the field.

One challenge to international collaboration such as the QuiveR project is the maintenance of versions of datasets, documents, scripts and other electronic files. Whilst it is easy to transfer data files between collaborators, tracking the most current version of a single dataset can be difficult and confusing. It is recommended that GA and PHIVOLCS investigate a data sharing environment that provides the security and accessibility needed for effective data exchange. An agreed system of file management and naming would also benefit future engagement. Further recommendations on the design and implementation of field surveys are provided in Appendix XV.

Finally, as has been observed in undertaking similar exposure database development in Australia, there is often no standard data schema or storage format. Likewise, in the Philippines, processing of other LGU tax assessment data is likely to require individual methods to parse the data into a format that can be used as an exposure database system. Consequently, it is likely the processes used in Iloilo, as outlined in Appendices VII and VIII, will require modification following a review of LGU data.

Vulnerability

The fragility curves developed by UPD-ICE in the QuiveR Project were the first generation of building fragility curves developed for the Philippines by Philippine engineers. Consequently, it is acknowledged that these functions will continue to evolve as the knowledge of the behaviour of Philippine buildings in response to ground shaking is better understood, not only in Iloilo City but in other parts of the country as well. We recognise that these functions require an iterative approach to converge on reality.

Moreover, the building types observed in Iloilo City represent a subset of the building types that would be observed in the GMMA. Consequently, additional functions beyond those developed by Pacheco *et al*. (2011) described herein will be required for the GMMA. In particular, high-rise buildings were not common in Iloilo City, whereas, these structural types are common throughout Metro Manila.

Impact Assessment Module

The impact module developed for the QuiveR program was developed specifically to work with Generic Mapping Tools (Wessel and Smith, 1991) grid files within REDAS to determine the number of buildings damaged per barangay across Iloilo City. The tool was designed specifically so that it could extract the number of buildings in any given damage state for any earthquake scenario for a spatial area. The advantage of the grid-based approach is that it can consider the spatial variation of ground-motion, and its impact on the built environment, across a barangay. However, one limitation in this module is that the resolution of the grid must be smaller than the smallest barangay, so that each barangay is sampled within the grid. Over a large spatial area, such as the Greater Metro manila Area, this approach will result in very large computation times.

One alternative is to apply a point-based impact approach. This approach will enable the user to calculate earthquake impacts for many barangays in a relatively short computation time. However, because all of the barangay attributes are aggregated to a single point, it does not consider any potential variation in ground-motion across a barangay. Consequently, this approach will not represent impacts to barangays of large spatial extent very well, unless the barangay usage other than the built environment is specified and removed from the grid of interest.

Conclusions

The earthquake impact pilot study undertaken for Iloilo City has led to many significant achievements. Some of the key achievements of this work include:

1. the active participation of key stakeholders (e.g., UPD-ICE and the Iloilo City LGU) in QuiveR activities through institutional arrangements;
2. promotion of the development of the first national building typology of the Philippines;
3. introduction of a framework for the development of a building exposure database using national and LGU data that can be systematically improved with time;
4. development of an inexpensive building data capture system that can run without the need of proprietary software;
5. development of earthquake vulnerabilities for key building types in the Philippines;
6. application of new exposure and impact modules in REDAS;
7. calculation of earthquake impact assessments for Iloilo City; and
8. demonstration of the value of natural hazard impact assessments to support disaster management and land use planning in the Iloilo LGU.

These are significant achievements, particularly since many of the models and methods used herein were developed specifically for this study. However, it is acknowledged that there is significant scope to improve the methods used herein though: 1) the further review of ground-shaking models, 2) the collection of new exposure data to validate our underpinning assumptions, 3) the review and revision of first generation Philippine fragility functions and 4) the implementation of more complex impact modelling techniques.

This program has been successful in strengthening natural hazard risk assessment capacity for Government of the Philippine technical agencies. PHIVOLCS have adopted these methodologies and integrated them into their standard REDAS training module. Consequently, the methodologies developed herein are presently being applied to other municipalities in the Philippines. The Greater Metro Manila Area Risk Assessment Project is currently leveraging off many of the advances made through the QuiveR program, and this work will further enhance existing methods and models to further advance the risk assessment capabilities in the Philippines.

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Appendices

APPENDIX I – DIRECTORY STRUCTURE OF ELECTRONIC MATERIAL

Table I.1: *Directory structure indictating location of the electronic material gathered in the process of undertaking the earthquake impact assessments of Iloilo City.*

DIRECTORY NAME	DESCRIPTION OF ELECTRONIC MATERIAL
Assessors Office	Iloilo City Assessors Office description of building classification system
Conference Papers	Papers presented at conferences on the QuiveR study
Field Survey Notes	Handout notes used for the field surveys in Iloilo City
IEC Flyer	Summary flyer produced for the Information, Education and Communication workshop in Iloilo City
REDAS Impact Code	Python codes and associated data required to develop exposure input data for REDAS and to undertake earthquake impact assessments. See Appendices XI and XII for more information.
Survey Data	All data gathered during the two field surveys. Data includes a summary spreadsheet of all data collected and additional post-processing (Final_Building.xls). The xls file includes links to all photographs taken in the surveys
UPD-ICE Report	Development of the Philippine building typology and fragility curves of key building types in the Philippines
Workshop I	Presentations from Workshop I in Clark, Pampanga
Workshop II	Presentations from Workshop II in Tagaytay
Workshop III	Presentations from the engineering Workshop III at PHIVOLCS

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Woody M. Cabardo	ASEP / Cor Jesu College	Instructor	0918-9451016	cabardowoody@yahoo.com
Daniel Peckley	KASC-Kalinga	Project Officer V	0917-8979986	dan.peckley@gmail.com

APPENDIX III – AGENDA OF EARTHQUAKE EXPOSURE AND VULNERABILITY WORKSHOP, 13-14 NOVEMBER 2009, CLARK AIR BASE

Earthquake Exposure and Vulnerability Workshop

13-14 November 2009
Clark Economic Zone, Pampanga

Aims, Attendee List and Agenda

Background & Aims:

The Philippine Institute of Volcanology and Seismology (PHIVOLCS) and Geoscience Australia (GA) are currently engaged in a program to better understand and reduce the risks associated with earthquake hazards in the Philippines. The program will build upon existing tools and methods to estimate impact for local earthquakes.

PHIVOLCS has developed the Rapid Earthquake Damage Assessment System (REDAS) software that can model ground motion, liquefaction, earthquake-induced landslides, and tsunami hazards. The PHIVOLCS-GA partnership intends to enhance impact assessment modules in REDAS to incorporate earthquake damage functions for specific structure types across the Philippines. Fundamental to any earthquake impact study is the need to develop a framework to classify and gather building inventory information.

Consequently, the workshop discussion will be targeted to advance the following project aims:

1. to develop a uniform classification scheme for the Philippines building stock (Day 1);
2. to develop simple seismic vulnerability models for key building types (Day 2);
3. to anticipate the applicability of the classification scheme to other major hazards such as floods, storms, and landslides (Day 1 and Day 2)

The process through which these aims will be achieved will be through:-

4. reviewing the scope of the overall project;
5. reviewing current Philippines research on earthquake exposure, vulnerability and risk for metropolitan buildings;
6. reviewing the lessons learned from historical earthquake impacts as to building vulnerability;
7. reviewing currently available information on exposure;
8. reviewing techniques for systematic exposure information capture;
9. examining the range of approaches to link severity of ground motion to damage and casualties;
10. achieving a consensus on the approach to relatively rank earthquake vulnerability for the full range of buildings; and,
11. scoping future research directions to be considered in support of the project goals.

Agenda:-

Session One

Friday 9:00 am to 12:30 pm

(Chair:-Ishmael C. Narag)

Preliminaries 20mins

- **Welcome & Introductions** Renato U. Solidum,Jr.
- **AusAid/GA** **(To be invited)**

Background to Project 40mins

–
– Aims/
– The significance of understanding earthquake risk
– Ishmael C. Narag
– REDAS Maria Leonila P. Bautista
– READY Renato U. Solidum, Jr
– DMAPS Benito M. Pacheco

General discussion facilitated by session chair 10mins

Historical Seismic Events 30mins

– Back analysis of previous seismic events Maria Leonila P. Bautista
    – Ground motion intensity
    – Exposure
    – Severity of damage

General discussion facilitated by session chair 10mins

Urban Development and Building Regulations   Carlos Villaraza
30mins

- Development and enforcement of building regulations
- Identification of pivotal years and urban development milestones
- Regional variation of construction type and regulations
- Comparison of Philippines standards with those in the US

Urban Development and Building Regulations in Japan
(Takahashi, Oyointer) 15 mins

General discussion facilitated by session chair 10mins

Exposure Data Sources   50mins

- National Statistics Office
    - Classification
    - Building stock data – Why collecting? Who's using?
    - Demographics
    - Data resolution

- Local Government SourcesIloilo City Assessor (25 mins)
    - Classification
    - Building stock data – Why collecting? Who's using?

Data resolution

General discussion facilitated by session chair 20mins

- ***Guide Questions 1: Are there available catalogues of building types (at the local and national levels)? How can our NSO and local building data be made more directly useful for earthquake damage estimation? How about for estimation of damage due to other hazards?***

Session Two
Friday 1:30 pm to 5:00 pm
(Chair:- Mark Leonard)

Exposure Classification [c/o various presenters] 100mins

–
– MMEIRS categorisation (c/o PHIVOLCS) Angelito G. Lanuza (30 mins)
– Building types that historically have contributed to damage (c/o PHIVOLCS)
–

– Mapping of building types (where possible) to HAZUS types drawing on comparison between codes and level of enforcement.(c/o UP, PICE)
– Usage in DMAPS and DQRP (c/o PICE and ASEP)
– Jorge Genota (40 mins)
–
–
– Pre-Earthquake Classification tools used by FEMA 154 (e.g.ROVER) (c/o GA)Trevor Allen (30 mins)

–

General discussion facilitated by session chair 20mins

- ***Guide Questions 2: What is an appropriate building type classification for the Philippines? (initially for earthquakes, but for other hazards in the long term) Does the classification adequately reflect specific examples? Do certain types indicate greater vulnerability?***

Some Types Considered in Field Surveys 50mins

–
– ATC 20
  – Pre- and post-disaster information capture (c/o GA)Mark Edwards

General discussion facilitated by session chair 30mins

- ***Guide Question 3: How can we harmonize a local building classification into the FEMA building classification?***

Session Three
Saturday 9:00 am to 12:30 pm
(Chair:-Carlos Villaraza)

Historical Disaster Events 100mins

- Floods — Engr Espiritu /Iloilo City Engr
- Tsunami — Rannie Ison
- Wind — Adam Abinales
- Landslides — Daniel Peckley, Jr.Different vulnerabilities Willy Lopez

General discussion facilitated by session chair 30mins

Seismic Vulnerability Function Types 80mins

- Intensity Scales: MMI, EMS and PEIS (PHIVOLCS) — Ishmael NaragMMEIRS Damage Functions — Angelito Lanuza
- CSM methodology as incorporated into HAZUS (c/o GA) Mark Edwards
Intensity Based Vulnerability Functions (c/o GA) Mark Edwards

General discussion facilitated by session chair 30mins

- ***Guide Questions 4: What parameter (e.g.intensity,pga,pgv) do we want to use as our basis for our seismic damage functions?***
- ***What methodology do we want to use to derive damage function curves? How about for estimation of damage due to other hazards?***

Session Four
Thursday 1:30 pm to 3:30 pm
(Chair:- Benito M. Pacheco)

Example: Intensity Based Vulnerability Functions (c/o GA) 60mins

- Methodology review — Trevor Allen
- Exposure definition schema
- Benchmark curves for key types
- Relative ranking approach
- Use in seismic loss estimation

Research Needs in Seismic Loss Estimation (Guide Questions)

- Observations on applicability of examples — Benito M. Pacheco
- Summary of issues behind research
- Overview of research activities
- Summary of desired outcomes and outputs

General discussion facilitated by session chair 60mins

Closing Ceremonies:

Workshop Close

APPENDIX IV – SUMMARY OF EARTHQUAKE AND WIND VULNERABILITY WORKSHOP, 12-13 MARCH 2010, TAGAYTAY

Earthquake and Severe Wind Vulnerability Workshop

12th and 13th March 2010, Tagaytay

Aims, Attendee List and Agenda

Background & Aims:-

The Philippine Institute of Volcanology and Seismology (PHIVOLCS), the Philippine Atmospheric, Geophysical & Astronomical Services Administration (PAGASA) and Geoscience Australia (GA) are currently engaged in programs to better understand and reduce the risks associated with natural hazards in the Philippines. These programs will build upon existing tools and methods to estimate impact for local natural hazard events.

The present workshop follows the highly-successful Philippine Earthquake Exposure & Vulnerability Workshop, 14-15 November 2009, held at Clark Airfield, Pampanga, which laid the framework for natural hazard risk assessments in the Philippines. The present workshop will build upon lessons from the previous meeting and develop a basic suite of vulnerability models for common structural types in the Philippines, which can subsequently be used in severe wind and earthquake impact assessments. It is intended that these initial models will be refined and updated through future activities to be discussed on the second day of the workshop.

The key aims for Day One are:-

- to review the building stock categorisation schema developed for earthquake at the previous workshop and subsequently circulated for review. In particular, the applicability of the schema to severe wind and flood inundation will be reconsidered;
- to review the process developed for generating an exposure database for the Philippines and the associated statistical data requirements. The role of targeted field survey activity will be reviewed;
- to review the progress being made on field survey tool development in support of an exposure database for the Philippines and, in due course, post disaster survey activity;
- to review the process for wind impact assessment and to reach a consensus on the nature of the vulnerability models to be developed and implemented;
- to review wind hazards in the Philippines
- to review historically the design of Philippines buildings for severe wind and the implications for wind resistance;
- to review the historical performance of Philippines structures when subject to severe wind;
- to develop a benchmark suite of wind vulnerability relationships; and,
- to agree on the out-of-session process to follow for populating the full building stock schema through a relative ranking approach.

The key aims for Day Two are:-

- to review the process for earthquake impact assessment and to reconfirm the nature of the vulnerability models to be developed and implemented;
- to be briefed on the design base shear / seismic performance implications of the historical development of Philippines building regulations for earthquake;
- to review historical performance of structures subjected to strong earthquake ground motion
- to develop a benchmark suite of earthquake vulnerability relationships
- to agree on the out-of-session process for populating the full building stock schema
- to resolve on the next steps for deriving a better understanding of the vulnerability of Philippines buildings to severe wind and earthquake.

Agenda:-

Session One **Friday 9:00 am to 12:30 pm**

(Chair:- __________)

Preliminaries

Welcome & Introductions (AusAID, PAGASA) 30mins

Workshop Aims and Approach (Mark Edwards) 15mins

Review of last workshop outcomes (Benny Pacheco) 30mins

- Objectives
- Impact frameworks for earthquake
- Building stock categorisation

Exposure

Review of Schema (Benny Pacheco) 30mins

- Feedback on applicability for multiple hazards
- Discussion on local hazard variation implications on vulnerability level.
- Are industrial buildings adequately covered?

General discussion facilitated by session chair

Exposure Database Development (Krishna Nadimpalli) 20mins

- Datasets and integration process for Iloilo
- Mapping to schema
- Statistical data requirements

General discussion facilitated by session chair

Field Survey Tool Development (Trevor Allen) 20mins

- Description of tool
- Review of fields
- Future utilisation

General discussion facilitated by session chair

Wind Vulnerability

Severe Wind Hazard of the Philippines (PAGASA) 20mins

- Probabilistic hazard spatially across the Philippines
- Wind event types and predominance for infrastructure design

Implications of Philippine Building Regulation Development to Wind Resistance 50mins

- Historical review of urban development in the Philippines
- Development and enforcement of building regulations
- Regional variation of construction type and regulations
- Identification of pivotal years
- Implied wind resistance (3s wind gust) for compliant structures
- Level of compliance of schema building categories with time

General discussion facilitated by session chair

Session Two

Friday 1:30 pm to 5:00 pm

(Chair:- __________)

Wind Impact Framework and Vulnerability Models (Craig Arthur)

30mins

- Impact assessment process
- Nature of wind vulnerability models
- Consensus on approach

General discussion facilitated by session chair

Historical Building Performance to Severe Wind (PAGASA) 60mins

- Review of severe historical wind events and their impacts.
- Learnings on wind vulnerability

General discussion facilitated by session chair

Benchmark Wind Vulnerability Curve Development (Benny Pacheco & Mark Edwards)

90mins

- Review of vulnerability model concepts, assessment process and tools
- Identification of 6 to 8 building types selected from schema categories
- Review of vulnerability knowledge for each.
- Consensus on vulnerability curve

Heuristic Out of Session Process **(Benny Pacheco)** 30mins

- Discussion of process
- Review of tools with demonstration

General discussion facilitated by session chair

Session Three

Saturday 9:00 am to 12:30 pm
(Chair:- __________)

Earthquake Vulnerability

Context for Earthquake Impact Assessments **(Leyo Bautista)** 20mins

Earthquake Impact Framework and Vulnerability Models **(Trevor Allen)** 20mins

- Impact assessment process
- Nature of wind vulnerability models
- Consensus on approach

General discussion facilitated by session chair

Implications of Philippine Building Regulation Development for Seismic Resistance **(Carlos Villaraza)** 30mins

- Extension of Workshop One presentation
- Implied base shear for compliant structures
- Level of compliance of schema building categories with time

General discussion facilitated by session chair

Historical Building Performance to Earthquake **(ASEP/PICE?)** 60mins

- Review of severe historical earthquake events and their impacts.
- Learnings on earthquake vulnerability in the context of building stock schema

General discussion facilitated by session chair

Benchmark Earthquake Vulnerability Curve Development **(Benny Pacheco & Mark Edwards)** 90mins

- Identification of 6 to 8 building types selected from schema categories
- Review of vulnerability knowledge for each.
- Comparison with Padang Earthquake results for similar structures
- Consensus on vulnerability curve

Heuristic process facilitated by session chair with

Session Four
Saturday 1:30 pm to 4:00 pm
(Chair:- ___________)

Heuristic Out of Session Process (Mark Edwards) 30mins

- Discussion of process
- Review of tools

General discussion facilitated by session chair

Earthquake Vulnerability Research Opportunities (Benny Pacheco) 60mins

- Selection of schema structure types for fundamental research
- Framework for vulnerability development (CSM?)
- Outline of research proposals to be developed out of session

General discussion facilitated by session chair

Next Steps

Workshop Summary and Next Steps (Session Chair) 60mins

- Summary of outcomes
- Out of session ranking processes
- Integration of respondent rankings to produce vulnerability model suite.
- Field survey activity
- Methodologies for post-disaster surveys
- Research opportunities
- Future workshop activity

Workshop Close

APPENDIX V – HISTORICAL MACROSEISMIC INTENSITY DATA

Table V.1: *Earthquake source information for events used to evaluate macroseismic intensity prediction methods. Source information is obtained from PAGER-CAT (Allen et al., 2009). The identification number (ID) is derived from the earthquake origin time and is of the format YYYYMMDDhhmm.*

ID	EARTHQUAKE LOCATION	LON	LAT	DEPTH (KM)	MAG
196808012019	Casiguran	122.078	16.383	52.1	7.7
197001101207	Davao	126.687	6.786	59.7	7.3
197004070534	Baler	121.659	15.771	29.7	7.2
197204251930	Lubang Island	120.312	13.388	29.7	7.2
197205220604	Tuguegarao	122.220	16.620	42.0	6.9
197212020019	Davao	126.654	6.461	82.7	7.4
197303170830	Ragay Gulf	122.794	13.400	45.0	7.5
197402190330	Alabat	122.129	14.024	18.7	6.1
197510310828	Samar	125.999	12.537	51.1	7.6
197608161611	Moro Gulf	124.091	6.292	58.5	8.0
197611101728	Surigao	126.838	8.023	57.5	5.5
197703182143	Eastern Luzon	122.273	16.749	42.5	7.2
198003311241	Eastern Luzon	121.907	16.123	29.4	6.4
198010260514	Eastern Samar	125.459	11.776	55.9	6.3
198111221505	Northeastern Luzon	120.835	18.738	34.3	6.4
198201110610	Bicol	124.337	13.833	31.7	7.1
198308171217	Laoag	120.792	18.222	28.7	6.6
198504240107	Northern Luzon	120.812	16.541	5.1	6.1
199002080715	Bohol	124.629	9.766	23.5	6.7
199006140740	Panay	122.045	11.390	17.8	7.1
199007160726	Luzon	121.180	15.723	23.8	7.7
199411141915	Mindoro	121.059	13.540	28.2	7.1
200203052116	Palimbang	124.210	6.020	31.0	7.5
200302151101	Masbate	124.010	12.200	9.0	6.2

Table V.2: *Macroseismic intensities digitized from historical reports of Philippine earthquakes (e.g., Tong-Yuen and Kintanar, 1985). The corresponding earthquake source information is provided in Table V.1.*

ID	EVENT	INTENSITY	OBSERVATION LOCALITY	OBS. LAT	OBS. LON
19680801201921	Casiguran	9	Maddela	16.35	121.675
19680801201921	Casiguran	8	Casiguran	16.2768	122.1245
19680801201921	Casiguran	6	Tuguegarao City	17.613	121.728
19680801201921	Casiguran	8	San Pablo	17.447	121.792
19680801201921	Casiguran	8	Tumauini	17.277	121.805
19680801201921	Casiguran	8	Ilagan	17.1468	121.8858
19680801201921	Casiguran	8	Aurora	16.9917	121.6348
19680801201921	Casiguran	8	Baler	15.7589	121.5628
19680801201921	Casiguran	7	Aparri	18.358	121.637
19680801201921	Casiguran	6	Baguio	16.4016	120.594
19680801201921	Casiguran	7	Dagupan	16.043	120.333
19680801201921	Casiguran	7	Cabanatuan	15.4954	120.9761
19680801201921	Casiguran	7	Iba	15.33	119.975
19680801201921	Casiguran	6	Quezon City	14.623	121.004

