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Teaching Natural Hazards and Mitigation Strategies Using Information Technology

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Abstract: Natural and environmental hazards include earthquakes, volcanoes, hurricanes, flooding, landslides, among others. These hazards present high risk to human lives and infrastructure. This is particularly true when such systems affect populated areas, leaving devastated homes, highways, buildings and the social structure. A key aspect of natural hazard mitigation is the implementation of adequate strategies of data collection, processing, and sharing. The authors highlight the benefits of using Information Technology (IT) based solutions through a course they developed as part of the undergraduate program in Civil Engineering (CE) at the University of Puerto Rico at Mayagüez (UPRM). As most CE curriculums these focus primarily on the traditional areas of civil engineering education. Typically there is no formal student preparation in natural disasters although CE professionals could play a critical role in natural hazard risk mitigation and relief activities. The creation of such a course was well received particularly given the fact that Puerto Rico is a tropical island, with a variety of natural hazards associated to extreme climate events often associated with heavy rainfall events or related to the high seismicity of the region. The purpose of this article is to present an overview of the course developed in the CE Department at UPRM and highlight how the use of IT solutions was integrated in a seamless way as a fundamental component of the course. The inclusion of IT allowed students to participate in the development of an up-to-date technology based system to collect and manage natural hazard data.

1. Introduction

Most undergraduate programs in Civil Engineering (CE) are pressured to reduce their duration and number of credits and us such they often limit their coverage to the main specialization areas such as structures, transportation, geotechnical engineering, hydraulics, environmental, and construction management. At the University of Puerto Rico at Mayagüez this is also the case, despite this being a five year program the curriculum focuses primarily in the traditional areas of civil engineering education. Thus there is no formal student preparation in natural disasters although CE professionals could play a major role in natural hazard mitigation, relief activities, or development of solutions for more resilient communities. Given its geographic location, Puerto Rico is exposed to a variety of natural hazards that could result in natural disasters. Examples of such natural events are hurricanes, earthquakes, rapid floods, landslides, coastal and river erosion, etc. The annual hurricane season in the island typically starts in July and ends in November, with September usually being the month with most activity. The damages associated with tropical storms and hurricanes can range from destruction due to strong winds to problems associated with floods, landslides, erosion, among others, due to the heavy rain associated with such systems. The exposure to this multiplicity of natural hazards in Puerto Rico makes this field very relevant and of great interest to CE students at UPRM.

Despite the high recurrence of natural hazards, a considerable number of CE undergraduate students at UPRM do not have formal knowledge about the different types of natural hazards and associated risks to civil infrastructure represented by these systems. Furthermore, they typically do not acknowledge the important role that civil engineers could have in pre-, during, and post-disaster phases. Traditionally there has been little to no emphasis on the role of the civil engineers with respects to natural disasters mitigation, or emergency response during or after these events. At the graduate level, this topic is covered to some extent in structural engineering courses particularly on aspects dealing with structural design and analyses of structures subjected to earthquakes or wind loading. At UPRM there is a long history of research efforts related to monitoring and mitigation of effects of natural disasters to civil infrastructure. For example, the Puerto Rico Strong Motion Program is housed in the CE Department at UPRM. This program has been in operation for 100 years and has been active in applied research related to mitigation of seismic effects on civil infrastructure in the island. Similarly, there are other programs that perform different types of research related to natural disaster mitigation. At the government level, Puerto Rico has an agency devoted to emergency management and the local municipalities also have response teams. CE faculty at UPRM have collaborated over the years with these local and state agencies on natural hazard mitigation efforts.

Based on the relevance and importance of natural hazards and disaster mitigation, in general, but especially for Puerto Rico, the authors developed a CE undergraduate elective course focused primarily on mitigation of natural and environmental disasters. The course was designed with the idea of exposing students to the different types of natural disasters, their causes, their consequences to humans and civil infrastructure, and possible ways in which they could mitigate the negative effects on the population and infrastructure in the event of a natural disaster. In addition, the instructors presented engineering aspects considered when performing post-disaster inspections. This paper describes the course developed by the authors and summarizes the feedback received by students over a period of 3 years.