ID	EVENT	INTENSITY	OBSERVATION LOCALITY	OBS. LAT	OBS. LON
19680801201921	Casiguran	6	City of Manila	14.6	120.992
19680801201921	Casiguran	5	Infanta	14.7472	121.6483
19680801201921	Casiguran	6	Jomalig	14.714	122.372
19680801201921	Casiguran	6	Alabat	14.103	122.01
19680801201921	Casiguran	5	Laoag City	18.195	120.5922
19680801201921	Casiguran	4	Vigan	17.5767	120.3854
19680801201921	Casiguran	5	Lucena City	13.937	121.612
19680801201921	Casiguran	5	Calapan City	13.3787	121.1828
19680801201921	Casiguran	4	Romblon	12.577	122.268
19680801201921	Casiguran	5	Legazpi City	13.1412	123.7296
19680801201921	Casiguran	5	Virac	13.585	124.23
19680801201921	Casiguran	5	Catarman	9.133	124.675
19680801201921	Casiguran	5	Tarlac City	15.488	120.588
19700110120708	Davao	7	Davao City	7.1	125.57
19700110120708	Davao	6	Hinatuan	8.3682	126.3362
19700110120708	Davao	6	Cagayan de Oro	8.48	124.642
19700110120708	Davao	5	Surigao City	9.791	125.4933
19700110120708	Davao	3	Cebu City	10.3	123.903
19700110120708	Davao	4	Tacloban City	11.2447	125.0066
19700110120708	Davao	4	Borongan	11.608	125.433
19700110120708	Davao	4	Catbalogan	11.778	124.88
19700110120708	Davao	4	Catarman	9.133	124.675
19700407053405	Baler	9	Baler	15.7589	121.5628
19700407053405	Baler	9	Dipaculao	15.8488	121.5373
19700407053405	Baler	8	Dingalan	15.4026	121.3874
19700407053405	Baler	6	Casiguran	16.2768	122.1245
19700407053405	Baler	6	Bayombong	16.487	121.152
19700407053405	Baler	7	Baguio	16.4016	120.594
19700407053405	Baler	7	Dagupan	16.043	120.333
19700407053405	Baler	7	Cabanatuan	15.4954	120.9761
19700407053405	Baler	7	Infanta	14.7472	121.6483
19700407053405	Baler	7	Tuguegarao City	17.613	121.728
19700407053405	Baler	6	Vigan	17.5767	120.3854
19700407053405	Baler	6	Laoag City	18.195	120.5922
19700407053405	Baler	5	Aparri	18.358	121.637
19700407053405	Baler	5	Tarlac City	15.488	120.588
19700407053405	Baler	5	Iba	15.33	119.975
19700407053405	Baler	6	Quezon City	14.623	121.004
19700407053405	Baler	7	City of Manila	14.6	120.992
19700407053405	Baler	4	Jomalig	14.714	122.372
19700407053405	Baler	6	Tanay	14.5	121.283
19700407053405	Baler	6	Alabat	14.103	122.01
19700407053405	Baler	7	Tayabas	14.028	121.588
19700407053405	Baler	5	Daet	14.116	122.958
19700407053405	Baler	5	Calapan City	13.3787	121.1828
19700407053405	Baler	6	Legazpi City	13.1412	123.7296
19700407053405	Baler	4	Catarman	9.133	124.675
19720425193009	Lubang Island	7	Lubang	13.8552	120.1212
19720425193009	Lubang Island	6	Olongapo	14.8423	120.2878
19720425193009	Lubang Island	6	Plaridel	14.885	120.858

ID	EVENT	INTENSITY	OBSERVATION LOCALITY	OBS. LAT	OBS. LON
19720425193009	Lubang Island	6	Quezon City	14.623	121.004
19720425193009	Lubang Island	6	Santa Rita	15.0005	120.6177
19720425193009	Lubang Island	5	Iba	15.33	119.975
19720425193009	Lubang Island	5	Cabanatuan	15.4954	120.9761
19720425193009	Lubang Island	4	Infanta	14.7472	121.6483
19720425193009	Lubang Island	3	Alabat	14.103	122.01
19720425193009	Lubang Island	6	Tayabas	14.028	121.588
19720425193009	Lubang Island	5	Coron	12.0056	120.1934
19720425193009	Lubang Island	5	Cuyo	10.853	121.007
19720522060402	Tuguegarao	7	Cabanatuan	15.4954	120.9761
19720522060402	Tuguegarao	6	Tuguegarao City	17.613	121.728
19720522060402	Tuguegarao	6	Baguio	16.4016	120.594
19720522060402	Tuguegarao	6	Dagupan	16.043	120.333
19720522060402	Tuguegarao	5	Aparri	18.358	121.637
19720522060402	Tuguegarao	4	Laoag City	18.195	120.5922
19720522060402	Tuguegarao	5	Iba	15.33	119.975
19720522060402	Tuguegarao	6	Quezon City	14.623	121.004
19720522060402	Tuguegarao	7	City of Manila	14.6	120.992
19721202001947	Davao	7	Davao City	7.1	125.57
19721202001947	Davao	6	General Santos	6.108	125.167
19721202001947	Davao	6	Cagayan de Oro	8.48	124.642
19721202001947	Davao	6	Malaybalay City	8.153	125.082
19721202001947	Davao	5	Hinatuan	8.3682	126.3362
19721202001947	Davao	3	Dipolog City	8.5861	123.3446
19721202001947	Davao	3	Cebu City	10.3	123.903
19721202001947	Davao	4	Borongan	11.608	125.433
19721202001947	Davao	4	Catbalogan	11.778	124.88
19721202001947	Davao	4	Catarman	9.133	124.675
19730317083051	Ragay Gulf	5	Daet	14.116	122.958
19730317083051	Ragay Gulf	4	Dagupan	16.043	120.333
19730317083051	Ragay Gulf	5	Quezon City	14.623	121.004
19730317083051	Ragay Gulf	4	Infanta	14.7472	121.6483
19730317083051	Ragay Gulf	6	City of Manila	14.6	120.992
19730317083051	Ragay Gulf	4	Tayabas	14.028	121.588
19730317083051	Ragay Gulf	3	Virac	13.585	124.23
19730317083051	Ragay Gulf	4	Legazpi City	13.1412	123.7296
19730317083051	Ragay Gulf	5	Romblon	12.577	122.268
19730317083051	Ragay Gulf	3	Catbalogan	11.778	124.88
19730317083051	Ragay Gulf	8	Lopez	13.8917	122.257
19730317083051	Ragay Gulf	8	Guinayangan	13.897	122.45
19730317083051	Ragay Gulf	7	Alabat	14.103	122.01
19730317083051	Ragay Gulf	6	San Francisco (Aurora)	13.3483	122.518
19740219033021	Alabat	4	Baguio	16.4016	120.594
19740219033021	Alabat	4	Dagupan	16.043	120.333
19740219033021	Alabat	5	Baler	15.7589	121.5628
19740219033021	Alabat	4	Cabanatuan	15.4954	120.9761
19740219033021	Alabat	4	Malolos	14.848	120.81
19740219033021	Alabat	5	Infanta	14.7472	121.6483
19740219033021	Alabat	6	Quezon City	14.623	121.004

ID	EVENT	INTENSITY	OBSERVATION LOCALITY	OBS. LAT	OBS. LON
19740219033021	Alabat	7	City of Manila	14.6	120.992
19740219033021	Alabat	4	Cavite	14.483	120.9088
19740219033021	Alabat	7	Alabat	14.103	122.01
19740219033021	Alabat	5	Tayabas	14.028	121.588
19740219033021	Alabat	7	Calauag	13.955	122.287
19740219033021	Alabat	5	Daet	14.116	122.958
19740219033021	Alabat	5	Boac	13.4483	121.838
19740219033021	Alabat	4	Legazpi City	13.1412	123.7296
19740219033021	Alabat	3	Catarman	9.133	124.675
19751031082802	Samar	6	Legazpi City	13.1412	123.7296
19751031082802	Samar	5	Catarman	9.133	124.675
19751031082802	Samar	4	Masbate	12.367	123.625
19751031082802	Samar	7	Catbalogan	11.778	124.88
19751031082802	Samar	7	Borongan	11.608	125.433
19751031082802	Samar	7	Tacloban City	11.2447	125.0066
19751031082802	Samar	4	Roxas City	11.5851	122.7555
19751031082802	Samar	5	Iloilo City	10.708	122.55
19760816161107	Moro Gulf	3	Virac	13.585	124.23
19760816161107	Moro Gulf	3	Legazpi City	13.1412	123.7296
19760816161107	Moro Gulf	3	Masbate	12.367	123.625
19760816161107	Moro Gulf	3	Catarman	9.133	124.675
19760816161107	Moro Gulf	3	Catbalogan	11.778	124.88
19760816161107	Moro Gulf	3	Borongan	11.608	125.433
19760816161107	Moro Gulf	8	Roxas City	11.5851	122.7555
19760816161107	Moro Gulf	3	Iloilo City	10.708	122.55
19760816161107	Moro Gulf	4	Palo	11.16	124.9904
19760816161107	Moro Gulf	4	Guiuan	11.032	125.725
19760816161107	Moro Gulf	4	La Carlota	10.425	122.925
19760816161107	Moro Gulf	4	Cebu City	10.3	123.903
19760816161107	Moro Gulf	5	Maasin (Capital)	10.132	124.8386
19760816161107	Moro Gulf	4	Surigao City	9.791	125.4933
19760816161107	Moro Gulf	4	Dumaguete City	9.305	123.307
19760816161107	Moro Gulf	4	Tagbilaran City	9.6539	123.867
19760816161107	Moro Gulf	6	Butuan	8.9524	125.5292
19760816161107	Moro Gulf	6	Dipolog City	8.5861	123.3446
19760816161107	Moro Gulf	5	Cagayan de Oro	8.48	124.642
19760816161107	Moro Gulf	7	Iligan	8.23	124.237
19760816161107	Moro Gulf	6	Malaybalay City	8.153	125.082
19760816161107	Moro Gulf	4	Hinatuan	8.3682	126.3362
19760816161107	Moro Gulf	9	Pagadian	7.8262	123.4367
19760816161107	Moro Gulf	8	Sibuco	7.292	122.067
19760816161107	Moro Gulf	9	Margosatubig	7.578	123.165
19760816161107	Moro Gulf	10	Cotabato	7.1999	124.231
19760816161107	Moro Gulf	5	Davao City	7.1	125.57
19760816161107	Moro Gulf	8	Zamboanga	6.9	122.08
19760816161107	Moro Gulf	10	Lake Sebu	6.2682	124.73
19760816161107	Moro Gulf	5	General Santos	6.108	125.167
19760816161107	Moro Gulf	8	Jolo	6.053	120.997
19761110172823	Surigao	4	Catbalogan	11.778	124.88
19761110172823	Surigao	4	Borongan	11.608	125.433

ID	EVENT	INTENSITY	OBSERVATION LOCALITY	OBS. LAT	OBS. LON
19761110172823	Surigao	4	Tacloban City	11.2447	125.0066
19761110172823	Surigao	4	Guiuan	11.032	125.725
19761110172823	Surigao	6	Surigao City	9.791	125.4933
19761110172823	Surigao	7	Butuan	8.9524	125.5292
19761110172823	Surigao	5	Cagayan de Oro	8.48	124.642
19761110172823	Surigao	8	Hinatuan	8.3682	126.3362
19761110172823	Surigao	5	Malaybalay City	8.153	125.082
19761110172823	Surigao	3	Cotabato	7.1999	124.231
19761110172823	Surigao	5	Davao City	7.1	125.57
19761110172823	Surigao	3	General Santos	6.108	125.167
19770318214352	Eastern Luzon	2	Calayan	19.2811	121.4637
19770318214352	Eastern Luzon	3	Laoag City	18.195	120.5922
19770318214352	Eastern Luzon	2	Vigan	17.5767	120.3854
19770318214352	Eastern Luzon	7	Tuguegarao City	17.613	121.728
19770318214352	Eastern Luzon	8	Palanan	17.06	122.437
19770318214352	Eastern Luzon	4	Baguio	16.4016	120.594
19770318214352	Eastern Luzon	5	Dagupan	16.043	120.333
19770318214352	Eastern Luzon	5	Cabanatuan	15.4954	120.9761
19770318214352	Eastern Luzon	3	Infanta	14.7472	121.6483
19770318214352	Eastern Luzon	2	Bataan	7.6175	126.096
19770318214352	Eastern Luzon	5	City of Manila	14.6	120.992
19770318214352	Eastern Luzon	5	Cavite	14.483	120.9088
19770318214352	Eastern Luzon	4	Alabat	14.103	122.01
19770318214352	Eastern Luzon	3	Tayabas	14.028	121.588
19770318214352	Eastern Luzon	4	Lucena City	13.937	121.612
19770318214352	Eastern Luzon	4	Calapan City	13.3787	121.1828
19770318214352	Eastern Luzon	2	Virac	13.585	124.23
19800331124147	Eastern Luzon	3	Aparri	18.358	121.637
19800331124147	Eastern Luzon	3	Vigan	17.5767	120.3854
19800331124147	Eastern Luzon	4	Tuguegarao City	17.613	121.728
19800331124147	Eastern Luzon	6	Palanan	17.06	122.437
19800331124147	Eastern Luzon	6	Baguio	16.4016	120.594
19800331124147	Eastern Luzon	5	Bayombong	16.487	121.152
19800331124147	Eastern Luzon	7	Casiguran	16.2768	122.1245
19800331124147	Eastern Luzon	5	Dagupan	16.043	120.333
19800331124147	Eastern Luzon	6	Baler	15.7589	121.5628
19800331124147	Eastern Luzon	6	Cabanatuan	15.4954	120.9761
19800331124147	Eastern Luzon	5	Tarlac City	15.488	120.588
19800331124147	Eastern Luzon	4	Iba	15.33	119.975
19800331124147	Eastern Luzon	5	Infanta	14.7472	121.6483
19800331124147	Eastern Luzon	5	Quezon City	14.623	121.004
19800331124147	Eastern Luzon	6	City of Manila	14.6	120.992
19800331124147	Eastern Luzon	6	Cavite	14.483	120.9088
19800331124147	Eastern Luzon	5	Tayabas	14.028	121.588
19800331124147	Eastern Luzon	5	Daet	14.116	122.958
19801026051419	Eastern Samar	3	Virac	13.585	124.23
19801026051419	Eastern Samar	3	Legazpi City	13.1412	123.7296
19801026051419	Eastern Samar	4	Catarman	9.133	124.675
19801026051419	Eastern Samar	5	Catbalogan	11.778	124.88
19801026051419	Eastern Samar	7	Borongan	11.608	125.433

ID	EVENT	INTENSITY	OBSERVATION LOCALITY	OBS. LAT	OBS. LON
19801026051419	Eastern Samar	6	Tolosa	11.065	125.037
19801026051419	Eastern Samar	6	Dulag	10.955	125.033
19801026051419	Eastern Samar	6	Guiuan	11.032	125.725
19801026051419	Eastern Samar	3	Cebu City	10.3	123.903
19801026051419	Eastern Samar	5	Maasin (Capital)	10.132	124.8386
19801026051419	Eastern Samar	3	Surigao City	9.791	125.4933
19811122150520	Northeastern Luzon	5	Calayan	19.2811	121.4637
19811122150520	Northeastern Luzon	8	Pagudpud	18.5784	120.7923
19811122150520	Northeastern Luzon	7	Burgos	18.513	120.643
19811122150520	Northeastern Luzon	6	Pasuquin	18.337	120.617
19811122150520	Northeastern Luzon	7	Bacarra	18.253	120.61
19811122150520	Northeastern Luzon	6	Laoag City	18.195	120.5922
19811122150520	Northeastern Luzon	3	Aparri	18.358	121.637
19811122150520	Northeastern Luzon	5	Magsingal	17.688	120.423
19811122150520	Northeastern Luzon	3	Vigan	17.5767	120.3854
19811122150520	Northeastern Luzon	3	Tuguegarao City	17.613	121.728
19811122150520	Northeastern Luzon	4	Baguio	16.4016	120.594
19811122150520	Northeastern Luzon	8	Pagudpud	18.5784	120.7923
19811122150520	Northeastern Luzon	5	Santa	17.482	120.433
19811122150520	Northeastern Luzon	4	Calayan	19.2811	121.4637
19820111061006	Bicol	3	Baguio	16.4016	120.594
19820111061006	Bicol	3	Dagupan	16.043	120.333
19820111061006	Bicol	5	Baler	15.7589	121.5628
19820111061006	Bicol	4	Quezon City	14.623	121.004
19820111061006	Bicol	4	Infanta	14.7472	121.6483
19820111061006	Bicol	7	Virac	13.585	124.23
19820111061006	Bicol	2	Calapan City	13.3787	121.1828
19820111061006	Bicol	5	Catarman	9.133	124.675
19820111061006	Bicol	2	Roxas City	11.5851	122.7555
19820111061006	Bicol	5	Catbalogan	11.778	124.88
19820111061006	Bicol	5	City of Manila	14.6	120.992
19820111061006	Bicol	5	Legazpi City	13.1412	123.7296
19820111061006	Bicol	4	Tacloban City	11.2447	125.0066
19830817121756	Laoag	7	Pagudpud	18.5784	120.7923
19830817121756	Laoag	8	Pasuquin	18.337	120.617
19830817121756	Laoag	8	Laoag City	18.195	120.5922
19830817121756	Laoag	7	Paoay	18.062	120.52
19830817121756	Laoag	7	Badoc	17.928	120.473
19830817121756	Laoag	6	Aparri	18.358	121.637
19830817121756	Laoag	6	Vigan	17.5767	120.3854
19830817121756	Laoag	6	Santa	17.482	120.433
19830817121756	Laoag	5	Tuguegarao City	17.613	121.728
19830817121756	Laoag	5	Baguio	16.4016	120.594
19830817121756	Laoag	4	Dagupan	16.043	120.333
19900208071532	Bohol	6	Tagbilaran City	9.6539	123.867
19900208071532	Bohol	8	Jagna	9.6531	124.3694
19900208071532	Bohol	8	Guindulman	9.7631	124.4861
19900208071532	Bohol	7	Garcia Hernandez	9.6146	124.2953
19900208071532	Bohol	7	Loboc	9.6373	124.0304
19900208071532	Bohol	7	Valencia	9.6094	124.2067

ID	EVENT	INTENSITY	OBSERVATION LOCALITY	OBS. LAT	OBS. LON
19900208071532	Bohol	7	Anda	9.7434	124.5757
19900208071532	Bohol	5	Cagayan de Oro	8.48	124.642
19900208071532	Bohol	5	Dumaguete City	9.305	123.307
19900208071532	Bohol	4	Canlaon	10.384	123.219
19900208071532	Bohol	4	Cotabato City	7.1999	124.231
19900614074056	Panay	7	Culasi	11.427	122.055
19900614074056	Panay	7	Libacao	11.49	122.3
19900614074056	Panay	6	Balete	11.552	122.375
19900614074056	Panay	6	Kalibo	11.712	122.363
19900614074056	Panay	6	Madalag	11.531	122.306
19900614074056	Panay	6	Numancia	11.705	122.323
19900614074056	Panay	6	Altavas	11.54	122.487
19900614074056	Panay	6	Makato	11.717	122.29
19900614074056	Panay	6	Sigma	11.422	122.663
19900614074056	Panay	6	Cuartero	11.343	122.67
19900614074056	Panay	6	Calinog	11.123	122.533
19900614074056	Panay	4	Romblon	12.577	122.268
19900614074056	Panay	3	Cebu City	10.3	123.903
19900614074056	Panay	3	Taal	13.878	120.922
19900614074056	Panay	3	Palo	11.16	124.9904
19900716072634	Luzon	8	Cabanatuan	15.4954	120.9761
19900716072634	Luzon	8	Dagupan	16.043	120.333
19900716072634	Luzon	8	Baguio City	16.4016	120.594
19900716072634	Luzon	7	City of Manila	14.6	120.992
19900716072634	Luzon	6	Santa	17.482	120.433
20020305211609	Palimbang	7	Koronadal	6.507	124.843
20020305211609	Palimbang	6	General Santos	6.108	125.167
20020305211609	Palimbang	5	Cotabato City	7.1999	124.231
20020305211609	Palimbang	5	Zamboanga	6.9	122.08
20020305211609	Palimbang	4	Davao City	7.1	125.57
20020305211609	Palimbang	3	Bislig	8.2126	126.3162
20020305211609	Palimbang	3	Pagadian	7.8262	123.4367
20020305211609	Palimbang	3	Malaybalay City	8.153	125.082
20030215110159	Masbate	7.5	Palanas	12.148	123.921
20030215110159	Masbate	7.5	Dimasalang	12.193	123.857
20030215110159	Masbate	7	Uson	12.223	123.787
20030215110159	Masbate	7	San Fernando	12.4772	123.761
20030215110159	Masbate	6	Batuan	12.4238	123.7724
20030215110159	Masbate	6	Milagros	12.218	123.508
20030215110159	Masbate	6	Cataingan	12.0163	123.9943
20030215110159	Masbate	5	Masbate City	12.369	123.619
20030215110159	Masbate	5	Monreal	12.6417	123.675
20030215110159	Masbate	5	Placer	11.87	123.921
20030215110159	Masbate	5	Pio V. Corpuz	11.9	124.031
20030215110159	Masbate	5	San Jacinto	12.568	123.732
20030215110159	Masbate	5	Baleno	12.475	123.495
20030215110159	Masbate	5	Aroroy	12.513	123.397
20030215110159	Masbate	5	Irosin	12.705	124.03
20030215110159	Masbate	5	Legazpi City	13.1412	123.7296
20030215110159	Masbate	4	Palo	11.16	124.9904

ID	EVENT	INTENSITY	OBSERVATION LOCALITY	OBS. LAT	OBS. LON
20030215110159	Masbate	4	Naga City	13.625	123.183
20030215110159	Masbate	4	Roxas City	11.5851	122.7555
20030215110159	Masbate	3	Cebu City	10.3	123.903
20030215110159	Masbate	3	Mandaon	12.23	123.285
19850424010714	Northern Luzon	7	Baguio City	16.4016	120.594
19850424010714	Northern Luzon	5	San Fernando	15.032	120.692
19850424010714	Northern Luzon	4	Lingayen	16.0347	120.2228
19850424010714	Northern Luzon	4	Subic	14.882	120.23
19850424010714	Northern Luzon	4	Santa	17.482	120.433
19850424010714	Northern Luzon	3	Pasuquin	18.337	120.617
19850424010714	Northern Luzon	3	Baler	15.7589	121.5628
19850424010714	Northern Luzon	3	City of Manila	14.6	120.992
19850424010714	Northern Luzon	2	Quezon City	14.623	121.004
19941114191530	Mindoro	8	Baco Oriental	13.358	121.098
19941114191530	Mindoro	3	Guinayangan	13.897	122.45
19941114191530	Mindoro	3	Lucban	14.12	121.555
19941114191530	Mindoro	3	Tagaytay	14.122	120.967
19941114191530	Mindoro	3	City of Manila	14.6	120.992
19941114191530	Mindoro	2	Masbate	12.367	123.625
19941114191530	Mindoro	2	Legazpi City	13.1412	123.7296
19941114191530	Mindoro	7	Verde Island	13.537	121.069

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PHIVOLCS (1994) “15 November 1994 Mindoro Earthquake, Preliminary Report of Investigation”, PHIVOLCS Special Report No. 2, Quick Response Teams, *Philippine Institute of Volcanology and Seismology*, Department of Science and Technology, December 1994.

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APPENDIX VI – SAMPLE SURVEY FORMS FROM 2007 NSO CENSUS

CP FORM 1
AUGUST 1, 2007

NSCB Approval No.:
NSO-0706-01

Expires on:
March 31, 2008

Republic of the Philippines
NATIONAL STATISTICS OFFICE
Manila

2007 CENSUS OF POPULATION
LISTING BOOKLET

620209 **1A**

AUTHORITY: Commonwealth Act No. 591 authorizes this census and the National Statistics Office to collect information on the population.

CONFIDENTIALITY: Section 4 of Commonwealth Act No. 591 states that all information furnished in this form shall be kept STRICTLY CONFIDENTIAL.

GEOGRAPHIC IDENTIFICATION

MONTH OF VISIT
PROVINCE
CITY/MUNICIPALITY
BOOKLET ___ OF ___ BOOKLETS
BARANGAY
ENUMERATION AREA NUMBER

CERTIFICATION

I hereby certify that the data set forth were obtained/reviewed by me personally and in accordance with the instructions given.

ENUMERATOR (SIGNATURE OVER PRINTED NAME) DATE SIGNED

LISTING RECORD

LINE NO	DAY OF VISIT / INDICATOR (1)	BUILDING SERIAL NUMBER (BSN) (2)	HOUSING UNIT SERIAL NUMBER (HUSN) (3)	HOUSEHOLD SERIAL NUMBER (HSN) (4)	INSTITUTIONAL SERIAL NUMBER (ISN) (5)	NAME OF HOUSEHOLD HEAD OR NAME/TYPE OF INSTITUTION [IF VACANT HOUSING UNIT, WRITE VHU; IF VACANT BUILDING, WRITE VBLDG] / ADDRESS [ENTER HOUSE NUMBER AND STREET OR SITIO NAME] (6)	POPULATION COUNT: TOTAL (7)	MALE (8)	FEMALE (9)	REMARKS (10)
1										
2										
3										
4										
5										
6										
7										
8										
9										
TOTAL		(A)	(B)	(C)	(D)	TOTAL HOUSEHOLD POPULATION	(E)	(F)	(G)	
VACANT						TOTAL INSTITUTIONAL POPULATION	(H)	(I)	(J)	
						TOTAL POPULATION				

CP FORM 2
AUGUST 1, 2007

NSCB Approval No.:
NSO-0706-02

Expires on:
March 31, 2008

POPCEN 2007
Republic of the Philippines
NATIONAL STATISTICS OFFICE
Manila

2007 CENSUS OF POPULATION
HOUSEHOLD QUESTIONNAIRE

26273418 **2A**

AUTHORITY:
Commonwealth Act No. 591 authorizes this census and the National Statistics Office to collect information on the population.

CONFIDENTIALITY:
Section 4 of Commonwealth Act No. 591 states that all information furnished in this form shall be kept STRICTLY CONFIDENTIAL.

CERTIFICATION

I hereby certify that the data set forth were obtained/reviewed by me personally and in accordance with the instructions given.

ENUMERATOR
(SIGNATURE OVER PRINTED NAME)

DATE ACCOMPLISHED

TEAM SUPERVISOR
(SIGNATURE OVER PRINTED NAME)

DATE REVIEWED

CENSUS AREA SUPERVISOR
(SIGNATURE OVER PRINTED NAME)

DATE REVIEWED

RD/PSO/STAT/DSO/SCO/CO
(SIGNATURE OVER PRINTED NAME)

DATE REVIEWED

GEOGRAPHIC IDENTIFICATION

BOOKLET ☐ OF ☐ BOOKLETS

PROVINCE

CITY/MUNICIPALITY

BARANGAY

ENUMERATION AREA NUMBER

BUILDING SERIAL NUMBER

HOUSING UNIT SERIAL NUMBER

HOUSEHOLD SERIAL NUMBER

LINE NUMBER OF RESPONDENT

NAME OF HOUSEHOLD HEAD — LAST NAME — FIRST NAME

ADDRESS — HOUSE NUMBER AND STREET NAME OR NAME OF SITIO

INTERVIEW RECORD

NUMBER OF VISITS	VISIT 1	VISIT 2	VISIT 3
DATE OF VISIT MONTH:DAY			
TIME BEGAN HOUR:MINUTE			
TIME ENDED HOUR:MINUTE			
RESULT OF VISIT * (SEE CODES)			
NEXT VISIT			
DATE MONTH:DAY			
TIME HOUR:MINUTE			

SUMMARY OF VISIT

ENUMERATOR'S CODE

NUMBER OF VISITS MADE

FINAL RESULT OF VISIT *

NUMBER OF HOUSEHOLD MEMBERS

NUMBER OF MALES

NUMBER OF FEMALES

*** CODES FOR RESULT OF VISIT**

1 Completed
2 Partly Completed
3 Refused
4 Postponed
5 Self-Administered
6 Household Not Around/No Respondent Around
7 Others, ________ SPECIFY

HOUSEHOLD DEFINITION

A **household** is a social unit consisting of a person living alone or a group of persons who sleep in the same housing unit and have a common arrangement in the preparation and consumption of food.

HOUSEHOLD MEMBERSHIP

PLEASE LIST THE PERSONS OR HOUSEHOLD MEMBERS IN THIS ORDER:

- Head
- Spouse of the head
- Never-married children of head/spouse from the oldest to the youngest
- Ever-married children of head/spouse and their families from the oldest to the youngest
- Other relatives of head
- Nonrelatives of head

2D HOUSING CENSUS QUESTIONS

B1. CONSTRUCTION MATERIALS OF THE ROOF

PLEASE WRITE AN X MARK IN ONE OF THE BOXES BELOW.

- ☐ 1 Galvanized iron/aluminum
- ☐ 2 Tile concrete/clay tile
- ☐ 3 Half galvanized iron and half concrete
- ☐ 4 Wood
- ☐ 5 Cogon/nipa/anahaw
- ☐ 6 Asbestos
- ☐ 7 Makeshift/salvaged/improvised materials
- ☐ 8 Others, ______________ SPECIFY

B2. CONSTRUCTION MATERIALS OF THE OUTER WALLS

PLEASE WRITE AN X MARK IN ONE OF THE BOXES BELOW.

- ☐ 01 Concrete/brick/stone
- ☐ 02 Wood
- ☐ 03 Half concrete/brick/stone and half wood
- ☐ 04 Galvanized iron/aluminum
- ☐ 05 Bamboo/sawali/cogon/nipa
- ☐ 06 Asbestos
- ☐ 07 Glass
- ☐ 08 Makeshift/salvaged/improvised materials
- ☐ 09 Others, ______________ SPECIFY
- ☐ 10 No walls

H1. TENURE STATUS OF THE LOT

PLEASE WRITE AN X MARK IN ONE OF THE BOXES BELOW.

Do you own or amortize this lot occupied by your household, do you rent it, or do you occupy it rent-free with consent of owner or rent-free without consent of the owner?

- ☐ 1 Owned/being amortized/owner-like possession
- ☐ 2 Rented
- ☐ 3 Rent-free with consent of owner
- ☐ 4 Rent-free without consent of owner
- ☐ 5 Not applicable, ______________ SPECIFY

QUESTIONS FOR HOUSEHOLDS IN TEMPORARY RELOCATION AREA

H2. CURRENT RESIDENCE

IF THE HOUSEHOLD IS RESIDING IN TEMPORARY RELOCATION AREA, WRITE AN X MARK IN THE BOX FOR YES. OTHERWISE, WRITE X IN THE BOX FOR NO.

☐ 1 Yes ☐ 2 No **END INTERVIEW**

H3. DATE MOVED TO CURRENT RESIDENCE

When did your household move to the temporary relocation area?

☐☐ MM ☐☐☐☐ YYYY

H4. PREVIOUS RESIDENCE

Where was the household's usual place of residence before moving to the temporary relocation area?

IF THE SAME BARANGAY AS THE PRESENT RESIDENCE, WRITE 000 IN THE BOXES FOR BARANGAY.
IF ANOTHER BARANGAY, SPECIFY THE NAME OF BARANGAY, CITY/MUNICIPALITY AND PROVINCE ON THE SPACES PROVIDED.

______________ ☐☐☐ BARANGAY ______________ ☐☐ CITY/MUNICIPALITY ______________ ☐☐ PROVINCE

IF H4 IS '000', END INTERVIEW.

H5. INTENTION TO RESIDE IN PREVIOUS RESIDENCE

Within one year, does your household intend to reside in _________ (MENTION PREVIOUS RESIDENCE SPECIFIED IN H4)*?*

☐ 1 Yes ☐ 2 No

CODES FOR P2 (RELATIONSHIP TO HOUSEHOLD HEAD)

01	Head	**21**	Stepson	**31**	Grandson	**41**	Brother	**51**	Nephew	**61**	Boarder
02	Spouse	**22**	Stepdaughter	**32**	Granddaughter	**42**	Sister	**52**	Niece	**62**	Domestic Helper
03	Son	**23**	Son-in-law	**33**	Father	**43**	Uncle	**53**	Other relative		
04	Daughter	**24**	Daughter-in-law	**34**	Mother	**44**	Aunt	**54**	Nonrelative		

CODES FOR P9 (GRADE/YEAR CURRENTLY ATTENDING)* AND P11 (HIGHEST GRADE/YEAR COMPLETED)

	Elementary	High School	Post Secondary **	College **
00 No Grade Completed **01** Pre-school	**21** Grade 1 **22** Grade 2 **23** Grade 3 **24** Grade 4 **25** Grade 5 **26** Grade 6 **27** Grade 7 **28** Elementary Graduate	**31** 1st Year **32** 2nd Year **33** 3rd Year **34** 4th Year **35** High School Graduate	**41** 1st Year **42** 2nd Year **43** 3rd Year ** IF GRADUATE, SPECIFY COURSE	**81** 1st Year **82** 2nd Year **83** 3rd Year **84** 4th Year **85** 5th Year **86** 6th Year or Higher

*** CODES '00', '28' AND '35' ARE NOT VALID FOR P9.**

90 Post Baccalaureate

CP FORM 5 AUGUST 1, 2007 NSCB Approval No.: NSO-0706-04 Expires on: March 31, 2008	Republic of the Philippines NATIONAL STATISTICS OFFICE Manila **2007 CENSUS OF POPULATION** **BARANGAY SCHEDULE** (TO BE ACCOMPLISHED BY TEAM SUPERVISOR)	**5A** **AUTHORITY:** Commonwealth Act No. 591 authorizes this census and the National Statistics Office to collect information on the population. **CONFIDENTIALITY:** Section 4 of Commonwealth Act No. 591 states that all information furnished in this form shall be kept STRICTLY CONFIDENTIAL.

CERTIFICATION	GEOGRAPHIC IDENTIFICATION
I hereby certify that the data set forth were obtained/reviewed by me personally and in accordance with the instructions given.	PROVINCE ______
______ TEAM SUPERVISOR (SIGNATURE OVER PRINTED NAME)	CITY/MUNICIPALITY ______
______ DATE ACCOMPLISHED	BARANGAY ______
______ CENSUS AREA SUPERVISOR (SIGNATURE OVER PRINTED NAME)	NAME OF RESPONDENT ______ ______ LAST NAME FIRST NAME
______ DATE REVIEWED	DESIGNATION/POSITION IN THE BARANGAY ______ ADDRESS OF THE BARANGAY HALL
______ RD/PSO/STAT/DSO/SCO/CO (SIGNATURE OVER PRINTED NAME)	______ NUMBER AND STREET NAME OR NAME OF SITIO
______ DATE REVIEWED	**INTERVIEW RECORD** DATE OF VISIT MM:DD TIME BEGAN HR:MINUTE TIME ENDED HR:MINUTE

Part I – Barangay Facilities/Characteristics

INSTRUCTION: ENCIRCLE APPROPRIATE CODE.

Q1	*Is your barangay, a…*		
	a. *part of the town/city proper?*	1 Yes	2 No
	b. *former poblacion of the municipality?*	1 Yes	2 No
	c. *poblacion/city district?*	1 Yes	2 No
Q2	*Does your barangay have a street pattern, i.e., networks of streets of at least three streets or roads?*	1 Yes	2 No
Q3	*Is this barangay accessible to the national highway?*	1 Yes	2 No, GO TO Q4a
	IF YES, *how many kilometers away is the distance between the nearest point of this barangay and the national highway using the access road?*	1 2 kms. or less 2 more than 2 but less than 5 kms.	3 5 kms. or more 9 Don't know
Q4	*In the barangay, is there a …*		
	a. *town/city hall or provincial capitol?*	1 Yes, GO TO Q4b	2 No
	IF NO, *what is the distance of the nearest town/city hall or provincial capitol from the barangay hall?*	1 2 kms. or less 2 more than 2 but less than 5 kms.	3 5 kms. or more 9 Don't know
	b. *church, chapel or mosque with religious service of at least once a month?*	1 Yes, GO TO Q4c	2 No
	IF NO, *what is the distance of the nearest church, chapel or mosque from the barangay hall?*	1 2 kms. or less 2 more than 2 but less than 5 kms.	3 5 kms. or more 9 Don't know
	c. *public plaza or park for recreation?*	1 Yes, GO TO Q4d	2 No
	IF NO, *what is the distance of the nearest public plaza or park from the barangay hall?*	1 2 kms. or less 2 more than 2 but less than 5 kms.	3 5 kms. or more 9 Don't know
	d. *cemetery?*	1 Yes, GO TO Q4e	2 No
	IF NO, *what is the distance of the nearest cemetery from the barangay hall?*	1 2 kms. or less 2 more than 2 but less than 5 kms.	3 5 kms. or more 9 Don't know

5B Part I – Barangay Facilities/Characteristics

Q4		*In the barangay, is there a ...*	
	e.	*market place or building where trading activities are carried out at least once a week?*	1 Yes, GO TO Q4f; 2 No
		IF NO, *what is the distance of the nearest market place or building where trading activities are carried out from the barangay hall?*	1 2 kms. or less; 2 more than 2 but less than 5 kms.; 3 5 kms. or more; 9 Don't know
	f.	*elementary school?*	1 Yes, GO TO Q4g; 2 No
		IF NO, *what is the distance of the nearest elementary school from the barangay hall?*	1 2 kms. or less; 2 more than 2 but less than 5 kms.; 3 5 kms. or more; 9 Don't know
	g.	*high school?*	1 Yes, GO TO Q4h; 2 No
		IF NO, *what is the distance of the nearest high school from the barangay hall?*	1 2 kms. or less; 2 more than 2 but less than 5 kms.; 3 5 kms. or more; 9 Don't know
	h.	*college/university?*	1 Yes, GO TO Q4i; 2 No
		IF NO, *what is the distance of the nearest college/university from the barangay hall?*	1 2 kms. or less; 2 more than 2 but less than 5 kms.; 3 5 kms. or more; 9 Don't know
	i.	*public library?*	1 Yes, GO TO Q4j; 2 No
		IF NO, *what is the distance of the nearest public library from the barangay hall?*	1 2 kms. or less; 2 more than 2 but less than 5 kms.; 3 5 kms. or more; 9 Don't know
	j.	*hospital?*	1 Yes, GO TO Q4k; 2 No
		IF NO, *what is the distance of the nearest hospital from the barangay hall?*	1 2 kms. or less; 2 more than 2 but less than 5 kms.; 3 5 kms. or more; 9 Don't know
	k.	*puericulture center or barangay health center/station?*	1 Yes, GO TO Q4l; 2 No
		IF NO, *what is the distance of the nearest puericulture center or barangay health center/station from the barangay hall?*	1 2 kms. or less; 2 more than 2 but less than 5 kms.; 3 5 kms. or more; 9 Don't know
	l.	*landline telephone system or calling station?*	1 Yes, GO TO Q4m; 2 No
		IF NO, *what is the distance of the nearest calling station from the barangay hall?*	1 2 kms. or less; 2 more than 2 but less than 5 kms.; 3 5 kms. or more; 9 Don't know
	m.	*cellular phone signal?*	1 Yes, GO TO Q4n; 2 No
		IF NO, *what is the distance of the nearest place with cellular phone signal from the barangay hall?*	1 2 kms. or less; 2 more than 2 but less than 5 kms.; 3 5 kms. or more; 9 Don't know
	n.	*postal service?*	1 Yes, GO TO Q4o; 2 No
		IF NO, *what is the distance of the nearest postal service from the barangay hall?*	1 2 kms. or less; 2 more than 2 but less than 5 kms.; 3 5 kms. or more; 9 Don't know
	o.	*community waterworks system?*	1 Yes, GO TO Q4p; 2 No
		IF NO, *what is the distance of the nearest place with community waterworks system from the barangay hall?*	1 2 kms. or less; 2 more than 2 but less than 5 kms.; 3 5 kms. or more; 9 Don't know
	p.	*seaport in operation?*	1 Yes, GO TO Q4q; 2 No
		IF NO, *what is the distance of the nearest seaport from the barangay hall?*	1 2 kms. or less; 2 more than 2 but less than 5 kms.; 3 5 kms. or more; 9 Don't know
	q.	*public fire-protection service?*	1 Yes, GO TO Q4r; 2 No
		IF NO, *what is the distance of the nearest public fire-protection service from the barangay hall?*	1 2 kms. or less; 2 more than 2 but less than 5 kms.; 3 5 kms. or more; 9 Don't know
	r.	*public-street sweeper?*	1 Yes; 2 No
Q5		*Do farmers, farm laborers, fishermen, loggers, and forest product gatherers constitute more than half of the population 10 years old and over?*	1 Yes; 2 No

Part II – Kinds of Establishments **5C**

INSTRUCTION: ENTER ANSWER IN BOXES PROVIDED OR ENCIRCLE APPROPRIATE CODE.		Number of Establishments with... less than10 employees	10-99 employees	100 employees or more
Q6 Commercial establishments like wholesale store, department store, bazaar, hardware store, drugstore, gasoline station, sari-sari store, or other stores with current merchandise worth P600 or more.	a. *How many commercial establishments in this barangay have less than 10 employees, 10 to 99 employees, and 100 employees or more?* →			
	b. *How many commercial establishments outside the barangay but within 2 kms. from the barangay hall have less than 10 employees, 10 to 99 employees, and 100 employees or more?* →			
	c. IF NONE IN (a) AND (b), THEN ASK: *What is the distance of the nearest establishment from the barangay hall?* →	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO NEXT COLUMN	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO NEXT COLUMN	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO Q7a
Q7 Recreational establishments like movie house, night club, bar, beer garden, billiard hall, bowling alley, video tapes/CD rental, computer games station, videoke, internet café, cockpit arena, gym, sports house, or other establishments for recreational activities.	a. *How many recreational establishments in this barangay have less than 10 employees, 10 to 99 employees, and 100 employees or more?* →			
	b. *How many recreational establishments outside the barangay but within 2 kms. from the barangay hall have less than 10 employees, 10 to 99 employees, and 100 employees or more?* →			
	c. IF NONE IN (a) AND (b), THEN ASK: *What is the distance of the nearest establishment from the barangay hall?* →	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO NEXT COLUMN	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO NEXT COLUMN	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO Q8a
Q8 Manufacturing establishments like rice or corn mill, food processing, e.g. bakery and noodle factory, ice cream production, ice plant, tailor or dress shop or shoe factory, furniture factory, blacksmith shop, or other manufacturing establishments.	a. *How many manufacturing establishments in this barangay have less than 10 employees, 10 to 99 employees, and 100 employees or more?* →			
	b. *How many manufacturing establishments outside the barangay but within 2 kms. from the barangay hall have less than 10 employees, 10 to 99 employees, and 100 employees or more?* →			
	c. IF NONE IN (a) AND (b), THEN ASK: *What is the distance of the nearest establishment from the barangay hall?* →	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO NEXT COLUMN	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO NEXT COLUMN	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO Q9a
Q9 Hotel, dormitory, motel or other lodging places.	a. *How many hotels, dormitories, motels and other lodging places in this barangay have less than 10 employees, 10 to 99 employees, and 100 employees or more?* →			
	b. *How many hotels, dormitories, motels or other lodging places outside the barangay but within 2 kms. from the barangay hall have less than 10 employees, 10 to 99 employees, and 100 employees or more?* →			
	c. IF NONE IN (a) AND (b), THEN ASK: *What is the distance of the nearest establishment from the barangay hall?* →	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO NEXT COLUMN	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO NEXT COLUMN	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO Q10a

5D **Part II – Kinds of Establishments**

INSTRUCTION: ENTER ANSWER IN BOXES PROVIDED OR ENCIRCLE APPROPRIATE CODE.		Number of Establishments with... less than10 employees	10-99 employees	100 employees or more
Q10 Banking institution, pawnshop, financing/investment or insurance company/agency, or others.	a. *How many banking institutions, pawnshops, financing/investment or insurance companies/agencies, or others in this barangay have less than 10 employees, 10 to 99 employees, and 100 employees or more?* →	☐☐☐	☐☐☐	☐☐☐
	b. *How many banking institutions, pawnshops, financing/investment or insurance companies/agencies, or others outside the barangay but within 2 kms. from the barangay hall have less than 10 employees, 10 to 99 employees, and 100 employees or more?* →	☐☐☐	☐☐☐	☐☐☐
	c. IF NONE IN (a) AND (b), THEN ASK: *What is the distance of the nearest establishment from the barangay hall?* →	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO NEXT COLUMN	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO NEXT COLUMN	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO Q11a
Q11 Auto repair shop, vulcanizing shop, electronic repair shop, or other repair shops.	a. *How many auto repair shops, vulcanizing shops, electronic repair shops, or other repair shops in this barangay have less than 10 employees, 10 to 99 employees, and 100 employees or more?* →	☐☐☐	☐☐☐	☐☐☐
	b. *How many auto repair shops, vulcanizing shops, electronic repair shops, or other repair shops outside the barangay but within 2 kms. from the barangay hall have less than 10 employees, 10 to 99 employees, and 100 employees or more?* →	☐☐☐	☐☐☐	☐☐☐
	c. IF NONE IN (a) AND (b), THEN ASK: *What is the distance of the nearest establishment from the barangay hall?* →	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO NEXT COLUMN	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO NEXT COLUMN	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO Q12a
Q12 Establishments offering personal services like restaurant, cafeteria, or refreshment parlor (excluding mobile eating places), beauty parlor, barber shop, massage parlor, industry shop, funeral parlor, or other establishments offering personal services.	a. *How many establishments offering personal services in this barangay have less than 10 employees, 10 to 99 employees, and 100 employees or more?* →	☐☐☐	☐☐☐	☐☐☐
	b. *How many establishments offering personal services outside the barangay but within 2 kms. from the barangay hall have less than 10 employees, 10 to 99 employees, and 100 employees or more?* →	☐☐☐	☐☐☐	☐☐☐
	c. IF NONE IN (a) AND (b), THEN ASK: *What is the distance of the nearest establishment from the barangay hall?* →	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO NEXT COLUMN	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO NEXT COLUMN	1 more than 2 but less than 5 kms. 2 5 kms. or more 9 Don't know GO TO Q13

Part III – Squatters (Informal Settlers)		REMARKS
Q13 *In this barangay, how many households dwell in. . .*		
a. *danger areas such as esteros, railroad tracks, garbage dumps, river banks, shorelines, waterways, and other public places such as sidewalks, roads, parks and playgrounds?*	☐☐☐☐☐	
b. *government land without legally recognizable claims to the land except those mentioned in (a)?*	☐☐☐☐☐	
c. *private land which they do not own except those mentioned in (a)?y*	☐☐☐☐☐	

APPENDIX VII – MAPPING FRAMEWORK BETWEEN ILOILO CITY ASSESSORS OFFICE AND NSO DATA

The exposure information has to be nationally consistent so that can be integrated with disaster risk reduction tools and maintain efficiently. The fundamental data sourced from various custodians including Assessors Office is not consistent to derive exposure information. In absence of a national standard, NSO data dictionary has been considered to be a nationally consistent for building type, wall type and roof type. The Iloilo Assessors Office data inventory and maintenance is primarily for revenue collection. The information relevant to derive exposure components, the Assessors Office data was collected and matched with national standard classes as shown in the table.