2. Course Outline

The course was developed as 3 credit hours which in a 15 weeks semester equating to 45 lecture hours. The course is divided into four sections, namely: i) review of probability, risk and hazard concepts; ii) review of planet earth and human population as they relate to natural hazards; iii) coverage of different natural hazards in the form of genesis, mechanisms, types, consequences, recurrence, and case histories (Table 1 provides a list of the natural hazards usually covered in the course; Table 2 provides some of the case histories discussed in class); and iv) IT as a Natural Hazard management tool. This fourth section is described in more detail in the following page.

Table 1: List of Natural Disasters Covered in the Course

Natural Disaster	
Earthquakes	Hurricanes
Floods and river erosion	High Winds
Landslides	Tsunamis

Table 2: List of Case Studies Discussed in the Course

Case Histories	
Hurricane Katrina	1985 Mexico City Earthquake
Hurricane Hugo	Puerto Plata, Dominican Republic Earthquake
Mameyes Landslide in Puerto Rico	Flood instances in Puerto Rico
Ica, Perú Earthquake	1989 California Earthquake

2.1 Incorporation of IT in the Course

Preparation and response in the event of a natural disaster greatly relies on the information available before, during and after an event has taken place. It is a task that may require a lot of effort, especially due to the large amount of information that must be collected, sorted and analyzed to make informed decisions. The information that flows through different means must be available in real time in order to provide updated and well-planned responses during all phases of the event. This type of information can be related to: existing conditions, weather conditions, services, government decisions, reconstruction, geographic data, insurance information, particular problems and current state of affairs being attended, among others.

Innovations in Information Technology (IT), especially in aspects of portability and software advances in Geographic Information Systems (GIS), can allow easier and more effective on site data collection and analysis, and the use of visualization and interpretation tools. This technology can be used to obtain quantitative and qualitative information related to natural disasters mitigation activities. Based on this, the authors proposed the framework shown in Figure 1 to collect process and manage natural hazard related data. Throughout this process, inspectors in the field use the application developed by the students to make an assessment of the situation on site after a natural disaster happens. The inspector in the field, in addition to having available the application developed by the student, could have other information available including soil types, hydrology, topography, among others, if the inspector has access to a database with this information that must be available on a server. The information collected in the field is sent to a database where it is synchronized with information that is already stored. This information is processed by the people in the office. After the information has been processed, it will be available for use by the people responsible for making decisions to mitigate the situation after the disaster occurs. This information may be available through a local wireless network or through a GIS web based system.

One of the key issues when trying to implement IT as a means for natural hazards information management is identifying which information is relevant during a natural disaster. Therefore, it is important to identify what questions to ask during a natural disaster. In order for the system to be effective, the implementation of technology should not undermine communication at the societal, community, and/or organization levels. Another important issue is to remember that IT is being used as a means for optimizing the process. The important issue is the information related to the natural disaster and not the IT application.

The tools should be used for to communicate warning or hazard information to decision makers, to the general population in an efficient manner. This could help enhance their disaster preparedness and response. For this project, the authors decided to include computational tools as an important part of the course. The availability, portability and the fact that applications can be developed or purchased, make computers useful for data collection. Due to these factors, the authors intended to expose students to existing technology that allows automating the collection, transmission and storage of inspection data related to natural disasters.
This could allow the data to be immediately available for people who need to make decisions based on the needs caused by the disaster.

2.2 Course Assessment

The informal feedback, through meetings and information sessions, from CE students and faculty was that the course was relevant and filled an important void. However, the authors implemented a course assessment module to measure qualitatively the impact the course had in students understanding of natural hazards and the main aspects covered in the course. One of the goals of the course was to identify the students' knowledge related to natural disasters before the topics were presented in class. In order to do the analysis, the instructors prepared and administered a questionnaire asking questions about different natural disasters. The questionnaire was repeated after the completion of the course to assess the level of student learning during the semester. Figure 2 depicts a part of the questionnaire that was administered to students.