EXPOSURE ELEMENTS	STANDARD CLASSES FROM NSO	INPUT DATA FROM ASSESSORS OFFICE
Roof Type	ASB - Asbestos	ABS, ASB
	CNC - Concrete Slab	CEM, CHB, CON, con, PC, RC, RD, SLAB, SLABS, ST
	COG – Cogon, NIPA, ANAHAW	CAN, COCO LEAVES, COGON, HUT, N, NB, NI, NIFA, NIPA, NISA, NN
	GIA-Galvanised Iron/ Aluminium	AMAC, Galvanised, GI*, GIA, GIC, GIN, GIS, gis, GIWS, GIZ, GOS, GS, GT, LANG, LONGS, OLD, ROUGH, S, SAL, SALV, SALVAGE, SIS, TIN, TIN SHEET, TIS
	IMP – Improvised Materials	ASPHALT
	MGC – Mixed Galvanised Iron and Concrete Tiles	CG, CHB/GIS
	TCC – Tile Concrete/Clay	BRICKS, C, CB, CCL, CMC, PL, PLACA DOMANO, PLACA ROMANA, ROOF TILES, TEGULA TILE, TIG, TL, TTT
	WOD – Wood	B,BA, BAMBOO, PLY, PLYWOOD, PW, W
Wall Type	ASB - Asbestos	ASB
	BSC – Bamboo/Sawali/ Cogon/NIPA	AMAC, AMACAN, AMAKAN, B &, BA, Bamboo, BAMBOO/SAWALI, BL, BN, BP, BR, BS, BT, HARDIFLEX, LANGCOB, N, NIPA, NS, NT, S, SAWALI, T, TAD, TIZZA
	CBS – Concrete/Brick/ Stone	AD, ADOBE, CHB, LASA, MACTAN CHB, MARBLE, PC/CHB, SA, SIS, Synthetic Brick, TL, V, VET, VINYL TILES
	GIA-Galvanised Iron/ Aluminium	GI, GIS, GRIL, GS, TIN
	IMP – Improvised Materials	ASSORTED, D, DRUM
	MCW – Mixed Concrete Wood	1ST CHB;@nd TIN SHEET/LAWANIT, CHB/LAWANTI, PLYWOOD/CHB, Z, ZO, ZOCALO
	NO – No Walls	NULL, OPEN
	OTH – Others	CAB, CANV, CB
	WOD – Wood	CC, CCL, CCW, COCO, LAW, LAWANIT, PLYWOOD, W,WOOD

APPENDIX VIII – MANUAL FOR PRODUCING EXPOSURE DATABASE USING THE ILOILO CITY ASSESSORS OFFICE DATABASE

This manual briefly describes the steps involved in creating the exposure database from Assessors Office database. The steps involved in deriving exposure information from different data sources have shown in Figure 1. In this process a software tool was developed in Python and all the data is stored in Microsoft Access. The Python programming code and access database is supplemented along with this document. This manual also explains how to run the software and contents of the database.

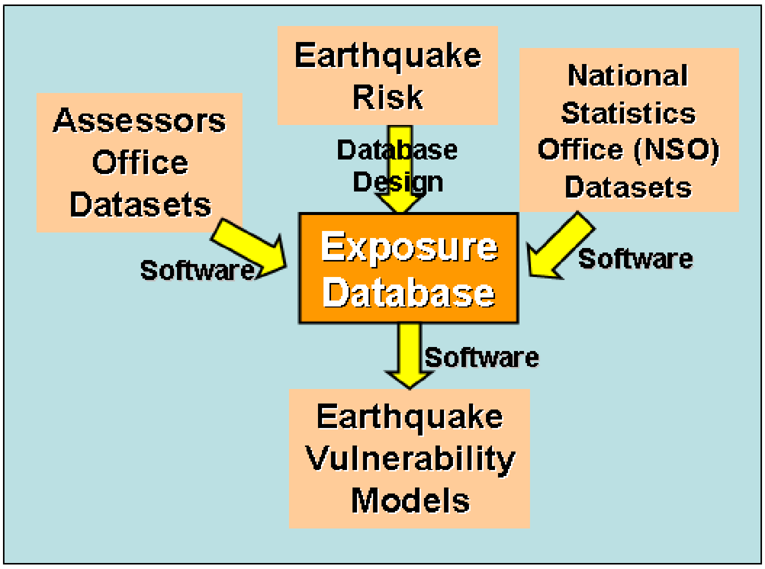


Figure VIII.1: *Exposure database development and where it fits in the information flow.*

Exposure Requirements

Exposure information requirements for the assessment of earthquake risk are prepared in consultation with the hazard and vulnerability users. The list consists of all structural elements and demographic profile is prepared.

Input Data

1. Import Assessors Office (AO) text files into Microsoft (MS) Access as separate tables. For Iloilo City six text files were provided (DIST01_BLDG_STRUC. txt files were named DIST01 – DIST06) and imported.
2. Multiple tables are merged into a single table (for example see DistrictData table in new_RegionalRisk.mdb)
3. The data was primarily collected for taxation purpose. This data was not consistent to derive exposure information without data massaging. The data was cleaned and checked with the data custodians to make meaningful assumptions.

Data Process

Python scripting language was built to extract and map data to the required output fields from MS Access. The resulting output table is created in MS Access (For example AssetExposureData table in new_RegionalRisk.mdb). The exposure elements required for risk assessment and available data items from input tables have shown in table 1. The python code automates populating the required exposure elements based on Assessors Office.

Table VIII.1: *Exposure elements requirements matched with available input data from the Iloilo City Assessors Office.*

REQUIRED EXPOSURE ELEMENTS	SOURCE FIELD NAME
General Information	
Unique Id	Calculated
Assessors Uid	TDN
Spatial Location	
Barangay Number	Extracted from TDN
Barangay Name	Look-up table
District Number	District
District Name	Look-up table
City	City
Province	Prov
Building Information	
Usage	Classification
Building Type	Struct Type
Foundation	Foundation
Beams	Beams
Truss	Truss Framing
Wall Type	Ext Walls
Roof Type	Roof
Year Built	D Occupied
Number of Storeys	
Condition	Maintenance
Total Floor Area	Floor Area
Replacement Cost Factor	Estimate calculated
Replacement Value	Estimate calculated

The code steps through each of the output fields populating it as follows:

Unique Id:

The unique Id is a 15 character calculated Id comprising:

- ILO – first three (3) characters from the city name - Iloilo city
- 02 – the next two (2) digits identify the District Number
- 002 – the following three (3) digits for the Barangay Number
- 00124 – the next five digits are from the last five digits of Assessors Uid
- 00 – the final two (2) digits identify any record with duplicate Assessor Uid. The final two digits will increase by one (01) for each duplicate.

Assessors Uid:

The Assessors Uid is the TDN field as supplied directly from the AO data.

Barangay Number:

The Barangay number is extracted from the Assessors Uid field
The third position delimitated by a (-) hyphen represents the Barangay Number (05-03-019-00401). The value is populated into the Barangay Number field.
If no item is not found, the Barangay Number is left blank. Blank records are deleted at the end of the Barangay Number extraction process as part of the cleaning. Note: Very few records were deleted in this process so this would have negligible impact on the accuracy or quality of the data.

Barangay Name:

The Barangay Name is populated from BarangayDistrictLookUp table using Barangay Number to extract Barangay Name.
Note : A BarangayDistrictLookUp table is a table managed in the Regional Risk MS Access database. The BarangayDistrictLookUp was created from information sources from the NSO. (*DataInventoryTemplatev3.xls*)

District Number:

The District Number is extracted the same way as the Barangay Number by splitting it from Assessors Uid field.
The second position delimitated by (-) hyphen represents the District Number (05-**03**-019-00401). The value is populated into the District Number field.

District Name:

The District Name is extracted the same way as Barangay_Name
The District Name is populated from BarangayDistrictLookUp table using District Number to extract District Name.
Note : A BarangayDistrictLookUp table is a table managed in the Regional Risk MS Access database. The BarangayDistrictLookUp was created from information sources from the NSO. (*DataInventoryTemplatev3.xls*)

City:

City is a code that identifies the City name for the area and is a direct match to the City field as supplied directly from the AO data.

Province:

Province is a code that identifies the province name of the area and is a direct match to the Prov field as supplied directly from the AO data.

Usage:

A land use classification lookup table (*ClassificationLookUp*) was created to manage the eight (8) land use classification for the study area. The classification type codes were replaces with the respective standard type classification in the *AssetExposure Data* table.

Building Type:

To simplify the variety of building types within the study area, fourteen (14) standard building types were identified to reflect the study area. All unique building types were mapped to the 14 standard types and managed as a lookup table (*BuildingTypeLookUp*) in the Regional Risk MS access database.

Foundation:

Foundation identifies the type of building construction foundation for buildings in excess of a three (3) storey building. Foundation is a direct match to the Foundation field as supplied directly from the AO data.

Beams:

Beams identify material use construction of the building. The Beams field is a direct match to the Beams field as supplied directly from the AO data.

Truss:

Truss identifies material use construction of the building. The Truss field is a direct match to the Truss_framing field as supplied directly from the AO data.

Wall Type:

To simplify the variety of wall types within the study area, eleven (11) standard wall types from the NSO data dictionary provided, were identified to reflect the study area. All unique wall types were mapped and managed as a lookup table (*WallTypeLookUp*) in the Regional Risk MS access database.

Roof Type:

Similar to the building wall types, ten (10) standard roof types from the NSO data dictionary provided, were identified to reflect the study area. All unique roof types were mapped and managed as a lookup table (*RoofTypeLookUp*) in the Regional Risk MS access database.

Year Built:

Year Built identifies the year of construction. The Year built field is a direct match to the D_Occupied field as supplied directly from the AO data. The D_Occupied field contains date as DD/MM/YYYY. Only YYYY is populated into the Year Built field.

Number of storeys:

The AO data contained the asset storey number. The highest storey number from the multiple building records is selected as the number of storeys of the building.

Condition:

Condition reflects the condition of the building at the time the data was captured. The Condition field is a direct match to the Maintenance field as supplied directly from the AO data.

Total Floor Area:

The Total Floor Area is the sum of the floor area of all assets of the building. The Total Floor Area field is a direct match to the Floor Area field as supplied directly from the AO data

Replacement Cost Factor:

The replacement cost factor is from the Tax ordinance document for each building type which is used to calculate Replacement value of each record.
Assumption: The base value of One Family Dwelling/Multiple Dwelling has been taken as the replacement cost factor for each building type (for further information, refer *tax_ordinance_2005002.pdf* document)

Replacement Value:

The replacement value is the product of Total Floor Area multiplied by the Replacement Cost factor of each record.

*Replacement_Value = Total_Floor_Area * Replacement Cost factor*

Operational Manual

1. The software tool was developed using Python programming. The source code is in the attached file.
2. The raw data collected from Assessors Office imported into Microsoft (MS) Access as separate tables. For Iloilo City six text files were provided (DIST01_BLDG_STRUC. txt files were named DIST01 – DIST06) and imported. The Access Database is attached.
3. Multiple tables are merged into a single table (for example see DistrictData table in new_RegionalRisk.mdb)
4. Create the following lookup tables
   - BarangayDistrictLookUp (created from NSO supplied data)
   - BuildingTypeLookUp (created as part of cleaning inconsistencies)
   - ClassificationLookUp (created as part of cleaning inconsistencies)

ReplacementCostLookUp (created from AO cost factors table)
RoofTypeLookUp (created from NSO supplied data)
StoreyLookUp (created from the AO data)
WallLookUp (created from NSO supplied data)

5. Run the above python code
    a. Navigate to the code in window explorer
    b. Right mouse click on the code and select “Edit with IDLE”
    c. In the code window select “Run” & “Run Module”
6. The code adds the out put as a new table in the same Access Database called “AssetExposureData”

APPENDIX IX – ATTRIBUTES FOR ARCPAD SURVEY FORMS

THEME	ATTRIBUTE	DESCRIPTION	DOMAIN NAME	FIELD NAME IN ARCGIS
HIDDEN FIELDS	LATITUDE	WGS84 Latitude of the building point		LATITUDE
HIDDEN FIELDS	LONGITUDE	WGS84 Longitude of the building point		LONGITUDE
GEOGRAPHY	BUILDING NAME	Name of the building (from sign, plaque or other indicator)		BLDG_NAME
GEOGRAPHY	STREET NUMBER	Number component of the address (if available)		STR_NUMBER
GEOGRAPHY	STREET NAME	Name of the street from which building is accessed		STR_NAME
GEOGRAPHY	BARANGAY	Name of the barangay	Barangays	BARANGAY
GEOGRAPHY	DISTRICT	Name of the district	Districts	DISTRICT
GEOGRAPHY	CITY	Name of the city		CITY
GEOGRAPHY	PROVINCE	Name of the province		PROVINCE
STRUCTURE	YEAR BUILT RANGE	Range of the year of construction of the building	YearBuilt	YRBUILT_R
STRUCTURE	YEAR BUILT	Actual year of construction of building (if available)		YRBUILT_Y
STRUCTURE	BUILDING TYPE	Type or style of building	BuildingTypes	BLDG_TYPE
STRUCTURE	LOCAL STRUCTURAL SYSTEM CLASS	Local definition of structural system of the building	LocalBuildingClasses	STRSYS_L
STRUCTURE	STRUCTURAL SYSTEM TYPE	National definition of structural system of the building	StructuralSystemType	STRSYS_TYP
STRUCTURE	PRIMARY VERTICAL PLAN SHAPE	Primary vertical plan shape class	VertPlanShape	VERTSHAPE1
STRUCTURE	SECONDARY VERTICAL PLAN SHAPE	Secondary vertical plan shape class	VertPlanShape	VERTSHAPE2
STRUCTURE	HORIZONTAL PLAN SHAPE	Horizontal plan shape class	HorzPlanShape	HORZ_SHAPE
STRUCTURE	WIDTH	Estimated width of building facing the street	WidthDepth	WIDTH_M
STRUCTURE	DEPTH	Estimated depth of building away from the street	WidthDepth	DEPTH_M
STRUCTURE	NUMBER OF STOREYS	Number of storeys of the building	Storeys	NO_STOREYS
STRUCTURE	OVERALL CONDITION	Overall condition of building	Condition	BLDG_CNDTN
STRUCTURE	SEISMIC SEPARATION LEFT SIDE	Details of seismic separation from adjacent buildings on left side	SeismicSep	SEISMSEP_L
STRUCTURE	SEISMIC SEPARATION RIGHT SIDE	Details of seismic separation from adjacent buildings on right side	SeismicSep	SEISMSEP_R
USE	USE 1	Primary use for the building	Uses	USE1
USE	USE 1 PERCENT	Estimated percentage of building allocated to primary use	Percent	USE1_PC

THEME	ATTRIBUTE	DESCRIPTION	DOMAIN NAME	FIELD NAME IN ARCGIS
USE	USE 1 PEOPLE	Estimate of number of people associated with primary use	People	USE1_PPL
USE	USE 2	Secondary use for the building	Uses	USE2
USE	USE 2 PERCENT	Estimated percentage of building allocated to secondary use	Percent	USE2_PC
USE	USE 2 PEOPLE	Estimate of number of people associated with secondary use	People	USE2_PPL
USE	USE 3	Tertiary use for the building	Uses	USE3
USE	USE 3 PERCENT	Estimated percentage of building allocated to tertiary use	Percent	USE3_PC
USE	USE 3 PEOPLE	Estimate of number of people associated with tertiary use	People	USE3_PPL
ROOF	MAIN ROOF ATTACHMENT	The primary attachment to the top of the building	RoofAttachments	R_ATTACH1
ROOF	OTHER ROOF ATTACHMENT	The secondary attachment to the top of the building	RoofAttachments	R_ATTACH2
ROOF	ROOF ATTACHMENT HEIGHT	Maximum height of the attachments on top of the building	AttachmentHeight	ATTACH_HT
ROOF	ROOF PITCH	Slope of the roof of the building	RoofPitch	ROOF_PITCH
ROOF	ROOF 1 TYPE	Primary roof type for the building	NSORoofTypes	ROOF1
ROOF	ROOF 1 PERCENT	Percentage of roof with primary roof type	Percent	ROOF1_PC
ROOF	ROOF 2 TYPE	Secondary roof type for the building	NSORoofTypes	ROOF2
ROOF	ROOF 2 PERCENT	Percentage of roof with secondary roof type	Percent	ROOF2_PC
ROOF	DECORATIONS	Presence and type of non-structural decorations at roof level	Decorations	DECORATION
WALLS	WALL 1 TYPE	Primary wall type for the building	NSOExtWallTypes	WALL1
WALLS	WALL 1 LOWEST LEVEL	Lowest storey of primary wall type	Storeys	WALL1_LOW
WALLS	WALL 1 HIGHEST LEVEL	Highest storey of primary wall type	Storeys	WALL1_HIGH
WALLS	WALL 2 TYPE	Secondary wall type for the building	NSOExtWallTypes	WALL2
WALLS	WALL 2 LOWEST LEVEL	Lowest storey of secondary wall type	Storeys	WALL2_LOW
WALLS	WALL 2 HIGHEST LEVEL	Highest storey of secondary wall type	Storeys	WALL2_HIGH
WALLS	MAIN WALL ATTACHMENT	The primary attachment to the walls of the building	WallAttachments	W_APPURT1
WALLS	OTHER WALL ATTACHMENT	The secondary attachment to the walls of the building	WallAttachments	W_APPURT2
FLOOR	FLOOR SYSTEM	System of lowest floor of the building	FloorSystems	FL_SYSTEM
FLOOR	FLOOR TYPE	Floor type for the lowest floor of the building	FloorTypes	FL_TYPE
FLOOR	FLOOR ELEVATION FROM STREET	The estimated height difference between the lowest floor and the street	FloorHeight	FL_ELEV

THEME	ATTRIBUTE	DESCRIPTION	DOMAIN NAME	FIELD NAME IN ARCGIS
FLOOR	SUB-FLOOR FOOTPRINT PERCENT	Area of sub-floor as a percentage of footprint of building	Percent	SUBFL_PC
FLOOR	SUB-FLOOR USE	Dominant use of sub-floor space (if present)	SubFloorUses	SUBFL_USE
FLOOR	BASEMENT PRESENT?	Presence of basement underneath lowest floor	YesNo	BASEMENT
FLOOR	GROUND SLOPE	Slope of the ground underneath the building	SlopeClasses	SLOPE
FLOOR	FOUNDATION	Type of ground underneath the building	Foundation	FOUNDTN
FAÇADE	FAÇADE 1	Description of primary façade material	FacadeTypes	FACADE1
FAÇADE	FAÇADE 2	Description of secondary façade material	FacadeTypes	FACADE2
FAÇADE	FAÇADE PROJECTIONS	Presence and type of any awning, balcony or verandah at façade	FacadeProjections	FAC_PROJ
FAÇADE	MAIN WINDOW TYPE	The dominant type of window for the building	WindowType	WIND_TYPE
SURVEY	ADDITIONAL COMMENTS	Any further comments on the building		COMMENTS
SURVEY	SURVEYED BY	Name of person surveying the building	SurveyTeam	SURV_BY
SURVEY	UNIT NUMBER	Number of the PDA unit used for the survey	UnitNumbers	UNIT_NO
SURVEY	DATE OF SURVEY	Date of the survey	Source from Calendar	DATE_SURV
SURVEY	CONFIDENCE	Estimate of confidence of recorded attributes	Confidence	CONFIDENCE
PHOTOS	PHOTO 1	Photo 1 of building		PHOTO1
PHOTOS	PHOTO 2	Photo 2 of building		PHOTO2
PHOTOS	PHOTO 3	Photo 3 of building		PHOTO3
PHOTOS	PHOTO 4	Photo 4 of building		PHOTO4

APPENDIX X – ILOILO BUILDING FIELD-SURVEY GUIDE

DOST
PHIVOLCS

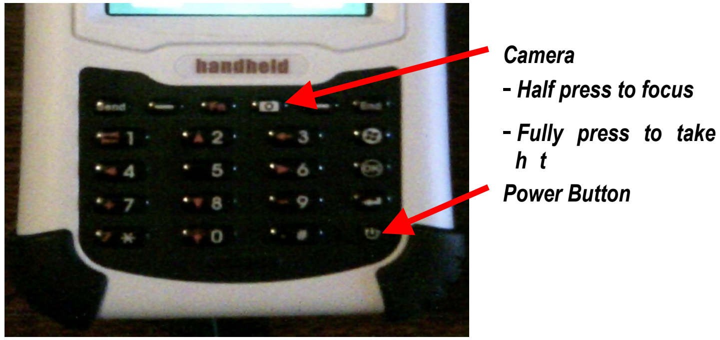
Australian Government
Geoscience Australia

Iloilo Building Field-Survey Guide

Contents

PDA Basics

- Turn PDA on by pressing the power button once, and wait for it to boot up.
- To power-down the PDA **screen only**, press the power button once (the PDA will remain active, but this will preserve battery life)
- To turn off PDA, press the power button and hold until the PDA powers down
- Use stylus on touch screen only – other implements will damage screens



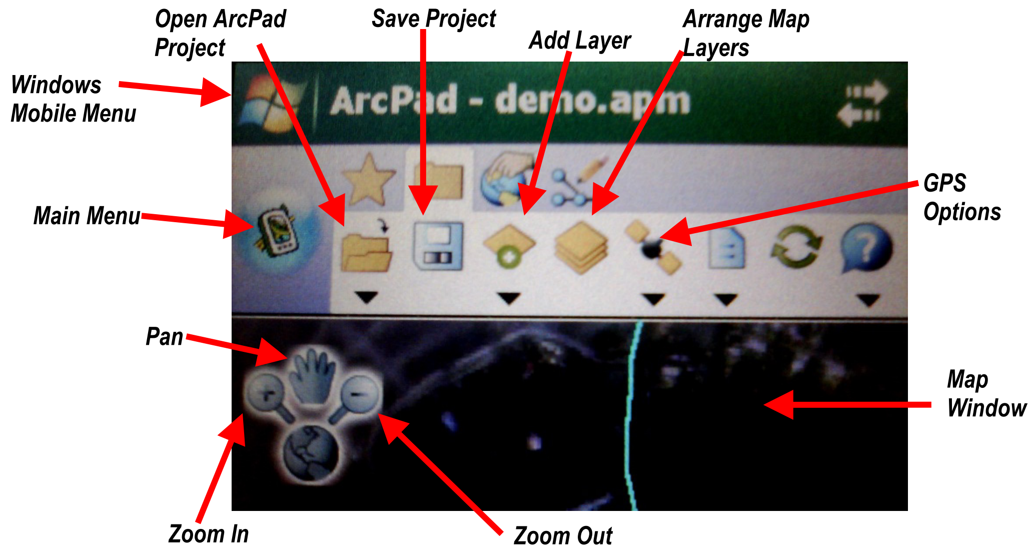
Swapping between applications on the PDA

Sometimes it will be necessary to swap between applications on the PDAs being used for the building surveys. For example, the user may wish to swap between ArcPad and Adobe Acrobat Reader. To do this on the PDA, simply tap the Windows icon in the top left-hand corner of the screen, and select the desired application.