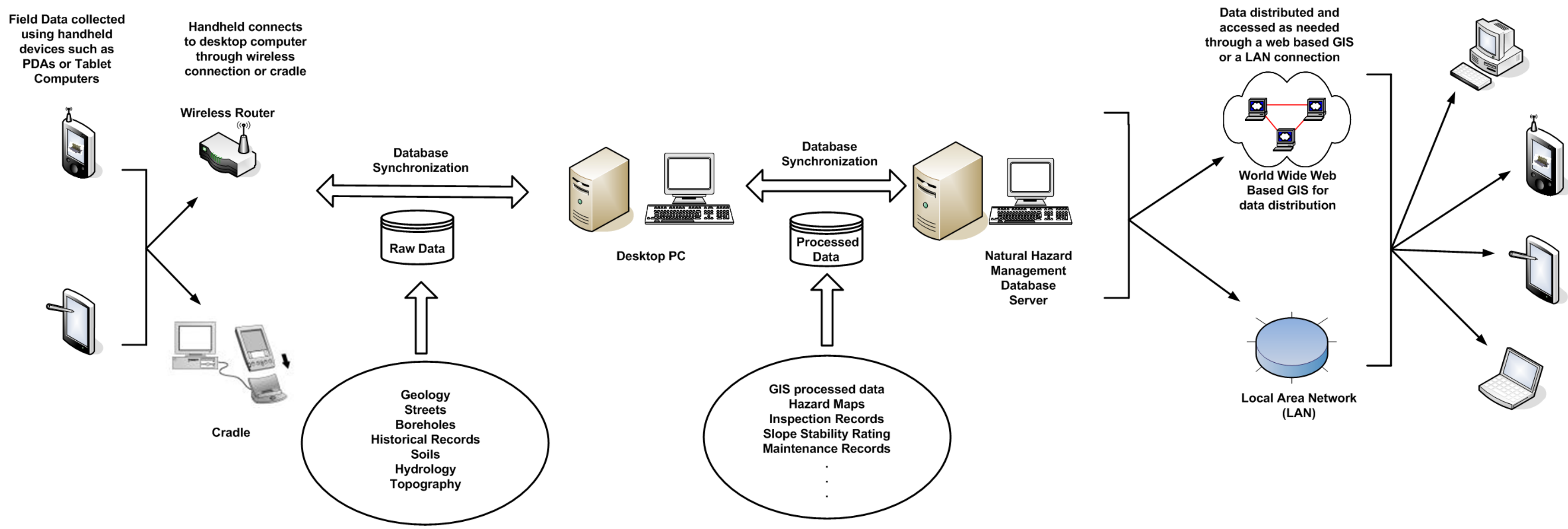
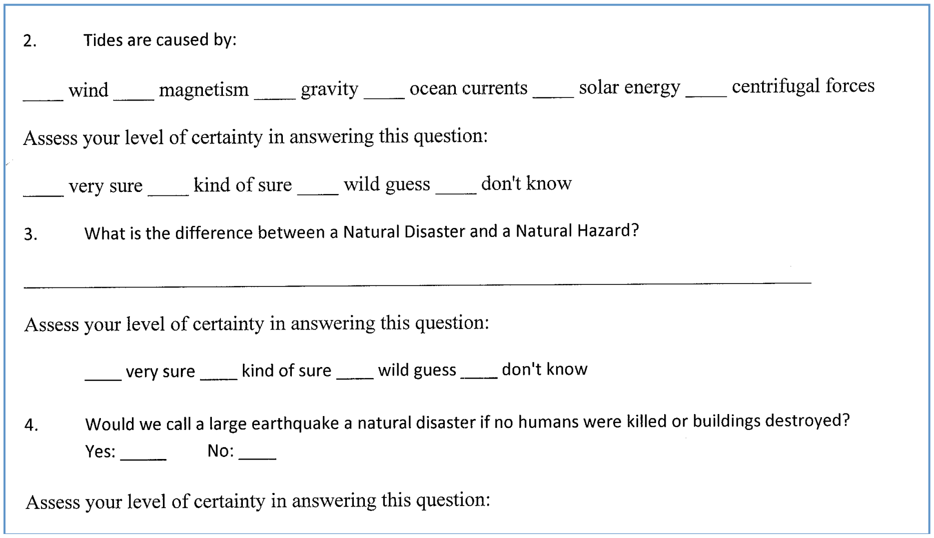


Figure 1: Structure of Information Transfer (Pando and Perdomo, 2005)



2. Tides are caused by:

____ wind ____ magnetism ____ gravity ____ ocean currents ____ solar energy ____ centrifugal forces

Assess your level of certainty in answering this question:

____ very sure ____ kind of sure ____ wild guess ____ don't know

3. What is the difference between a Natural Disaster and a Natural Hazard?

____

Assess your level of certainty in answering this question:

____ very sure ____ kind of sure ____ wild guess ____ don't know

4. Would we call a large earthquake a natural disaster if no humans were killed or buildings destroyed?
Yes: _____ No: ____

Assess your level of certainty in answering this question:

Figure 2: Portion of the Survey Administered to Students

Figure 3 depicts an analysis of the results for a question of the initial questionnaire given to the students at the beginning of the course. This question dealt with the fact that if an earthquake happens, but there is no damage to people or infrastructure, if it can be considered a natural disaster. As can be seen from the figure, the majority of the students answered No, which is correct, but only 25% of the students were very sure about their answer.

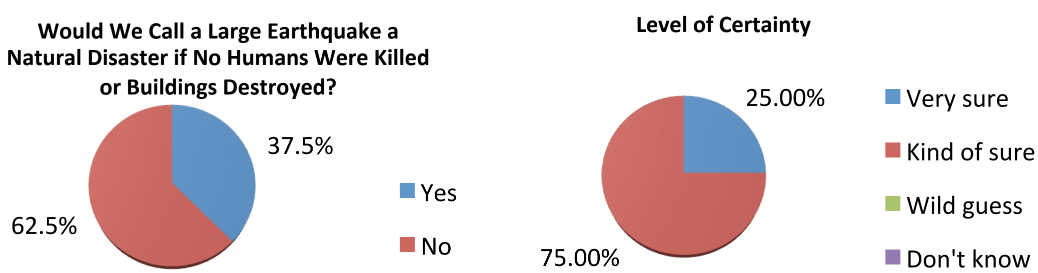


Figure 3: Results of Survey at the Beginning of the Course

Figure 4 depicts the results of the questionnaire administered at the end of the course. As can be seen from the figure, all students got the question correct. The majority of the students, 75% of the students, were very sure about their answer. In a sense, this demonstrates that students gain some knowledge about natural disasters in the course.

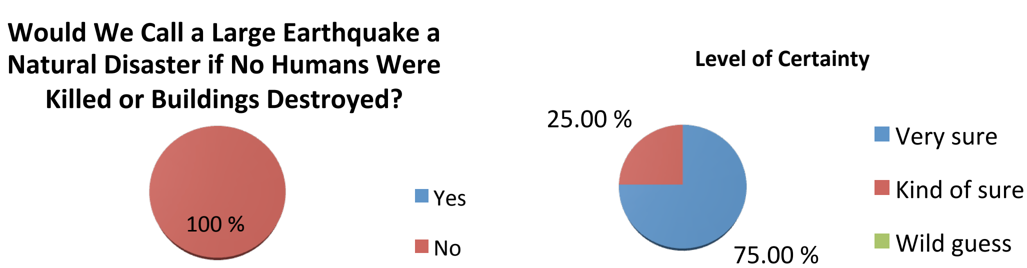


Figure 4: Results of Survey at the End of the Course

2.3 Information Technology Component of the Course

As was mentioned before, the second part of the course consisted of laboratory sessions where different topics related to IT were presented to students. The instructors offered workshops related to the use of MS Access®, information transfer to and from a server using file transfer programs (FTP), website design, preparation of electronic forms for data collection, spreadsheets for data analysis and graphical illustrations, among others.