Getting Started with ArcPad

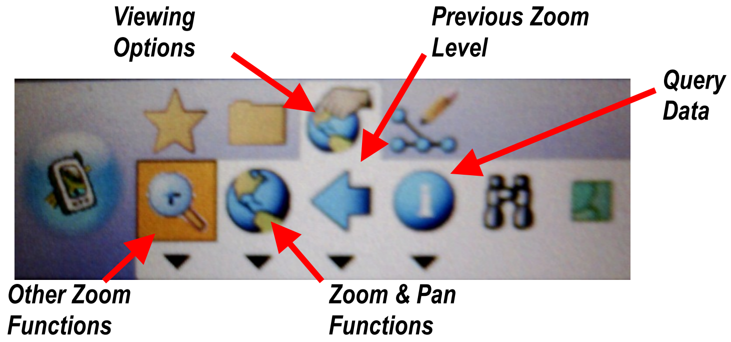
USING ARCPAD WITH GPS

- Go to PDA start menu and launch ArcPad
- To open ArcPad Project, select *File* icon, and follow prompts to desired project
- To enable GPS, select *GPS Options* then select *GPS Active* (when indoors, disable GPS by reselecting *GPS Active*)



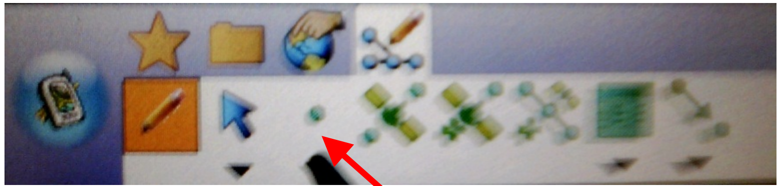
VIEWING FUNCTIONS IN ARCPAD

- To zoom in on the ArcPad project:
    - select the *Zoom In* icon
    - Drag stylus from the northwest to the southeast extent you wish to zoom to.
- To zoom out, select the *Zoom Out* icon, and gently tap on the map window.
- To revert to the previous zoom level/map window, select the *Previous Zoom Level* icon



ADDING A DATA POINT

- Identify the building you wish to record in the background image
- From the Menu bar, tap once on the *Add Point* icon, and then tap the screen at the building
- For simple building survey, skip critical infrastructure page and proceed with filling in form at the Geography page. When completed, go to the next page (Structure 1) by tapping once.
- Note that most items in the survey require a response, and you will only be able to proceed to the next page when these items are completed.
- If you wish to review all of the items, go to the Attributes page towards the end of the form.

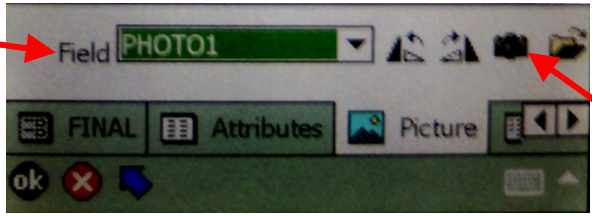


Add Point Icon

TAKING PHOTOS IN ARCPAD PROJECT

- On *Picture* tab, tap the *Camera* icon and wait for the camera screen to appear.
- Half-press the camera button to focus the image
- To take photograph, fully press camera button
- To take a second photo of a building, select another *photo field* from the drop-down menu (e.g., PHOTO2, PHOTO3, etc.) and repeat the previous 3 steps. To overwrite previous photo, do not change the *photo field*.

Photo Field



Camera

QUITTING ARCPAD

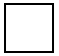
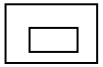
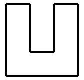
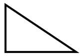
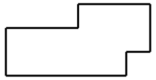
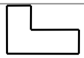
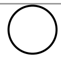
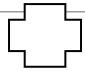
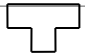
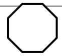
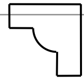
- Tap the ArcPad main menu (see second figure)
- Tap "Quit ArcPad" to close

Taking Appropriate Photographs

In order for building properties to be interrogated and validated, it is critical that good-quality photographs be taken of all structures. Ideally multiple photographs will be captured such that the buildings can be classified in an office, with only those data that cannot be captured in images being gathered in the field (e.g., building footprint, height above street level, etc.). We recommend that at least three pictures be taken of each building: one of the front façade, and photographs at an angle on the left and right sides of the building. If the field party can gain access to the rear of the building, then photos at this perspective are also encouraged. Alternatively, if there are any unique attributes of a particular building that might affect its vulnerability to a natural hazard, then this should also be documented by taking a picture. Please see examples of acceptable pictures below.

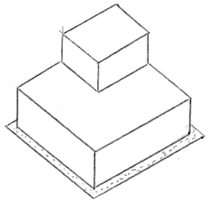
It is advised that field parties capture at least one photograph that shows the entire building from ground level to the top floor.

Horizontal Irregularities

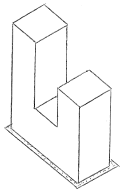
Square 	Hollow 	U shaped 
Rectangular 	A triangular 	X cranked 
L shaped 	Circular 	K cruciform 
T shaped 	Polygonal 	Irregular 

Vertical Irregularities

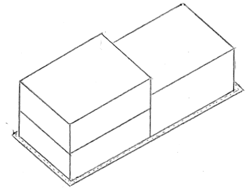
A1	**Setback floors**



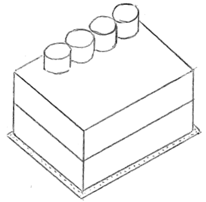

A2	**Multiple towers**



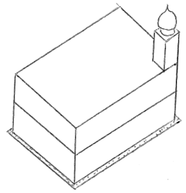
A3	**Split levels**



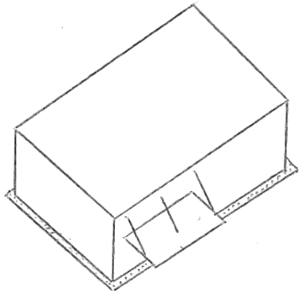

A4	**Non-uniform distribution of mass**




A5	**Heavy ornament**



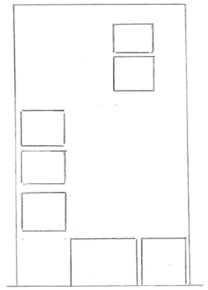

A6	**Long cantilever**

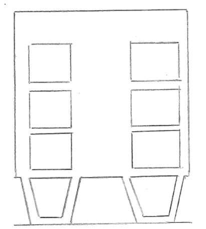


A7	Tall tower or chimney

B1	Soft storey

B2	Large or irregular openings in shear walls	B3	Transfer structures





B4	Interruption of beams

B5	Openings in floors (atria)

	
B6	Mixed structural systems
	
C1	Buildings on hillsides
	

Façade Types

Punch window
- A single pane window framed into the façade or wall

Panel window
- As for a punch window but with multiple panels

Strip window
- 3 or more horizontally adjacent panes supported top & bottom

Precast panel
- Concrete panels fabricated offsite and connected to the superstructure

Curtain Wall Façade
- Systems that hang from the superstructure. Typically feature vision and spandrel glass panels

Shopfront
- Variety of systems of ground floor façade that feature large panels of glass.

Planar Wall System
- Similar to shopfront and foyer wall systems but with bolted or proprietary patch systems connecting them to support structure.

Masonry Wall - Brick
- Clay brickwork, may be load bearing or supported at floor level. May be rendered.

Masonry Wall - Stone
- Variety of types of stone, usually locally sourced.

Balcony Wall
***-** A glass wall system that features sliding doors extending vertically between floor slabs.*

Key Domain Options

BUILDING TYPE	LOCAL STRUCTURAL SYSTEM CLASS	STRUCTURAL SYSTEM TYPE	HORIZONTAL PLAN SHAPE	VERTICAL PLAN SHAPE
One Family Dwelling	*I-A*	W1/W2	Square	Setback floors
Two Family Dwelling	*I-B*	W3	Rectangular	Multiple towers
Multiple Dwelling	*I-C*	N	L shaped	Split levels
"Accesoria" of Row House	*II-A*	CWS	T shaped	Non-uniform distribution of mass
Apartment House	*II-B*	CHB	Hollow	Heavy ornament
Hotel	*II-C*	URM	Triangular	Long cantilever
Boarding House	*II-D*	URA	Circular	Tall tower or chimney
Lodging House	*III-A*	RM1	Polygonal	Soft storey
Accesory Building	*III-B*	RM2	U shaped	Large or irregular openings in shear walls
Office Building	*III-C*	C1	X cranked	Transfer structures
Theater	*III-D*	C2	X cruciform	Interruption of beams
Warehouse	*III-E*	C4	Irregular	Openings in floors (atria)
Bodega	*IV*	PC1		Mixed structural systems
Cold Storage	Other	PC2		Buildings on hillsides
Supermarket	Unknown	S1		
Shopping Centers		S2		
Factory Building		S3		
Recreation Building		S4		
Saw Mills and Lumber Sheds				
Gasoline Service Station				
Commercial				
Other				
Unknown				

USE	
C	*Commercial*
I	*Industrial*
R	*Residential*
SC	*Commercial*
SG	*Government*
SH	*Hospital*
SO	*Office*
A	*Agriculture*
O	Other
U	Unknown

ROOF ATTACHMENT	ROOF PITCH	ROOF TYPE	DECORATIONS
None	Flat	*GIA*	None
Water Tank	Gentle	*TCC*	Ornaments
Billboard	Moderate	*WOD*	Lamps
TV Antenna	Steep	*COG*	Planter Pots
Transmission Tower	Curved	*ASB*	Weather Vane
Air Conditioning	Dome	*MGC*	Flag Pole
Exhaust/Ventilation Outlet	Mixed	*IMP*	Other
Solar panels	Other	*OTH*	
Parapet	Unknown	*CNC*	
Steeple			
Other			
Unknown			

WALL TYPE	WALL ATTACHMENT
None	None
Concrete	Transformers
Brick	Air conditioning units
Stone	Parallel signage
Wood	Electronic signage
Mixed Concrete & Wood	Perpendicular signage
Galvanised Iron	Downpipes
Aluminium	Awnings/Dormers
Bamboo	Planter boxes
Sawali	Fire escapes
Cogon	Other
Nipa	

FLOOR SYSTEM	SUB-FLOOR USE	FOUNDATION	FLOOR TYPE
On Ground	None	Hard Rock	None
Partially Elevated	Dwelling	Rock	Wood
Wholly Elevated	Workshop	Dense Soil/Soft Rock	Concrete
Unknown	Bathroom	Stiff soil profile	Bamboo
	Laundry	Soft soil	
	Storage	Unknown	
	Other		

FAÇADE TYPE	FAÇADE PROJECTIONS OR INDENTATIONS	DOMINANT WINDOW TYPE
Punch window	None	None
Window panel	Projecting balcony	Glass panels
Strip window	Indented balcony	Louvre
Pre-cast panel	Cantilever canopy	Glass blocks
Curtain wall façade	Supported canopy	Other
Shopfront	Stayed canopy	Unknown
Foyer wall system	Other	
Planar wall system		
Masonry wall - brick		
Masonry wall - stone		
Balcony wall		

Examples of Structural Systems & Building Materials

	Wall type: concrete hollow block Façade projection: supported balcony Primary façade type: masonry wall Secondary façade type: window panel
	Wall type: concrete hollow block Roof type: mixed Façade projection: balcony

	Primary use: church Roof attachment: other Roof pitch: moderate Façade projection: supported balcony
	Roof type: galvanised iron Wall type: concrete hollow block Vertical irregularity: set back
	Wall type: concrete hollow block Roof attachments: water tank Roof type: galvanised iron Roof style: gentle slope Wall attachments: fire escape Vertical plan: soft storey

	Building type: multiunit residential Horizontal plan: rectangular Wall type: reinforced concrete Roof style: flat Roof type: concrete Roof attachments: parapets Wall attachments: awning Number of stories: 3
	Building name: Days Hotel Building use: hotel (100%) Wall type: reinforced concrete Roof style: flat Roof type: concrete Façade type 1: curtain wall façade Façade type 2: strip window Number of stories: 5
	Number of stories: 3 Wall type: reinforced concrete Roof type: concrete Roof attachments: parapets Floor system: soft story Façade type 1: punch window Façade type 2: masonry wall - brick Façade projection: indented balcony

	Roof pitch: Flat Façade type 1: punch windows Façade projection: Cantilever canopy
	Vertical Plan Shape: Soft storey Façade type: curtain wall and panel windows Number of storeys: 4 Roof pitch: flat Roof type: concrete Window type: glass panels
	Wall type: concrete (90%); glass (10%) Roof style: mixed Projections or indentations: projecting balcony

	Building use: residential (90%); commercial (10%)
	Building use: church Wall type: stone Vertical plan: Heavy ornament Roof pitch: moderate slope Wall type: stone
	Vertical plan: soft storey Wall type: concrete hollow block (80%); wood (20%) Façade type: punch windows Projections: projecting balcony

	Roof pitch: Mixed Façade projection: supported balcony
	Primary wall type: wood Lowest primary wall story: 2 Highest primary wall story: 2 Lowest secondary wall story: 1 Highest secondary wall story: 1 Secondary wall type: concrete Wall attachments: air conditioner Vertical plan: mixed
	Wall type: wood Wall attachments: awnings Roof type: galvanised iron Projections: projecting balcony

	Wall type: concrete Horizontal plan: cranked Roof pitch: gentle slope Projections: supported balcony
	Roof pitch: Mixed Projections: projecting balcony Façade material: glass panel
	Building type: multiunit dwelling Horizontal plan: rectangular Roof slope: flat Roof attachment: parapet

Philippine Engineering Building Typology (from UPD-ICE)

Material	Type	Sub-Type	Description	Year of Construction		
				Pre-1972	1972-1992	Post-1992
Wood	W1*	W1-L	Wood Frame with Area ≤ 5,000 sq. ft (1-2 storeys)		√	
	W2*	W2-L	Wood Frame with Area > 5,000 sq. ft (1-2 storeys)		√	
	W3	W3-L	Bamboo (1-2 storeys)		√	
	N	N-L	Makeshift (1-2 storeys)		√	
Masonry	CWS	CWS-L	Half-Brick/Half-Wood (1-2 storeys)		√	
	CHB	CHB-L	Concrete Hollow Blocks (1-2 storeys)		√	
	URM*	URM-L	Brick (1-2 storeys)		√	
	URA	URA-L	Adobe (1-2 storeys)		√	
	RM1*	RM1-L	Flexible Diaphragm (1-2 storeys)		√	
	RM2*	RM2-L	Rigid Diaphragm (1-2 storeys)		√	
		RM2-M	Rigid Diaphragm (3-7 storeys)		√	
Concrete	C1*	C1-L	Moment Frame (1-2 storeys)		√	
		C1-M	Moment Frame (3-7 storeys)	√	√	√
		C1-H	Moment Frame (8-15 storeys)	√	√	√
	C2*	C2-L	Shear Walls (1-2 storeys)		√	
		C2-M	Shear Walls (3-7 storeys)	√	√	√
		C2-H	Shear Walls (8-15 storeys)	√	√	√
		C2-V	Shear Walls (16-25 storeys)	√		√
		C2-E	Shear Walls (26-35 storeys)	√		√
		C2-S	Shear Walls (36+ storeys)	√		√
	C4	C4-M	Shear Walls and Frames (3-7 storeys)	√	√	√
		C4-H	Shear Walls and Frames (8-15 storeys)	√	√	√
	PC1*	PC1-L	Precast Tilt-up (1-2 storeys)	√	√	√
	PC2*	PC2-L	Precast Frame (1-2 storeys)	√	√	√
		PC2-M	Precast Frame (3-7 storeys)	√	√	√
Steel	S1*	S1-L	Moment Frame (1-2 storeys)	√	√	√
		S1-M	Moment Frame (3-7 storeys)	√	√	√
		S1-H	Moment Frame (8-15 storeys)	√	√	√
	S2*	S2-L	Braced Frame (1-2 storeys)	√	√	√
		S2-M	Braced Frame (3-7 storeys)	√	√	√
		S2-H	Braced Frame (8-15 storeys)	√	√	√
		S2-V	Braced Frame (16-25 storeys)	√	√	√
		S2-E	Braced Frame (26-35 storeys)	√	√	√
		S2-S	Braced Frame (36+ storeys)	√	√	√
	S3*	S3-L	Light Metal (1-2 storeys)		√	
	S4*	S4-L	Frame w/ Cast-in-place Shear Wall (1-2 storeys)			√
		S4-M	Frame w/ Cast-in-place Shear Wall (3-7 storeys)			√
		S4-H	Frame w/ Cast-in-place Shear Wall (8-15 storeys)			√
		S4-V	Frame w/ Cast-in-place Shear Wall (16-25 storeys)			√
		S4-E	Frame w/ Cast-in-place Shear Wall (26-35 storeys)			√
		S4-S	Frame w/ Cast-in-place Shear Wall (36+ storeys)			√

L 1-2 storeys **M** 3-7 storeys **H** 8-15 storeys **V** 16-25 storeys **E** 26-35 storeys **S** 36 + storeys

* - very similar to a HAZUS-MH Model Building Type with the same label (e.g. W1)

Building Typology According to Iloilo City Assessor's Office

Material	Type	Sub-Type	Structural Characteristics							
			Cols	Beams	Walls	Floor	Roof Frame	Roofing	Upper Storey Wall	Upper Storey Floor
Reinforced Concrete	Type I	I-A	RC	RC	RC	RC	RC	RC	RC	RC
		I-B	RC	RC	CHB	RC	RC	RC	CHB	RC
		I-C	RC	RC	CHB	RC	Steel	G.I. Sheet	CHB	RC
Semi-Concrete	Type II	II-A	RC	RC	CHB	RC	Wood	G.I. Sheet	CHB	RC
		II-B	RC	RC	CHB	RC	Wood	G.I. Sheet	CHB	Wood
		II-C	RC	Wood	CHB	Wood	Wood	G.I. Sheet	Wood	Wood
		II-D	RC	Wood	Wood on Zocalo	Wood	Wood	G.I. Sheet	Wood	Wood
Strong Materials	Type III	III-A	1st Group Wood	1st Group Wood	Wood on Zocalo	RC	Wood	G.I. Sheet	Wood	Wood
		III-B	1st Group Wood	1st Group Wood	1st Group Wood	RC	Wood	G.I. Sheet	3rd Group Wood	3rd Group Wood
		III-C	1st Group Wood	1st Group Wood	1st Group Wood	1st Group Wood	Wood	G.I. Sheet	Wood	Wood
		III-D	3rd Group Wood	3rd Group Wood	3rd Group Wood	3rd Group Wood	Wood	G.I. Sheet	Wood	Wood
		III-E	3rd Group Wood	3rd Group Wood	3rd Group Wood	3rd Group Wood	Wood	G.I. Sheet	Wood	Wood
Light Materials	Type IV	IV	Makeshift/Improvised Materials							

from Grecia (2009)

RC	Reinforced Concrete
CHB	Concrete Hollow Blocks
G.I. Sheet	Galvanized Iron Sheet
1st Group Wood	Ipil-ipil, Molave, Tindalo, Narra, Yacal

APPENDIX XI – MANUAL FOR PRODUCING GMT BUILDING DENSITY GRIDS AND CALCULATING EARTHQUAKE IMPACTS FOR REDAS

This manual briefly describes the steps required to create Generic Mapping Tools (GMT) grid files of building and population exposure to be used in REDAS for undertaking earthquake loss modelling. The manual also describes the use of the exposure data for earthquake impact assessment. Figure XI.1 diagrammatically shows the inputs, processes and outputs for each step listed below.

Required Inputs

1. Barangay polygon boundaries in ESRI shapefile format. The shapefile must have one attribute field indicating National Statistics Office (NSO) barangay number that correlates to the NSO number provided in the data file with building floor area information (see Input 2).
2. A data file with aggregated NSO floor area for different building types in each barangay (for example see "NSO_data/NSO_floor_area_summary.csv"). This file can also contain NSO population information for each barangay, to be distributed equally among building types based on total floor area.
3. GoogleEarth kml or GMT formatted polygon files of areas to exclude from the computation
4. An input parameter file indicating the location of the necessary input files and output directories, including a GMT shaking intensity grid
5. Running the scripts requires the installation of:
    a. Generic Mapping Tools (Wessel and Smith, 1991)
    b. Python 2.x
    c. NumPy
    d. SciPy
    e. shapefile.py (must be in working directory)
    f. Matplotlib

Converting GoogleEarth™ kml Files to GMT Polygons

If the user has polygons of areas that they wish to exclude from the exposure computation area (e.g., waterways, oceans, fish ponds, farmland, forests, etc) that are in GoogleEarth™ format, these polygon files can be quickly converted to GMT-friendly polygon files using the function *kml2gmt_poly.py*. The usage of this function is:

python kml2gmt_poly.py <dir> <outfile>

where *dir* is the path to the kml files and *outfile* is the output ASCII file that can be used by GMT. Note that the function will locate all kml files in *dir* and merge them into a single GMT ASCII file.

Get Number of Grid Cells per Barangay

This step reads the barangay shapefile and calculates the number of grid cells per barangay with which to distribute the building density information. To compute these data, take the following step:

1. Open an example parameter file (see Appendix XII) and set variables (e.g. input/output directories, location of barangay shapefile, etc).
2. Save parameter file (e.g., *my_par_file.par*)
3. Open command widow in chosen directory and type the following command: "*python make_brgy_grd.py <my_par_file.par>*"
4. Running this *py* file will produce the output file "brgy_cells.txt" in the *expo_dir* (from the parameter file), which provides the number of cells per barangay. This code also produces a GMT grid file indicating NSO barangay number for each cell ("<*expo_dir*>/BRGY.grd"). Barangay cells excluded from polygons are not added to the total number of cells for the distribution of buildings and population

Translate NSO Data to Engineering Building Typology

The data exported from the NSO census data combines the floor area for buildings with a different combination of roof and wall type (e.g., "NSO_data/NSO_floor_area_summary.csv"). Because the earthquake fragility functions are defined in terms of an engineering typology, we need to translate the NSO data in the file *nso_floor_area* into a form that represents the floor area for different engineering building classes. To do this, a statistical representation of the building distribution is used to "paintbrush" the engineering building classes using the NSO data. The statistical distribution of engineering building classes as a percentage of each NSO roof and wall type combination was determined from the Iloilo City field surveys (see “Vulnerability_Dir/BUILDING_STATS_lookup.csv”). Because the NSO census data only represents residential buildings, a “swell factor” must be applied to obtain the total floor area of all building in a barangay. If available, this swell factor can be obtained from the LGU Assessors Office data, in terms of the percentage of residential buildings relative to the total floor area of all buildings (e.g., “Assessors_office/BarangayByUse.csv”). To translate NSO floor area data to an engineering classification, take the following steps:

1. Open parameter file and set (see Appendix XII) and set variables *nso_floor_area*, *swell_fact_file*.
2. Open command widow in chosen directory and type the following command: “*python modify_nso.py* <*my_par_file.par*>”
3. A file “up_class_agg_floor_area.csv” should now exist in *expo_dir* defined earlier

Calculate GMT grids of Building Density for different building types

This step takes the output from *make_brgy_grd.py* and *modify_nso.py* scripts and distributes the total floor area for each building type in the engineering typology equally across each grid cell for each barangay. It reads in “brgy_cells.txt” and “up_class_agg_floor_area.csv” and uses the BGRY.grd to map the distribution of building floor area across each barangay..