These lectures were presented with the idea of giving students the necessary knowledge needed to carry out the project of the semester. The project consisted on selecting a natural disaster that the student wanted to study. During the semester, the student made a research on the subject, in order to develop an application that would allow inspections in the field after the natural disaster has occurred. Once the form created by the student was approved by the instructors, the student had to create an electronic version of this form in order to able to perform automated inspections.

This faster access to the information has several advantages in the fact that immediate transfer of information allows making informed decisions quickly. With the traditional inspection process done with paper forms, it takes longer for the information to be available to those in charge. One can argue that cell phone use can cause information transfer to faster. However, the person making the decision will have only available the information that is being told and not all the information that may be available. In any case, it would be important to have both components, information from the inspection team and the information that can be provided, through the phone, to the people who are present at the site.

3. Example of IT Application for Natural Hazard Management Developed

As mentioned earlier one key component of the course is for students to develop a PC based questionnaire that can be used by emergency responders or post-disaster reconnaissance teams. This section describes one of the applications developed by a course participant that focused on hazard related to landslides. Landslides are an important natural hazard in Puerto Rico, because it is a mountainous island with numerous natural and man-made slopes. Every year, typically associated to heavy rainfalls during hurricane season, numerous landslides are reported in the island. This is a serious recurring problem that deserves better record keeping so that local and municipal emergency management agencies can develop rational landslide mitigation strategies for Puerto Rico.

The work has the potential to be expanded to build a portal for managing information related to landslides in Puerto Rico. In this course, the student designed and created a set of standard landslide data collection sheets, in both physical and electronic format, does enabling information collection in the field after the occurrence of a landslide. Figure 5 shows a part of the inspection sheet developed by the student. This sheet may be printed and used in the field while performing an inspection.

It was required that students created an electronic version of the form so that it could be used directly on the computer at the time of an inspection. In order to achieve this, the use MS Access® was recommended for developing the electronic version of the form.

Figure 6 depicts a portion of the application developed in MS Access® for inspections after a landslide occurs. This form includes all the information required at the time of inspection. In the figure, all the general information required about the landslide is shown. Information such as location, which may be obtained from a GIS system, geometry of the landslide, primary and secondary type of landslide, among others is required.

An important aspect that can be included in the application and it is quite difficult to include in paper forms, is the ability to add photos or videos of the landslide at the time of inspection. They can be attached to the report and sent immediately to the people in charge of the decision making process. This feature is shown in Figure 7.

Landslide/ Potential Landslide Report– Sheet 1	
Inspector's Information	
Name:	Report Date (D/M/Y/Time):
Institution:	Address:
Telephone:	
Reviewer Information	
Name:	Address:
Telephone:	
Date (M/D/Y):	
Information about the Landslide	
Select One: □ New Landslide □ Potential Landslide □ Landslide Monitoring	
Record Number:	
Date (D/M/Y/Time):	
Location	
Country:	Address:
Town:	
Neighborhood:	
Street:	
Km:	
Latitude:	
Longitude:	
Topographic Description: □ Mountain □ Antler □ Hill	 □ Valley □ Sink □ Aquifer

Figure 5: Part of Landslide Report (Prepared by UPRM student Emmanuel Padilla)

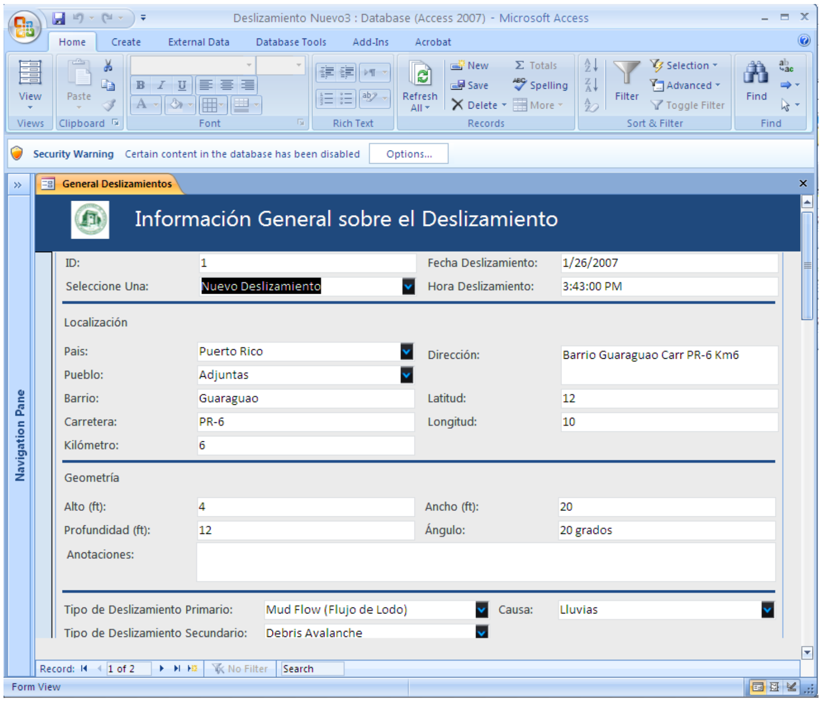


Figure 6: Automated Landslide Report (Prepared by UPRM student Emmanuel Padilla)

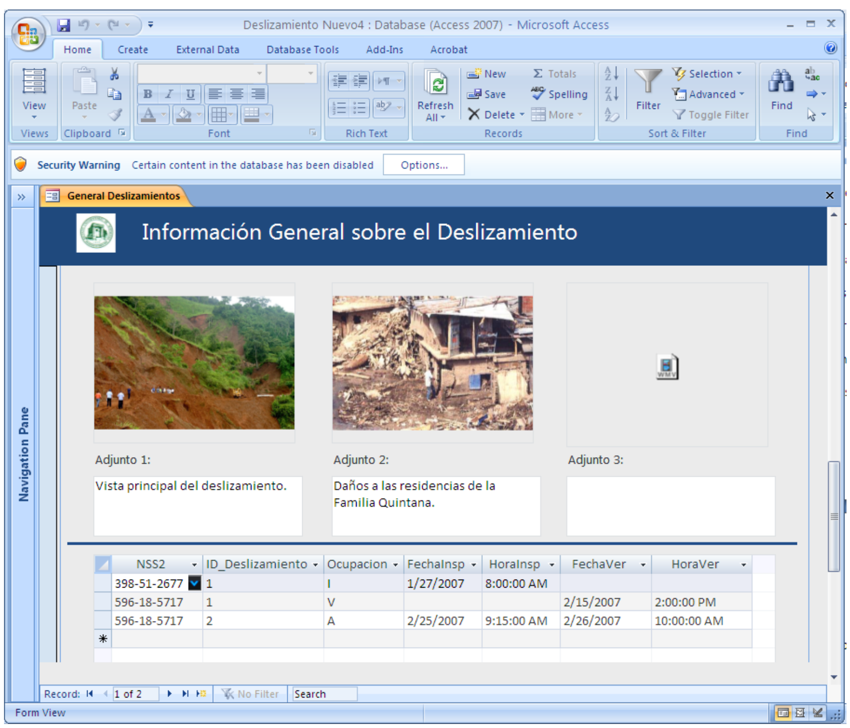


Figure 7: Photos and Videos Area (Prepared by UPRM student Emmanuel Padilla)

3.1 iPad Version

Recent IT advancements in portable devices, such as iPads and Tablets, in terms of computing power, size and portability motivated the instructors to adapt the inspection form for landslides to an iPad device.

The instructors used FileMaker Pro Advanced to develop the inspection form in order to be able to use it in the iPads. Figure 8 depicts a screenshot of portion of the electronic form in an iPad. As can be seen from this figure, the electronic form includes the most important aspects for the inspection. After the inspection has been completed, it can be sent through email to the people in charge of making decisions.