1. Open parameter file and set and set optional variables *cpt_palette* and *fixed_scale* (see Appendix XII for details).
2. Open command widow in chosen directory and type the following command: “*python make_building_grids.py* <*my_par_file.par*>”. This script creates GMT grid files of floor area per grid cell for each building type. The *py* code also creates postscript maps of the relative building density for each building type.

Calculate Building Impact from Scenario Earthquake

All of the previous steps have been conducted in order to produce an exposure dataset for the region of interest. This dataset can now be used to calculate the impact for any number of earthquake scenarios. The application of the impact calculation module requires two key inputs: 1) a suite of fragility curves for each building type in the engineering typology (calibrated to Modified Mercalli Intensity) and; 2) a grid of MMI calculated in REDAS for the scenario earthquake. The script, *calc_building_impact_fragility.py*, performs the following functions for each scenario:

1. Outputs a csv file for each damage state – slight, moderate, extensive and complete – indicating the total floor area of each building type in the given damage state for each barangay (e.g., “extensive_floor_area”)
2. Outputs a summary list of the total number of buildings for each building type, for each damage state (“num_buildings.csv”)
3. Outputs the total number of fatalities estimated for each building type
4. Grids and maps (in postscript format) of total damage

To run the script:

1. Open parameter file and set and set variables *scenario_dir*, *vuln_file* and *mmi_grd* (see Appendix XII for details)
2. Open command widow in chosen directory and type the following command: “*python calc_building_impact_fragility.py* <*my_par_file.par*>”. This script generates the aforementioned files describing the impacts to the scenario earthquake

Plot Damage by Building Type

If required, the script “*plot_damage_type.py*” can be used to plot a stacked bar chart indicating the number of buildings, for each building type, being in each damage state: slight, moderate, extensive and complete. The only requirement for the script is that “*calc_building_impact_fragility.py*” has been run. Once run, “*plot_damage_type.py*” will output a postscript file in the scenario directory specified in the parameter file. To generate this figure:

1. Open command widow in chosen directory and type the following command: “*python plot_damage_type.py* <*my_par_file.par*>”

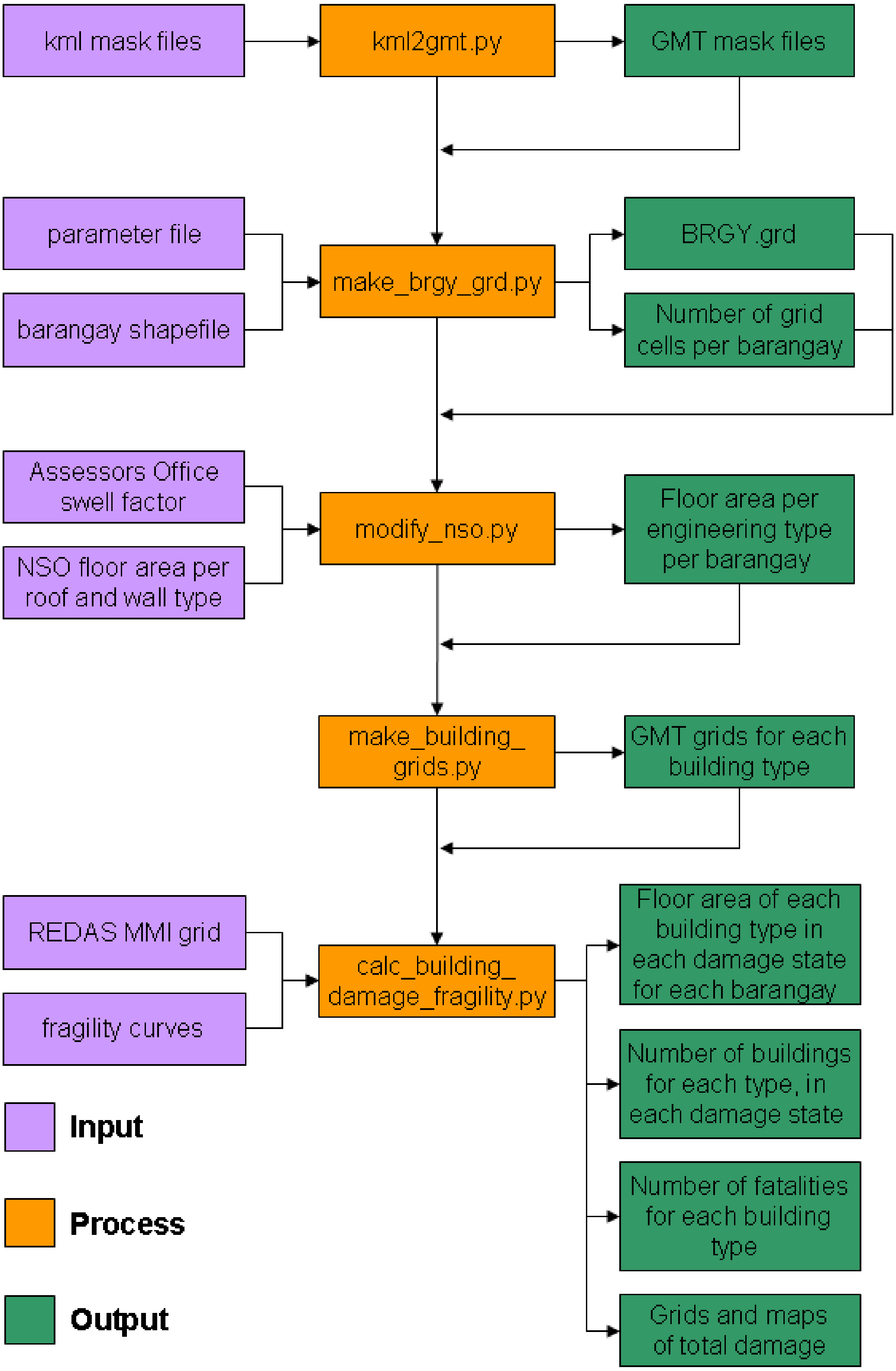


Figure XI.1. *Flow chart illustating the primary steps and inputs to undertake impact assessments in REDAS.*

APPENDIX XII – EXAMPLE OF REDAS INPUT PARAMETER FILE

The data file shown below provides an example of the input parameter file required to run codes to: 1) develop the building exposure databases; and 2) calculate earthquake impacts from scenario events.

```
# This file sets inputs to produce building exposure data and to calculate
# impact for a scenario earthquake
# Version 1.0 (2012-02-25)
#*************************************************************************************
#
# Specify output directory path relative to the program directory for exposure
# data (text input)

expo_dir: Exposure_Dir

#*************************************************************************************

# Specify output directory path for impact results from scenario events (text
# input)

scenario_dir: M6_3_precode_Dir

#*************************************************************************************
# Input shapefile with barangay polygons (text input)

shapefile: Shapefiles/Iloilo_matlab_v2.shp

#*************************************************************************************
# Input the name of Barangay number field in the shapefile. Takes a string
# input indicating the header for the 3 digit NSO identifier (text input)

brgy_fieldname: NSO_ID

#*************************************************************************************
# Grid resolution: sets resolution for given arc seconds (numeric input)
```

```
arcsec: 0.5

#****************************************************************************
# File to mask land area not to be considered for risk assessment (text input).
# The number of mask files can be as many as required by the user. The standard
# format is given below:
#
# maskfiles: <xy_poly_file_1>,flag; <xy_poly_file_2>,flag
#
# where: flag = 0 to exclude cells inside and include cells outside polygons
#flag = 1 to include cells inside and exclude cells outside polygons
#
# The polygons are specified using standard GMT xy point format. Multiple
# polygons can be included in the same xy point file using the line separator '>'

# example: maskfiles: Iloilo_land_pt.txt,1; file2.txt,0
maskfiles: Maskfiles/Iloilo_land_pt.txt,1; Maskfiles/fish_pond_all.txt,0

#****************************************************************************
# Data file extracted from the NSO data with floor area aggregated NSO roof and
# wall type. This file is used as an input in "modify_nso.py" to generate a
# file with the floor area of each building type in the engineering classification
# The output file, "up_class_agg_floor_area.csv" is exported to the expo_dir(text
# input)

nso_floor_area: NSO_data/NSO_floor_area_summary.csv

#****************************************************************************
# Because the NSO census data only represents residential buildings, a "swell
# factor" must be applied to obtain the total floor area of all building in a
# barangay. The swell factor is represented as the percentage floor area of
# residential buildings for a particular barangay from the total floor area of
# all buildings (e.g., commercial, industrial, etc). The format of this file is:
#
```

```
# Barangay_Name,NSO_Barangay_Number,Percentage_Residential
#
# If these swell factors are unknown, a dummy file can be generated using a single
# line of dummy parameters. The code "modify_nso.py" will treat this as an
# average swell factor for all barangays. The format of such a file would be
# (for example):
#
# Barangay_Name,NSO_Barangay_Number,Percentage_Residential
# UNKNOWN,00000,75.0

swell_fact_file: Assessors_Office/Percent_Res.csv

#********************************************************************************
# Path to fragility curve files (text input)
#
# Format of the file is:
#
# BUILD_TYPE,S_Median,S_Beta,M_Median,M_Beta,E_Median,E_Beta,C_Median,C_Beta
# C1L,1.94,0.18,2.08,0.16,2.2,0.15,2.3,0.15
# C1M,1.981,0.167,2.093,0.157,2.201,0.143,2.289,0.165

vuln_file: Vulnerability_Dir/UP.frag_curves_precode.csv

#********************************************************************************
# Path to REDAS intensity grid file (text input)

mmi_grd: Hazard_Dir/Mag6_3MMI.grd

#********************************************************************************
# Set GMT colour palette
# See http://www.geos.ed.ac.uk/it/howto/GMT/CPT/palettes.html for examples

cpt_palette: hot
```

```
#*******************************************************************************
# Set colour palette scale; if fixed_scale is set to true, the exposure maps will
# be plotted using a fixed scale for each UP building type based on the maximum
# floor area per grid cell for all UP building types combined. If set to false,
# the scale will vary by building type based on the maximum floor area per cell.

fixed_scale: true
```

APPENDIX XIII – REVIEW OF HISTORICAL PHILIPPINES EARTHQUAKE EVENTS AND BUILDING CONSEQUENCES

Published reporting on the impacts of historical earthquake events can provide useful information on the relative vulnerabilities of different building types. In support of the Rapid Earthquake Damage Assessment System (REDAS) enhancement program being managed by the Philippine Institute of Volcanology, and Seismology (PHIVOLCS) and the associated vulnerability model development led by the University of the Philippines, a review has been performed of available Philippines earthquake impact reporting.

The approach to this research has been to carefully review a collection of post-disaster reporting documents on historical Philippines earthquakes to obtain information on the event magnitude and maximum felt intensity. In parallel, the corresponding USGS *ShakeMap* intensity map generated by their automated processes was accessed in their web-accessible archive and the maximum felt intensity on land obtained. Further, for the named communities in the reporting specific comment on building damage severity was extracted for the usage categories of residential, commercial, public and industrial. This information was presented in a summary table for each event with each damage observation associated with the reported felt intensity in the reference document (as distinct from the *ShakeMap* prediction). Finally, the most salient comments were summarised in a table for possible use in constraining heuristic vulnerability curve assignment.

Presented below are:-

- Comments on the utility of the summary.
- A tabulated summary of key comments extracted from the review that are specific to building types of interest.
- The outcomes of the review presented in separate tables for each of 15 earthquake events and the reported impacts upon each of four building occupancy types (where available).
- A list of the references utilised in this review.

Comments on the Utilisation of the Summary Below

- The reporting of earthquake damage survey activity can provide indications on the threshold hazard levels for damage.
- Damage survey information sometimes provides information on the proportion of buildings undamaged and damaged.
- This summary is not able to provide statistically useful information as population based sampling was not undertaken in the underpinning field survey activity. The overall building exposure for the type of construction is not known.
- The survey information reported sometimes provides information on the intensity of shaking to cause widespread and severe damaged for a building type.
- Reported survey activity of non-residential buildings tends to focus on larger buildings of greater community significance.
- Survey activity on non-residential buildings tends to focus on more severely damaged structures from which lessons can be learnt on design and construction practices and the effectiveness of local building regulations.
- Sometime the attributed severity of shaking may have been biasing by the damage to very poorly constructed buildings locally observed.
- Sometime damage is attributable to geotechnical/foundation issues such as fault rupture and liquefaction. Observed damage is sometimes a combination of tsunami and earthquake shaking damage, making it difficult to separate the two.
- Building age is important but generally not provided.

Extracts From the Historical Event Reporting

EARTHQUAKE	DATE	LOCALITY	MMI	COMMENT	INFERENCE?
Traditional Residential					
Northern Luzon Earthquake	24/4/1985	Bokod	4	typical Igorot houses whose posts were not even buried into the ground collapsed.	Poorly constructed traditional residential vulnerable at MMI 4
Northern Luzon Earthquake	24/4/1985	Bokod	5	old Igorot huts collapsed. It was observed that posts failed at floor section.	Better constructed traditional residential vulnerable at MMI 5
Mindoro Earthquake	15/11/1994	Calapan	7	Old houses with nipa roofs collapsed due to ground shaking	Traditional construction severely damaged at MMI 7
Typical Masonry Residential					
Ragay Gulf Earthquake	17/3/1973	Calauag, Quezon	5	98 houses were totally destroyed and 270 others were partially destroyed.	Widespread residential damage at MMI 5
Moro Gulf Earthquake	17/8/1976		9 - 10	Many buildings, with unknown structural systems and close to the epicentre of the earthquake, collapsed or suffered severe damage after the earthquake	Severe residential damage at MMI 9 (note the large discrepancy with Pager MMI of 6. The reported isoseismals may indicate an overly large felt intensity)
North-Eastern Luzon Earthquake	22/11/1981	Magsingal	5	a few minor cracks in walls of houses made of hollow blocks	Minor damage to masonry residential buildings
North-Eastern Luzon Earthquake	22/11/1981	Bangued	5	many houses suffered cracks on the roofs and walls	Minor damage to masonry residential buildings
Eastern Bicol Earthquake	11/1/1982	Calapan and Roxas	4	cracks in walls made of hollow blocks were observed in some houses	Threshold of damage to masonry residential buildings
Laoag Earthquake	17/8/1983	Laoag City	7	many …….residential buildings suffered damage of varying degrees.	Widespread residential damage at MMI 7
Laoag Earthquake	17/8/1983	Barangay Barnagobong	7	41 houses collapsed. These houses were usually 2-storey building made of concrete hollow block and wood.	Collapse of some structure occurs at MMI 7 and typically 2 storey indicating greater vulnerability
Mindoro Earthquake	15/11/1994	Barangay Malaylay, Old Baco, Wawa, Baco Islands	7	Many buildings suffered complete or partial damage due to the earthquake which was followed by a tsunami	Widespread residential damage at MMI 7
Mindoro Earthquake	15/11/1994	Calapan and Baco	7	had the biggest number of totally destroyed houses	Significant number of homes completely damaged at MMI 7
Mindoro Earthquake	15/11/1994	Naujan and Gloria	6	had the biggest number of partially damaged houses.	Partial damage more predominant at MMI 6
Sogod Southern Leyte	11/2/1998	Barangay Libas	4	the earthquake caused minor damages to residential buildings particularly masonry	Poorly built unreinforced masonry buildings sustain minor damage at

Earthquake				structures not properly reinforced.	MMI 4
Masbate Earthquake	15/2/2003	Palanas and Dimasalang	7	Minor to severe damage such as fissures on floors and walls and collapse of walls ….were observed on non-engineered …houses.	Homes suffer minor to severe damage at MMI 7
Older URM (Churches etc)					
Palimbang Earthquake	6/3/2002	Tupi	6	Two old churches collapsed	Old unreinforced masonry construction can collapse at MMI 6
Commercial					
Moro Gulf Earthquake	17/8/1976	Cotabato	10	Approximately 30% of the commercial buildings in city were damaged	70% undamaged commercial at MMI 10 (note the large discrepancy with Pager MMI of 6. The reported isoseismals may indicate an overly large felt intensity)
Eastern Luzon Earthquake	18/3/1977	Manila	5	many buildings……with unknown structural systems suffered cracked walls and broken windows.	Minor damage to engineered commercial buildings at MMI 5
Laoag Earthquake	17/8/1983	San Nicolas	7	a 3-storey RC commercial-apartment building collapsed, all its upper floors piled up like a stack of pancakes.	Collapse of some structure commercial structures occurs at MMI 7
Laoag Earthquake	17/8/1983	Laoag City	7	a number of reinforced concrete buildings either totally collapsed or sustained major structural damage beyond rehabilitation. Nearly all the damaged buildings were of reinforced concrete frame. Most of the external walls and internal partitions were of concrete hollow blocks and some building with wood partitions.	Severe damage to commercial structures occurs at MMI 7
Public Buildings (Medical Care Centres and Schools)					
Ragay Gulf Earthquake	17/3/1973	Barrio Sumulong	5	70% of the school buildings were damaged.	30% undamaged schools at MMI 5
Eastern Luzon Earthquake	18/3/1977	Manila	5	at least four buildings such as Araullo High School, National Library, Bureau of Posts and Geronimo Elementary School suffered a various degree of damage including cracked walls and broken windows.	Minor damage to public buildings at MMI 5
North-Eastern Luzon Earthquake	22/11/1981	Vigan	5	minor cracks were observed at Vigan Synoptic Weather Station. The building, made of hollow blocks, suffered cracks in its wall facing south.	Threshold of damage concrete block masonry buildings

Laoag Earthquake	17/8/1983	Laoag City	7	many public…… buildings suffered damage of varying degrees.	Widespread damage to public buildings at MMI 7
Palimbang Earthquake	6/3/2002	Koronadal city and Tantangan	7	the school buildings collapsed and suffered damage.	Widespread damage to school buildings ranging from slight to more severe at MMI 7
Masbate Earthquake	15/2/2003	Palanas and Dimasalang	7	Minor to severe damage such as fissures on floors and walls and collapse of walls ….were observed on non-engineered …facilities.	Non engineering public assets suffer minor to severe damage at MMI 7

Summary Table of Historical Philippines Earthquake Events and Building Consequences

EVENTNAME	DATE	EARTHQUAKE MAGNITUDE AND MAXIMUM REPORTED MMI	MAXIMUM MMI (1) FROM PAGER MAP	DAMAGE OBSERVATIONS (OSOME *ET AL*, 1969)
Casiguran Earthquake	02/08/1968	M_s 9.0 MMI 9	Not available	**<u>Residential</u>** – Not applicable **<u>Commercial</u>** –There were some specific buildings located in **Manila (MMI VI)** which suffered damage: The 6-storey RC frame Ruby Tower building collapsed. The upper floors fell southwards while the southern end of the roof moved 9.15 metres south and 3.05 metres east. The lower floors appeared to fall close to their plan position. The 6-storey RC frame Philippine Bar Association building with offices and club rooms was damaged. Most of the first storey columns suffered total collapse or very severe damage and shortening. Exterior columns suffered greater damage and shortening than nearby interior columns. This resulted in a severe deformation of some interior beams and part of floor at each storey level. The 8-storey RC frame Aloha Theatre building suffered severe damage near its southern end. The damage was initiated by the collapsed of a few very short columns towards the southern end of the fourth floor. The 6-storey RC frame Tuason building suffered severe damage or very close to collapse. The columns along the southern side wrecked or severely damaged. The 7-storey RC frame Trinity building suffered considerable damage to short exterior columns and near the eastern and western corners, and some panel damage near eastern and northern corners.

				The 11-storey RC frame Diamond Tower building suffered considerable structural and non-structural damage due to transverse swaying. The 9-storey RC frame Liwayway Hotel building suffered some diagonal shear cracks and compression crushing in columns and damage to spandrel beams up to storey six around three sides of the building. The 6-storey RC frame Botica Boie building suffered considerable damage to panels of glass bricks. The 8-storey RC frame Araneta and Tuason building suffered considerable damage around the central light well and elsewhere, and a result of swaying in a SW-NE direction. The 3-storey Overseas Terminal building suffered severe damage, when the fill subsided by about 10 inches. **Public** – The 9-storey RC frame National Library building suffered damage to the axial shear walls. **Industrial** – Not applicable

EVENTNAME	DATE	EARTHQUAKE MAGNITUDE AND MAXIMUM REPORTED MMI	MAXIMUM MMI (1) FROM PAGER MAP	DAMAGE OBSERVATIONS (SKINNER *ET AL*, 1970)
Eastern Luzon Earthquake	07/04/1970	M_s 9.0 MMI 9	Not available	**Residential** – Many buildings located in **Baler (MMI IX)** and **Casiguran (MMI VI)**, with unknown structural systems and close to the epicentre of the earthquake, had suffered severe or partial damage but were safe for occupancy. Some of these buildings required general repair. It is not clear for buildings collapsed but at least 10 buildings were condemned. **Commercial** – Most of the buildings damaged in 1968 suffered some further damage in 1970, often as a result of forces in a direction quite different from the direction of attack during the earlier earthquake. While the recent damage was more severe in some buildings, it was less severe in many others, either because strengthening shear walls had been added or because the buildings had greater resistance to forces in the direction of attack of the 1970 earthquake. Some buildings located in **Manila (MMI VI)** suffered the following damage: The 6-storey RC frame Philippine Bar Association building of 6 x 4 bays suffered severe crushing of the first-storey columns. The 7-storey RC frame Trinity building of 6 x 4 bays suffered severe damage of few short columns. The 11-storey RC frame Diamond Tower building of 11 x 2 bays suffered considerable cracking at construction joints. The transverse shear walls suffered only local damage and general non-structural damage resulting from transverse movement was very small. The 9-storey RC frame Liwayway Hotel building suffered some diagonal shear cracks and compression crushing in columns. The 6-storey RC frame Botica Boie building of 9 x 6 bays suffered considerable damage in the spandrel beams and columns. The 8-storey RC frame Phoenix building of 12 x 4 bays had revealed that the end panels and low walls on the corresponding end bay suffered damage up to storey 6. The 8-storey RC frame La Tondena building of 1 x 5 bays suffered beam damage at the SE end and panel and column diagonal shear cranks at NE side of the building. The 7-storey RC frame Consolidated Apartment House building with the hollow ceramic-

				brick panels suffered moderate cracking of some beams and columns. The panels without openings suffered damage around the edges and incomplete panels suffered more severe damage. The 6-storey RC frame Gocheco building suffered diagonal cracks in columns from NW-SE swaying. The 3-storey RC United building suffered such severe column damage that it was very close to total collapse. Most of this column damage was caused by the attack of transverse panels during swaying of the building in a NW-SE direction. **Public** – The National Library, storeys 6 and 9 suffered local panel and glass damage. The 7-storey RC frame Far Eastern University building of 7 x 2 bays suffered beam damage adjacent to the shear tower formed at the eastern end by the elevator shaft. A shear failure occurred in a column associated with the eastern stairway and considerable damage occurred at the construction joints of columns and reinforced concrete walls. The L-shaped 3-storey P. Gueuarra Elementary School building collapsed completely. This 3-storey RC frame Agoncillo Elementary School building of 3 x 3 bays suffered severe damage in two first-storey columns. Beside the stairway, the concrete hollow panels on the first and second storeys had been severely damaged. This 4-storey wings RC frame Manila High School building suffered moderate frame damage and considerable panel damage at the first and second storeys. A long 3-storey Hope Christian High School building suffered moderate "X" cracks in the shortened columns. **Industrial** – Not applicable

1) MMI taken from maximum felt intensity predicted on land.