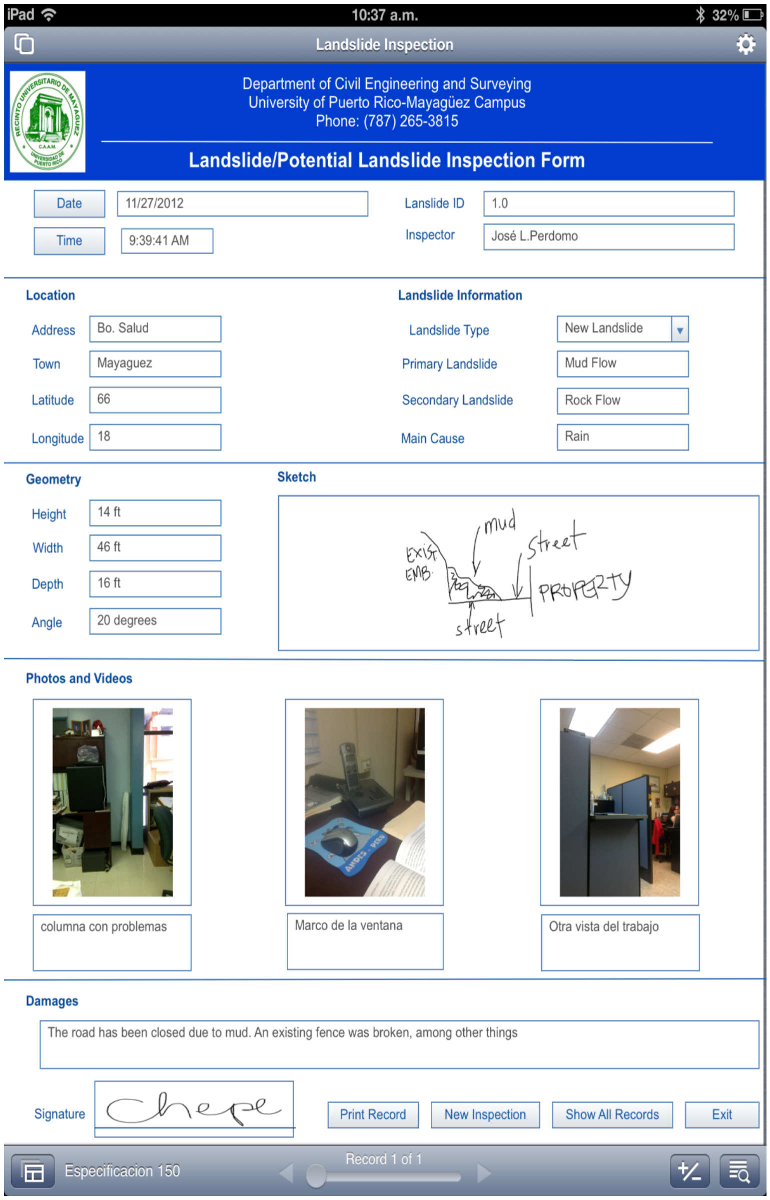


Figure 8: iPad Version of the Landslide Inspection Form

4. Summary and Conclusions

It is very important for civil engineers to develop awareness about the role that they could play in the event of a natural disaster. The developed course met the expectations of orienting students about the different types of natural disasters and the role they could play depending on the type of disaster that occurs. The authors believe that the course should continue as an offering available to the students in our department. It is of great benefit for students considering the threats to which the island is exposed and that could affect the lives of their residents. IT can play an important role in natural hazard management and mitigation. Application of developed technology solutions should not ignore the societal needs, behaviour and responses.

5. Acknowledgements

The instructors want express their gratitude to Hewlett Packard and the HP Technology Grant Initiative for the equipment grant that made possible to offer this course with the proposed IT focus. Similarly, the authors want to thank the unconditional support of many people who selflessly offered their help with this course in the form of guest lecturers to describe different natural hazards. Particularly the following professors from the UPRM Department of Civil Engineering: Ismael Pagán (floods), Ricardo López (earthquakes), Raúl Zapata (floods and river erosion), José A. Martínez (earthquakes), and Luis Aponte (winds and hurricanes). In addition, the authors want to express their gratitude to Emmanuel Padilla for developing part of the work used as example in this paper.

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