EVENTNAME	DATE	EARTHQUAKE MAGNITUDE AND MAXIMUM REPORTED MMI	MAXIMUM MMI (1) FROM PAGER MAP	DAMAGE OBSERVATIONS (MORANTE *ET AL*, 1974)
Ragay Gulf Earthquake	17/03/1973	M_s 7.0 MMI 9	MMI 8	**Residential** – The town worst hit by the earthquake is ***Calauag***, **Quezon (MMI V)** where 98 houses were totally destroyed and 270 others were partially destroyed. The damaged houses were largely wooden and some were poorly built concrete buildings. Effects on strongly built ones were limited to the topping of concrete hollow-block walls and decorative tiles. A residential 3-storey concrete building was severely tilted to the north. **Commercial** – The ***Hondagua*** **(MMI V)** theatre which had been converted into a restaurant completely collapsed. **Public** – In **Barrio Sumulong (MMI V)** of the same town, 70% of the school buildings were damaged. The concrete hollow block retaining walls of a 5-room PTA building of the Lopez provincial school collapsed. Similarly the concrete hollow block walls of the Library building were badly cracked. The façade of the St Rosario Catholic church of **Lopez (MMI V)** suffered cracks and some parts of the concrete hollow block walls on both sides toppled down. The Catholic chapel of the **Barrio (MMI V)** was partially destroyed. Its façade toppled down and its concrete hollow block walls were cracked. **Industrial** – Philippine Flour Mills in **Hondagua (MMI V)** suffered damage to piers and building. The concrete columns of the housings of the conveyor machines buckled down. There was differential settlement of the ground along fills in the pier such that floorings of some of the building became uneven and were cracked.

1) MMI taken from maximum felt intensity predicted on land.

EVENTNAME	DATE	EARTHQUAKE MAGNITUDE AND MAXIMUM REPORTED MMI	MAXIMUM MMI (1) FROM PAGER MAP	DAMAGE OBSERVATIONS (HO *ET AL*, 1985)
Moro Gulf Earthquake	17/08/1976	M_w 7.1 MMI 10	MMI 6	**Residential** – Many buildings located in **Cotabato (MMI X)** and **Margosatubig (MMI IX)**, with unknown structural systems and close to the epicentre of the earthquake, collapsed or suffered severe damage after the earthquake and followed by tsunami which swept the coastal areas. In **Cotabato (MMI X)**, the New Residential Hall is a 3-storey building, with concrete exterior columns and thin concrete exterior walls and wood interior columns and floors and galvanized iron sheeting roof, suffered slight damage. Interior partitions were torn apart and some of the ceiling panels fell. There was considerable cracking of the ground floor slab. The 2-storey RC Melineen building pancaked. It was suspected that continuity over the supporting girders was minimal. Columns were light. **Commercial** – Approximately 30% of the commercial buildings in ***Cotabato*** **(MMI X)** city were damaged. Damage to structures consisted of crushing of first-storey columns leading to the total collapse of the buildings, collapse of first storeys and leaning of building. Non-structural damage included toppling of concrete hollow blocks, collapse of internal and external walls and cracks in walls and plastering. The 4-storey RC frame of Amicus and Sagittarius Hotel buildings and a 2-storey RC plus wood D'Max Restaurant building, a complex of three adjacent buildings, collapsed. The 4-storey RC frame with a timber foundation of First Gift & Book Store building collapsed. This building leaned north into the adjacent 3-storey structure, knocking it into a third building, the City Evangelical Church. Damage to the church was slight. The 2-storey RC frame Sultan Hotel building collapsed. It was believed that the collapse was caused by sudden change in rigidities compounding the torsional problem. The 4-storey RC frame with shear wall New Society Hotel building collapsed. The circular first-storey columns on the north and west sides of the building hinged at the top and bottom as the building experienced a heavy twisting motion. The 2-storey reinforced concrete with wood trusses and galvanized sheet iron roof LCT Hardware and Auto Supply building collapsed on the first storey of this building. The 3-storey RC frame with hollow block infill exterior walls Cotabato Auto Supply collapsed on the first storey of this building. A 1-storey lean-to concrete structure behind

				this building also collapsed. The 3-storey RC frame South Seas Trading building pancaked. It is important to note that the columns of this building also contained downpipes. The Tison building, designed with seismic considerations, suffered non-structural damage and only a slight crack in a concrete block partition. The 3-storey RC frame with masonry infills Melbourne Hotel building of 4 x 4 bays suffered heavy damage on the first-storey columns. On the east side of the building, masonry infills on the mezzanine storey buckled outward. The Imperial Hotel #2, Rita Theatre and Imperial Hotel #1 are situated together and face toward the south. Imperial #1, a 4-storey RC frame with masonry infills building, suffered a 38 centimetres permanent offset on the first storey. The rear portion of the building collapsed. The Rita Theatre is a 2-storey, with 12 metres tall RC frame in front, with a reinforced concrete plus masonry and wood auditorium section in rear. The auditorium roof has two elevations. The frame section in front drifted 38 centimetres west, along with Imperial #1. The auditorium frame, plus infilled wall on the east side, was knocked over by Imperial #1. The truss roof in this part of the roof collapsed. Imperial #2, a 6-storey RC frame building, suffered minor damage on a column, diagonal cracking on the first-storey and heavy cracking on the slab in the northwest corner of this building. The Cotabato Chinese Gymnasium building is a reinforced concrete plus wood structure including wood trusses and galvanized sheet iron covering. The walls fell outward and the roof fell in during the earthquake. The Cotabato Cenema Theatre is a large structure to rear of the Sultan Hotel. The hotel and the theatre were somehow connected. The hotel portion collapsed, which caused severe structural damage to the theatre complex. The 2-storey RC frame Boston Bakery building suffered a 60 centimetres drift to the west on the first storey. The RC frame plus wood Francel Theatre building collapsed. The 4-storey RC frame Tan Bo building with hollow block infilled walls and the timber piles suffered infilled panel cracks at the stair core. The 6-storey RC frame and wall Dawns Hotel building suffered damage at the floor joints of the wall on the south side of the building.

				The 3-storey RC frame Diamond Bazaar with masonry infill panels of building suffered damage at the second-storey exterior columns and to the adjoining architectural block screen. The 3-storey RC frame Chien Tian building with infill masonry panels suffered shear cracks of the infill panels and adjoining columns and plaster cover spalling on the first-storey. The 3-storey RC frame Un building with infill masonry panels suffered shear cracks on the infill panels and adjoining columns and plaster cover spalling on the first-storey. The 3-storey RC frame and slabs of the Mendoza building suffered damage at the wall panels, especially adjacent to the open stair and at the windowed interior panels. The 2-storey unknown structural system of Asiatic Commercial building suffered shear cracks at the piers in the windowed exterior walls. The 4-storey RC frame of To Tek So building suffered shear cracks on the first-storey corner piers and columns. **Public** – The Auditorium/Science building of Notre Dame university is a 48 x 30 metres auditorium, masonry used as infill for the reinforced concrete frames, crossed at its entrance by a 3-storey 51 x 12 metres science wing, a moment-resistant frame with RC floors and roof. The auditorium roof, corrugated sheet metal supported by purlins on steel trusses spanning the width, had the same elevation as the roof of the science wing. The entrance of the auditorium was destroyed when the science wing collapsed. The 2-storey RC frame Technical School building suffered moderate damage. The first-storey columns were damaged at the head and sill levels, failing in shear. The fins were also damaged at similar locations. This building is linked to an adjacent building by a common wood canopy. This canopy, supported on round steel columns, collapsed at its end bay. The 3-storey RC frame with hollow block walls of Administration building suffered slight damage. The hollow block walls were damaged along with the louvre mullions. This building was originally designed for 3-storey RC frame of 19 x 2 bays with the fourth and wood-framed fifth storey being added later with no strengthening of the lower storeys in Harvardian Collage Campus. The fifth storey collapsed but remained flat on top of the fifth floor. The first-storey columns of this building collapsed totally on the south side. This was the extent of the collapse at the west end, but at the east end the south second-storey columns also collapsed. The Immaculate Conception Church building suffered a settlement of about 15 centimetres

				of its tower. The church grounds were very soft and the tower was apparently not on piles. The reinforced brick walls with interior timber columns and wood roof of Tamontaka Catholic Church building suffered severe damage. The 2-storey RC frame of Cotabato Chinese School Administration building suffered minor damage on some of the masonry frame infills. The 4-storey RC frame ***Zamboanga City*** **(MMI VIII)** Agricultural and Engineering College building suffered damage at parapets and some beam-to-column connections being distressed on the upper floors. **Industrial** – The masonry walls, timber trusses and corrugated metal roof of Waterfront Warehouses collapsed. They were poorly-built and apparently non-engineered structures.

EVENTNAME	DATE	EARTHQUAKE MAGNITUDE AND MAXIMUM REPORTED MMI	MAXIMUM MMI (1) FROM PAGER MAP	DAMAGE OBSERVATIONS (HO *ET AL*, 1985)
Eastern Luzon Earthquake	18/03/1977	M_w 7.2 MMI 8	MMI 8	**Residential** – In ***Palanan*** **(MMI VIII)**, it was believed that at least a dozen buildings with unknown structural systems were destroyed. **Commercial** – In **Manila (MMI V)**, many buildings including Bank of the Philippine Islands, Insular Life building, First and International Hotels, Elizalde building, First United Bank and Timberland Hotel with unknown structural systems suffered cracked walls and broken windows. **Public** – In **Manila (MMI V)**, at least four buildings such as Araullo High School, National Library, Bureau of Posts and Geronimo Elementary School suffered a various degree of damage including cracked walls and broken windows. **Industrial** – In **Manila (MMI V)**, Magsaysay Plywood Industries building suffered cracked walls.

1) MMI taken from maximum felt intensity predicted on land.

EVENTNAME	DATE	EARTHQUAKE MAGNITUDE AND MAXIMUM REPORTED MMI	MAXIMUM MMI (1) FROM PAGER MAP	DAMAGE OBSERVATIONS (HO *ET AL*, 1985)
North-Eastern Luzon Earthquake	22/11/1981	M_w 6.4 MMI 7	MMI 8	**Residential** – In ***Santa*** **(MMI V)**, objects inside the houses swung and old frames fell down. The structural systems of the houses were unknown. In ***Magsingal*** **(MMI V)**, a few minor cracks in walls of houses made of hollow blocks. In ***Bangued*** **(MMI V)**, many houses suffered cracks on the roofs and walls. **Commercial** – In ***Laoag*** **(MMI VII)**, the DBP building suffered cracks in the window. The third-floor windows of an eight-storey PVA building were broken. **Public** – In **Laoag (MMI VII)**, the city's church tower sank by one foot below the ground. In ***Bacarra*** **(MMI VII)**, the municipal building suffered minor cracks. A large portion of church belfry fell down. The roof of the main building of **Burgos (MMI VII)** Lighthouse had been damaged and almost toppled down. The kitchen suffered cracks through and through. The lighthouse glass prisms were almost all broken. In ***Vigan*** **(MMI V)**, minor cracks were observed at Vigan Synoptic Weather Station. The building, made of hollow blocks, suffered cracks in its wall facing south. **Industrial** – Not applicable

1) MMI taken from maximum felt intensity predicted on land.

EVENTNAME	DATE	EARTHQUAKE MAGNITUDE AND MAXIMUM REPORTED MMI	MAXIMUM MMI (1) FROM PAGER MAP	DAMAGE OBSERVATIONS (HO *ET AL*, 1985)
Eastern Bicol Earthquake	11/01/1982	M_w 7.1 MMI 7	MMI 8	**Residential** – In ***Calapan*** **(MMI IV)** and ***Roxas*** **(MMI IV)**, cracks in walls made of hollow blocks were observed in some houses. **Commercial** – Not applicable **Public** – In ***Bato*** **(MMI V),** the Central Lyceum College building suffered damage on the concrete posts and concrete hollow block walls. In ***Bato*** **(MMI V)**, the Radar Station building was heavily damaged. Concrete walls on the ground floor collapsed. In ***Payo*** **(MMI V)**, both side walls of the church cracks, separating them from the back wall. Cracks of one metre long in the floor. In ***Bagomoc*** **(MMI V)**, the municipal building suffered cracks in the walls and floors. **Industrial** – Not applicable

1) MMI taken from maximum felt intensity predicted on land.

EVENTNAME	DATE	EARTHQUAKE MAGNITUDE AND MAXIMUM REPORTED MMI	MAXIMUM MMI (1) FROM PAGER MAP	DAMAGE OBSERVATIONS (VALENZUELA *ET AL*, 1983)
Laoag Earthquake	17/08/1983	M_w 6.6 MMI 8	MMI 8	**<u>Residential</u>** – In ***Laoag city*** **(MMI VII)*,*** many public and residential buildings suffered damage of varying degrees. In ***Vintar*** **(MMI VII)*,*** at least 100 houses suffered partial and severe damage. There were too many houses, located at **Bocarra (MMI VII)**, **Pasuquin (MMI VII)**, **San Nicolas (MMI VII)** and **Sarrat (MMI VI)** , suffered partial or severe damage, and partial or complete collapse. In **Pagudpud (MMI VII)**, a house near the beach, built with concrete hollow block walls reinforced with bamboo slats and palm thatch roofing, collapsed. In **Barangay Barangobong (MMI VII)**, 41 houses collapsed. These houses were usually 2-storey building made of concrete hollow block and wood. In ***Bacsil*** **(MMI VI)*,*** a total of 56 houses made of concrete hollow block, wood and galvanized iron sheets suffered partial collapse. **<u>Commercial</u>** – In **San Nicolas (MMI VII)**, a 3-storey RC commercial-apartment building collapsed, all its upper floors piled up like a stack of pancakes. In **Laoag city (MMI VII)**, a number of reinforced concrete buildings either totally collapsed or sustained major structural damage beyond rehabilitation. Nearly all the damaged buildings were of reinforced concrete frame. Most of the external walls and internal partitions were of concrete hollow blocks and some building with wood partitions. In **San Nicolas (MMI VII)**, Kaunlaran building, which housed a shop and bodega on the ground floor and apartments on the second and third storeys and the penthouse, collapsed. E.M. Laeno's building consisting of three storeys but first floor totally collapsed giving the appearance of only two storeys. Mezzanine floor of Teresa building suffered severe damage. The west portion of the second floor of the PVB building was ruined exposing the inside of the establishment of bricks. Sunrise building, walls cracked, plaster peeled and glass panes broken, tilted to NW direction. Five Sisters' Twin Cinema building, concrete hollow block walls and plaster on at least one column at midsection ground floor appeared to be sheared. The Kanlaon building completely collapsed, looking like a stack of pancakes. In **Panili (MMI VI)** , Don Mariano Marcos Memorial Hospital partially collapsed. In **Sarrat (MMI VI)**, a Rural Health Unit Centre suffered very severe damage. **<u>Public</u>** – In **Vintar (MMI V)**, a single-storey concrete building of the Central School was

				divided by a crack of three inches. In **Barangay Barangobong (MMI VII)**, three school buildings collapsed. The main altar, façade and tower of a church completely collapsed. There were some school and church buildings, located in **Bocarra (MMI VII)** and **Sarrat (MMI VI)**, suffered partial or severe damage, and partial or complete collapse. The municipal hall buildings, located at **Burgos (MMI IV)** and **Sarrat (MMI VI)**, suffered cracks of varying degrees. In **Burgos (MMI IV)**, the Cape Bojeador lighthouse building partially damaged. In **Laoag city (MMI VII)**, some portions of the terminal building at Laoag International Airport suffered slight cracks and several buildings collapsed. The floors of Municipal Hall tilted. **Industrial** – Not applicable

1) MMI taken from maximum felt intensity predicted on land.

EVENTNAME	DATE	EARTHQUAKE MAGNITUDE AND MAXIMUM REPORTED MMI	MAXIMUM MMI (1) FROM PAGER MAP	DAMAGE OBSERVATIONS (PAGASA, 1985)
Northern Luzon Earthquake	24/04/1985	M_w 6.1 MMI 8	MMI 8	**Residential** – In **Baguio city (MMI VI)**, the Skyworld Condominium building suffered cracks on walls at 1st, 2nd and 3rd floors. In **Bokod (MMI IV)**, typical Igorot houses whose posts were not even buried into the ground collapsed. At **Sitio-an (MMI IV)**, two houses along side each other collapsed. In **Sitio Bonagan (MMI V)**, old Igorot huts collapsed. It was observed that posts failed at floor section. In **LA Trinidad (MMI IV)**, a couple of houses, made of wood and galvanized iron, had their foundation shifted due to cracks on the ground. **Commercial** – At **Dennis Molintas (MMI IV)**, the General Hospital suffered all partitions made of concrete hollow blocks collapsed. **Public** – The **Baguio (MMI VI)** Central Elementary school building suffered damage in broken window panes and cracked walls along the posts and beams. The library building of Saint Louis university suffered the broken window panes and cracks on plaster at every floor. The 6-storey engineering building of university of **Baguio (MMI VI)** suffered cracks on beams, fallen plaster and broken window panes. In **LA Trinidad, Benguet (MMI IV)**, the decorative parapet of the Gymnasium of Mountain State Agricultural college collapsed completely. **Industrial** – The narrow open shelves-nailed to the wall at a height of approximately 2.5 metres from the floor were toppled in the Bureau of Mine regional office.

EVENTNAME	DATE	EARTHQUAKE MAGNITUDE AND MAXIMUM REPORTED MMI	MAXIMUM MMI (1) FROM PAGER MAP	DAMAGE OBSERVATIONS (EQE, 1990)
Northern Luzon Earthquake	16/07/1990	M_w 7.7 MMI 9	MMI 10	**Residential** – North and east from **Cabanatuan (MMI IX)** to **Baguio(MMI IX)**, into the mountains, massive landslides buried numerous houses and reportedly buried entire villages. Ground settlement over large populated areas caused extensive damage to houses. Additional large areas of liquefaction-induced ground settlement destroyed small village from the **Tarlac (MMI VIII)** area north to **Dagupan (MMI VIII)**, and north from **Dagupan** along the coast to **San Fernando (MMI IX)**. **Commercial** – The central business district of **Dagupan city (MMI VIII)**, at the bottom of the Gulf of **Lingayen (MMI VIII)**, was essentially destroyed due to extensive ground settlement. In **Baguio City (MMI IX)**, A 10-storey reinforced concrete frame building suffered severe crushing of the first-storey columns. A 9-storey hotel building in the centre on the city collapsed. In **Dagupan city (MMI VIII)**, vertical displacement across the one-level sidewalk next to two- and three-storey buildings that settled about one metre in the central business district. A 3-storey apartment building, which because of uneven settlement, leaned against a neighbouring feed store. In **Dagupan City (MMI VIII)**, an estimated 90% of the buildings in the centre district sank about one to two metres relative to the street. Dozens of structures tilted throughout the business district because of soil liquefaction and the resulting foundation-bearing capacity failure beneath the structures. In **Baguio (MMI IX)**, a 3-storey hotel building fractured connections to the concrete frame and infill walls near the top of the first storey. The upper two floors of the structure dislodged and sat down across the sidewalk. Also in central Baguio, a 6-storey hotel building collapsed to one side. This type of total building collapse was less common than buildings whose upper floors remained intact as they sat down on a soft first storey. In **Baguio (MMI IX)**, the largest hotel building, an 11-storey tower collapsed onto the adjacent older section during the earthquake. It appears that excessive flexure of the building caused it to sway to one side, collapsing as column-beam connections failed and the structure became unstable. In **Baguio (MMI IX)**, the older 8-storey sections of the hotel building did not collapse but had heavy structural damage, much of which was due to lack of ductile detailing.

				<u>Public</u> – In **Agoo (MMI VIII)**, large pieces of fallen masonry from the collapse of the partially reinforced walls of the religious shrine. In **Camiling (MMI VII)** and **Naguilian (MMI VII)**, the unreinforced masonry building of churches suffered cracks on the exterior plastering walls. In **Cabanatuan (MMI VIII)**, a 6-storey reinforced concrete frame college building collapsed. The third floor collapsed and the rear of the building pancaked in this 7-storey, non-ductile reinforced concrete frame structure at the university of Baguio. Buildings on top of the fault were destroyed. Buildings immediately adjacent to the fault, but not on perturbed ground, appeared to be unaffected by the earthquake. The ruptured fault, seen to the right, just missed an elementary school building in **Rizal (MMI VIII)**. The school building did not appear to be seriously damaged. In **Gerona (MMI VIII)** and **Pura (MMI VIII)**, severe damage occurred to automobile service stations affected by liquefaction. In such cases, the buildings typically settled, the paving was shattered, and the underground piping connecting the underground tanks was severely damaged. In **Agoo (MMI VIII)**, the 6-storey reinforced concrete frame municipal services building had little apparent provision for lateral loads, and collapsed into a soft first storey. In **Agoo (MMI VIII)**, settlement due to liquefaction at a gas filling station the more buoyant, partly empty underground tanks have pushed up the pavement. **<u>Industrial</u>** – A cement plant building near **Sison (MMI VIII)** suffered minor damage. Based on the minor level of damage to building structures in Sison, the intensity of shaking at the cement plant was probably not severe. The Baguio Export Processing Zone is an industrial park near the airport, which includes warehouses and light manufacturing operations. Within the export zone, five large concrete frame buildings collapsed. The non-ductile 4-storey reinforced concrete frame manufacturing building collapsed and its twin severely damaged building. The plant had minor structural damage and most of the damage was caused by earth fill settlement along the periphery of the buildings. Another corporation in **Baguio (MMI IX)**, the plant is housed in two single-storey concrete frame high bays, suffered cracking and spalling in the concrete-frame and infill block walls.

EVENTNAME	DATE	EARTHQUAKE MAGNITUDE AND MAXIMUM REPORTED MMI	MAXIMUM MMI (1) FROM PAGER MAP	DAMAGE OBSERVATIONS (PHIVOLCS, 1994)
Mindoro Earthquake	15/11/1994	M_w 7.1 MMI 8	8	**Residential** – Many buildings suffered complete or partial damage due to the earthquake which was followed by a tsunami which swept the coastal areas, **Barangays Malaylay (MMI VII)**, **Old Baco (MMI VII)**, **Wawa (MMI VII)** and **Baco Islands (MMI VII)**. Old houses with nipa roofs collapsed due to ground shaking in **Calapan (MMI VII)**. Wall and flooring of nipa hut swept by tsunami in **Barangay Malayay and Baco (MMI VII)**. The ground rupture caused severe damage to structures. Severely damaged residential buildings along the ground rupture in **Barangay Communal and Calapan (MMI VII)**. Damage consisted of displacement of walls, beams and floorings, and twisting or rotation of the entire structures. Those made of light materials, bamboos and nipa, sustained less damage compared to the affected semi-permanent and permanent dwellings. The municipalities of **Calapan (MMI VII)** and **Baco (MMI VII)** had the biggest number of totally destroyed houses. **Naujan (MMI VI)** and **Gloria (MMI VI)** had the biggest number of partially damaged houses. Sandboils in residential areas resulted to ground settlements and caused cracks on floors, pavements, and walls, tilted houses, or to their partial or total collapse. In **Barangay Balete (MMI VII)** and **Gloria (MMI VI)**, the effect of liquefaction was extensive and many houses, mostly nipa huts and bamboo-and-concrete buildings, were damaged. In **Barangay Lumang and Baco (MMI VII)**, the pier was torn off from its foundation and was dragged several metres away due to lateral spreading. The adjacent buildings similarly suffered from major settlement and tilting that rendered it useless. **Commercial** – Damage is not clear for commercial buildings from report. **Public** – Where buildings and other structures were presented, ground undulations were preserved in deformed houses. The wavelength measured was 20 metres at **Bancurro (MMI VI)** elementary school. In **Barangay Barcenaga (MMI VI)**, a part of the high school building tilted 3 degrees and settled by 20 centimetres. **Industrial** – Not applicable

EVENTNAME	DATE	EARTHQUAKE MAGNITUDE AND MAXIMUM REPORTED MMI	MAXIMUM MMI (1) FROM PAGER MAP	DAMAGE OBSERVATIONS (JORGIO *ET AL*, 1998)
Sogod Southern Leyte Earthquake	11/02/1998	Ms 5.9 MMI 6	Not applicable	**Residential** – In **Barangay Libas (MMI IV)**, the earthquake caused minor damages to residential buildings particularly masonry structures not properly reinforced. Cracks were developed between floor slab and concrete wall on the residential house of Mr. Nestor Rollo at San Antonio St., **Sogod (MMI VI)**. The kitchen floors of a house made up of lumber collapsed. **Commercial** – Cracks were developed between wall-column joints and flooring at the **Roca (MMI IV)** Pension House of K. Tan Memorial Hospital Inc. Compound. A long and wide crack was developed in the hallway going to the **Roca (MMI IV)** restaurant. Adjacent to Radiology room, some part of the wall collapsed. Vertical crack at the corner wall of the radiology room was developed. **Public** – In **Sogod (MMI VI)**, one of the corner columns of the building of St. Thomas Aquinas college suffered cracks. In the computer room, cracks were developed in the column. **Industrial** – A section walling of the bodega building collapsed facing NS direction of **Cagayan (MMI V)** de Ore Oil Mill at Rizal St.

EVENTNAME	DATE	EARTHQUAKE MAGNITUDE AND MAXIMUM REPORTED MMI	MAXIMUM MMI (1) FROM PAGER MAP	DAMAGE OBSERVATIONS (ABIGANIA *ET AL*, 1999)
Inland of Luzon Earthquake	12/12/1999	M_w 7.2 MMI 7	MMI 7	**Residential** – Not applicable **Commercial** – In **Metro Manila (MMI VII)**, seven sites including six commercial and one public buildings were reported in the following: The 7-storey central block building of Philippines General Hospital suffered the vertical cracks and chipped-off concrete plastering in the 1^{st} to 7^{th} floors. At the 1^{st} floor of the same building, one inner wall had a chipped-off plastering about an inch wide and which continued as a hairline crack upward reaching the ceiling and continuing to the 2^{nd} floor. At its 2^{nd} floor, the plastering on the centre of one wall chipped-off to about 2 inches wide and reaching the ceiling. From 2^{nd} to 6^{th} floor, vertical and some diagonal hairline cracks were observed mostly on wall and column joints. The Philippine international Convention Centre building suffered cracks on the wall-column joints that propagated on the floor. Some plastering chipped-off but the shear walls and columns at the first floor undamaged. At the back entrance, there was a crack along the length of the first step and the floor plastering in front of it chipped-off. The Manila Film Centre building suffered cracks on the 2^{nd} and 3^{rd} floors. Horizontal and vertical cracks were noticeable on the concrete columns outside the building. Concrete plastering on posts and some walls also chipped-off. The Golden Bay Hotel building had no damage except for a 20-metre length crack along the cemented sidewalk of the building. The 28-storey residential/commercial Chinatown Steel Tower Condominium building suffered horizontal and diagonal hairline cracks on the 4^{th} floor car park outdoor walls and columns. There was also chipped-off plastering on walls along the staircase and cracks on its outside plaster. **Public** – The tower style structure at the façade of the school building of San Sebastian College fell. There was also a horizontal plastering crack on a wall in the same building. **Industrial** – Not applicable

EVENTNAME	DATE	EARTHQUAKE MAGNITUDE AND MAXIMUM REPORTED MMI	MAXIMUM MMI (1) FROM PAGER MAP	DAMAGE OBSERVATIONS (PHIVOLCS, 2002)

Palimbang Earthquake	06/03/2002	M_w 7.5 MMI 8	MMI 8	**Residential** – In **Palimbang, Sultan Kudarat (MMI VII)**, many buildings with unknown structural systems and close to the epicentre of the earthquake had suffered severe or partial damage. In **Barangay Kawa (MMI IV)** and **Mabay (MMI V)**, the unreinforced terrace of a house fell and a house with unknown structural system collapsed. Five houses were totally destroyed in **Kiamba (MMI VII)**, the walls of 14 houses cracked in **Tacurong (MMI VII)** and a house collapsed in **Surallah (MMI VI)**. Four houses were washed out due to floodwaters in **T'boli (MMI VI)** and two houses collapsed in **Lake Sebu (MMI VI)**. A house totally collapsed in **General Santos city (MMI VI)** and nine houses made of light material collapsed in **Cotabato City (MMI V)**. **Commercial** – Two markets made of wood located in **Barangay Kiamba (MMI VII)** and **Lagundi (MMI VI)** collapsed. In **Lutayan (MMI VI)**, a market also collapsed. The market building in **Barangay Kalawag (MMI VII)** and the department store building in **Kalawag (MMI V)** sustained cracks. In **Koronadal (MMI VI)**, the KCC mall, the overpass of the South Cotabato Provincial hospital and Elan building suffered cracks. In **T'boli (MMI VI)**, a cooperative building and a health centre collapsed. A health centre, 15 houses in **Lake Lahit (MMI VI)** , the terminal building and restaurants in **Santo Nino (MMI VI)** , the Filipino building and Hotel Dolores in **General Santos city (MMI VI)** and the Mega Market building in **Cotabato City (MMI V)** suffered damage. **Public** – A concrete chapel collapsed in **Palimbang (MMI VII)** and a Baptist church tilted and the Edenson Mission College building was partially damaged in **Maitum (MMI V)**. In **Kiamba (MMI VII)**, a cross on top of Methodist church tilted and partial of its unreinforced wall fell. The other three churches sustained slight damage. The walls of the Iglesia ni Cristo church also suffered cracks, two walls in two classrooms of the Suli Elementary school fell. At the Southern Cotabato academy and the Bagtasan Elementary school, a fence and a wall collapsed respectively. In **Glan (MMI VII)**, a mosque collapsed and an old school building was totally damaged. In Isulan, a Catholic church suffered cracks. In **Koronadal city (MMI VI)**, two classrooms of the Barangay Cacub Elementary school and the stage of the Siodina Elementary school building collapsed.

				In **Santo Nino, South Cotabato (MMI VI)**, the concrete fences of Barangay Elementary school collapsed and in **Tantangan (MMI VI)**, an old elementary school building at Barangay Libas collapsed. Two old churches collapsed in **Tupi (MMI VI)**, an old elementary school building at Barangay Libas collapsed and the walls and floors of the New Lambunao Elementary school cracked. In **Banga (MMI V)**, a span of the Rizal Elementary school building collapsed and Philippine National Police Headquarters fell in General Santos city. **<u>Industrial</u>** – Two warehouses in **Norala (MMI V)** suffered partial damage. A portion of a warehouse collapsed while cracks were observed along the Asian Glass building in **General Santos city (MMI VII)**.

EVENTNAME	DATE	EARTHQUAKE MAGNITUDE AND MAXIMUM REPORTED MMI	MAXIMUM MMI (1) FROM PAGER MAP	DAMAGE OBSERVATIONS (PHIVOLCS, 2003)
Masbate Earthquake	15/02/2003	M_w 6.2 MMI 7	MMI 8	**Residential** – In **Masbate (MMI VI)**, many houses were damaged by the foreshock that was manifested as visible cracks on walls and floors. In **Barangay Suba (MMI VI)** and **Dimasalang (MMI VII)**, some houses along the ground rupture were totally damaged caused by significant horizontal and vertical displacements. Based on ocular investigation, many concrete or semi-concrete houses in **Palanas (MMI VII)** and **Dimasalang (MMI VII)** suffered severe damages. Minor to severe damage such as fissures on floors and walls and collapse of walls and houses were observed on non-engineered houses and facilities. Significant displacements along the PFZ caused a maximum intensity of Intensity VIII and caused damages to structures along or close to the ground rupture. Intensity distribution showed that ground shaking and damages were concentrated near the epicentral area and along the ground rupture. **Commercial** – Not applicable **Public** – In the island of **Magcaraguit**, **Dimasalang (MMI VII)**, the non-reinforced walls of a chapel collapsed. In **Masbate (MMI VI)** National Comprehensive High school, several reinforced concrete buildings suffered severe shear cracks and column-wall joint failure. In the same buildings, some longitudinal and transversal fractures along length of the beam and of the column were likewise observed. In **Masbate city (MMI VI)**, the Provincial Health Office's Administration building suffered a possible longitudinal rupture on the middle concrete roof beam. The same mode of failure was observed in at least two buildings in Jose Zurbito Sr. Elementary school. **Industrial** – Not applicable

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APPENDIX XIV – PROGRAM FOR THE IEC

Earthquake Risk Assessment of Iloilo City
Quick Unified Inventory of Vulnerability and Exposure for REDAS (QuiveR Project)

16 June 2011, Westown Hotel, Iloilo City

0730	Registration	
0800	Opening Prayer and National Anthem	
0810	Welcome Remarks	Hon. Jed Patrick E. Mabilog City Mayor, Iloilo City
0825	Opening Remarks Introduction to PHIVOLCS	Dr. Renato U. Solidum, Jr. PHIVOLCS Director
0850	Brief Profile of Iloilo City	Mr. Francis C. Cruz Executive Assistant, Iloilo City
0915	The Scenario Earthquake of 25 January 1948 M8.2 Earthquake	Dr. Ma. Leonila P. Bautista Associate Scientist, DOST
0940	Quick Unified Inventory of Vulnerability and Exposure for REDAS (QuiveR)	Mr. Ishmael C. Narag OIC, SOEPD – PHIVOLCS
1000	*Coffee Break*	
1015	Introduction to Rapid Earthquake Damage Assessment System (REDAS Software)	Dr. Ma. Leonila P. Bautista Associate Scientist, DOST
1035	Overview: Development Plan of Iloilo City	Mr. Butch Penalosa, CPDO, Iloilo City
1100	Development of Exposure Database	Dr. Bartolome C. Bautista PHIVOLCS, Deputy Director
1135	Building Typology of the Philippines (Engineering and Assessor's Office)	Engr. Reniel Suiza UPD – ICE
1215	*Lunch Break*	
1315	Development of Vulnerability Curves for Iloilo City and the Philippines	Prof. Ulpiano Ignacio, Jr. UPD - ICE
1345	Earthquake Risk Assessment of Iloilo City: Preliminary Result	Dr. Trevor Allen Geoscience Australia
1430	WORKSHOP (Break out Groups) Action Plans in Reducing Earthquake Risk in Iloilo City (How can we prepare for the next damaging earthquake in Iloilo City?)	Facilitators: Ronan Seal Castro, City of Iloilo Janila Deocampo, PHIVOLCS Rapporteurs: Angelito Lanuza, PHIVOLCS Kathleen Papiona, PHIVOLCS

1515 Coffee Break

1530	Plenary Session	Facilitators: Ronan Seal Castro, City of Iloilo Angelito Lanuza, PHIVOLCS Rapporteurs: Janila Deocampo, PHIVOLCS Kathleen Papiona, PHIVOLCS
1630	Message	Dr. Rowen Gelonga Regional Director, DOST VI Vice Chairman, RDRRMC
1645	Closing Remarks	Ms. Rose Cabrera Regional Director, OCD VI Chairman, RDRRMC

Emcees: Ramil Atando, PHIVOLCS Marvin Malones, DOST VI

APPENDIX XV – DESIGN AND IMPLEMENTATION OF FUTURE BUILDING SURVEYS

Future surveys of buildings

Definition of intention for the survey

From the outset, the aim and purpose of the survey should be made clear to all those involved in the planning of the survey. This will help to inform:

- Range of information to be collected;
- Method(s) to categorise buildings;
- Sample size needed;
- Spatial distribution of required samples (e.g. clustered or random);
- Extent of survey; and
- Choice of spatial representation (point or polygon).

Selection of buildings and/or barangays to be surveyed

Preparation for a building survey should start well in advance of the proposed survey date. This includes:

- Developing an understanding of the profiles of various barangays in GMMA, including:
    - attributes about the land area within the barangay;
    - percentage of urban areas, critical facilities, and rural areas within a barangay;
    - general history of the barangay (e.g. established, growing, under re-development);
- Agreement on the types of buildings to be surveyed (all residential, all commercial, all in Critical Facilities etc);
- Agreement on the numbers of buildings to be surveyed, or a selection of complete areas to be surveyed;
- Identification of appropriate barangays to be surveyed; and
- Identification of any known or perceived challenges (e.g. threats to personal safety).

It is recommended that maps be prepared for the areas to be surveyed. These maps would be useful in identifying areas requiring survey and will assist in tasking survey teams to particular areas.

Availability and assembly of existing information

Since field survey data capture can be challenging on many fronts, the use of existing information wherever possible is crucial to the success of the survey. Information that is useful during the planning of a survey includes:

- Accurate spatial datasets depicting the barangay boundaries and road network;
- Recent aerial imagery of the area to be surveyed;
- Building locations or footprints (if available);
- Existing building data (from LGUs or others); and
- Other spatially referenced information that assists in locating buildings in the field.

These datasets should be assembled in a spatial database and re-organised into a consistent spatial reference and data formats. Data should be sourced from the most reliable sources. Updates to datasets should be provided to relevant participants.

Once available data has been assembled, it would be useful to prepare maps of the areas intended for survey. These maps can be referred to during discussions and meetings during the planning, preparation and execution of the survey. Maps printed on large sheets of paper are easier to refer to during group discussions and may be one of the resources used to track and monitor progress during the survey.

Use of Points or Polygons to Represent Buildings

Before a survey template is created or modified, it would be best to decide whether buildings will be represented as points or polygons. This will depend largely on the survey platform's ability to handle the complex geometry of polygons, and the density of buildings within heavily built-up areas.

Use of Building Footprints as Features

The availability of building footprint polygon data in a GIS format will be beneficial to any building survey. Aerial imagery can be difficult to interpret in the field, and placing points GPS

locations may vary due to multi-path effects in urban areas, it may be easier for field survey teams to identify buildings based on their footprint shape. Even if points are used to represent buildings, they can still be placed within an existing building footprint (if available).
Building footprints are typically created from digitising over aerial imagery or extracting objects from LiDAR or other remotely sensed source. There are several advantages to using building footprints instead of points as the features to attach survey information. These are:

- Footprints enable an accurate calculation of footprint area and floor area; and
- Only buildings to be surveyed can be displayed in the map viewer and selected for editing.

There are also some drawbacks to using footprints, including:

- Some footprints may be created as a single polygon for more than one adjacent building (which would need to be split by an operator in the field); and
- Some footprints may represent structures different to actual buildings (e.g. petrol station forecourts, shade structures).

Future surveys of buildings - Preparation

Future Preparation of Survey Forms and Templates

Based on the needs identified earlier, the preparation of survey forms and templates in the PDA and laptop tools should accommodate all necessary survey information. Since forms are already in existence, these forms can be built upon for any surveys in GMMA. Any future changes to the templates in both tools should be prepared such that:

- All questions are present in both tools and worded consistently;
- All agreed lists of values are consistent in both tools (including text case and use of characters);
- All pages/screens are identically named and have similar or identical styles;
- All fields contain the same default values;
- The database table contains attribute fields in the same order;
- All GPS and camera settings for both tools are identical or very similar; and
- Survey templates should be tested together before templates are finalised.

The PDAs for the second survey in Iloilo City were prepared using the AXF file system in ArcGIS. This file system presented some challenges when consolidating and merging datasets, particularly once the survey had been completed. The AXF file system is not particularly flexible when checking data back in to a File Geodatabase (as it requires checking in to the original Geodatabase). Shapefiles provide a much more flexible platform for managing data, and it is recommended that the next generation of survey forms be developed using shapefiles.

Revision of Roof and Wall Attachment Types

The current survey template contains lists for roof and wall attachments. This list has been created from common attachments observed in the field (and was prepared following a reconnaissance of the Jaro district in Iloilo). This list contains specific named attachments. It may be more appropriate to prepare a list of generic attachment types based on the size, shape and distribution of mass for these roof and wall attachments. This list could be generated in consultation with the engineering community, who should be able to advise on the various types that would be of interest in risk assessments for various hazard classes.

Additions to the Survey Manual

The inclusion of the following information in the Survey Manual would be beneficial for future surveys:

- A building diagram, showing the location and extent of the relevant features to be surveyed;
- Additional imagery to depict the various types of roof systems, windows, attachments etc.

Attribution of Buildings Prior to Survey

It may be appropriate to capture as much detail from existing data and imagery to reduce the effort required in the field. Whether buildings are represented as points or polygons, the availability of a number of sources of data (such as high resolution aerial imagery) in the survey area provides an opportunity to ‘pre-fill’ survey forms before embarking on field work. Attributes that may be available from existing data or visible in aerial imagery includes:

- Geographic attributes (Street name, Barangay, District, City etc from various sources);
- Horizontal Plan Shape (from aerial imagery or footprint data);
- Seismic Separation (from aerial imagery or footprint data);
- Number of Storeys (may be visible from some oblique satellite imagery such as Quickbird scenes);
- Roof System (from aerial imagery);
- Roof Attachments (from aerial imagery);
- Roof Type (from aerial imagery);
- Wall Attachments (from aerial imagery);
- Slope (from digital terrain model data); and
- Projections (from aerial imagery).

As well as high resolution aerial photography, another valuable resource for attributing buildings prior to the survey is Google Earth and the Panoramio file sharing website. Along with recent and reasonably high resolution imagery, Google Earth also has a Photos function that allows users to tag the location of photographs they upload into the Panoramio web site. These can be displayed in a pop-up window in Google Earth by clicking on the photo symbol. A high speed internet connection makes it possible to rapidly navigate across areas and display user-contributed photos.

Future surveys of buildings - Execution

Training and Briefing of Survey Teams

Well before a survey commences, a training session should be scheduled to discuss:

- the aim and purpose of the survey with participants;
- all the features of buildings to be surveyed;
- demonstrations of the forms used during the survey; and
- demonstrations of the operation of the device.

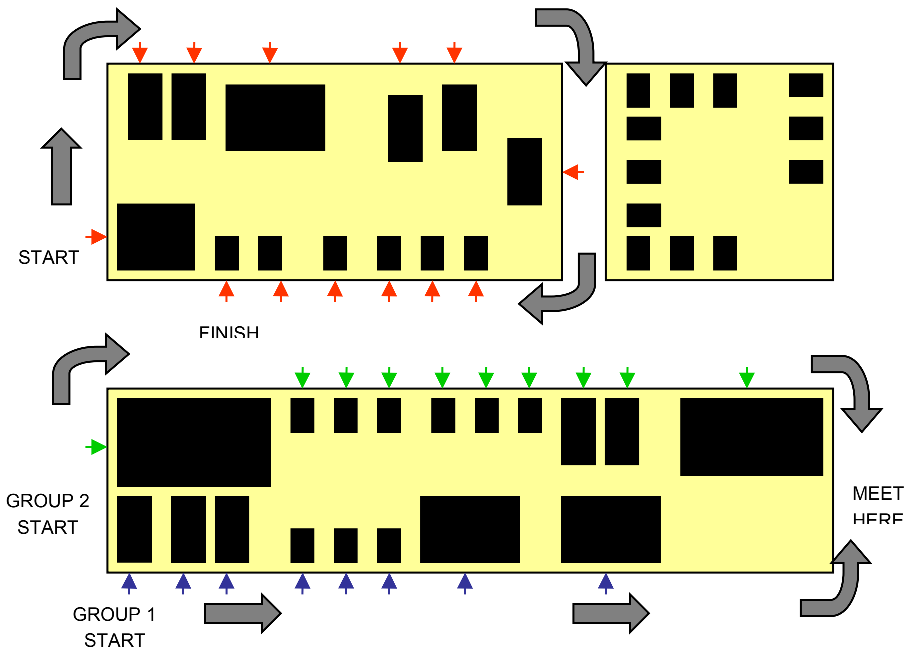
This can be followed by a mock survey of several buildings (using paper forms that mimic the fields in the template). A paper-based exercise would allow participants to fill in their responses in their own time, and the correct responses could be discussed for each building.

Assembly of Survey Teams

Depending upon the availability of participants, it may be beneficial to form survey teams comprising of one specialist from each participating organisation or agency. This would ensure that specific questions in the forms (e.g. building classifications according to Assessor's Office and UPD-ICE schema) are answered by the appropriate team member.

Tracking of Surveyed Buildings

With multiple survey parties working in the same area, there is always the possibility of buildings being recorded twice or not being surveyed at all. If the survey requires all buildings within an area to be surveyed, it is recommended that one or two survey parties are tasked to survey specific blocks. In the diagram below, there are two blocks being surveyed. The top left block is being surveyed by one team, and in the lower block there are two teams surveying the one block.



For the upper block, the team is surveying every building within the block until it is completed. For the lower block, the teams move in opposite directions and survey buildings until they meet approximately half way around the block. Again, this ensures that all buildings in that block are surveyed. The choice of method could depend on how many survey parties are available to carry out a survey.

Management of Survey Progress

It would be useful to identify key personnel for the duration of the survey, including:

- Survey Coordinator – to assemble available staff into teams, monitor and track survey progress, provide daily briefings on completed areas and new areas to be surveyed, liaise with survey team leaders on operational issues

- Survey Team Leader(s) – to lead a survey team in the field, liaise with the Survey Coordinator on daily progress and operational issues

Survey of Critical Facilities

Since the survey templates generate a Critical Facility ID based on the unique record identifier generated in the PDA and the laptop tool, it is recommended that only one unit be used to survey a specific critical facility. This will enable that unit to preserve the identifier for all buildings surveyed within the facility, eliminating the generation of multiple identifiers for the same facility across different devices.

Future Collaboration

Data Transfer and Version Control

One challenge to international collaboration is the maintenance of versions of datasets, documents, scripts and other electronic files. Whilst it is easy to transfer data files between collaborators, tracking the most current version of a single dataset can difficult and confusing. It is recommended that GA and PHIVOLCS investigate a data sharing environment that provides the security and accessibility needed for effective data exchange. An agreed system of file management and naming would also benefit future engagement.