DRMKC Support System

Project:

Tsunami Risk Assessment in Terms of Building Economic Losses Using GIS Tools

Task 1: Tsunami scenario Selection - Data collection

Authored by

MSc (PhD candidate) Ioanna Triantafyllou

Collaborator: Dr. T. Novikova

Supervisor: Dr. G.A. Papadopoulos

NOA, Athens, Greece

Athens, 17 February 2017
**Introduction**

Tsunamis are low frequency-high impact natural events causing extensive destruction and economic losses in the coastal areas that they hit. The North East Atlantic and the Mediterranean (NEAM) region is also exposed to tsunami hazard. However, due to the tsunami occurrence scarcity only few modern data have been collected as regards the tsunami impact in the NEAM region and worldwide. Therefore, only very few studies have been performed as regards the description of the tsunami risk in terms of economic losses. The scope of the requested service is to further develop methodologies that could provide an assessment of the expected economic losses from the impact of strong tsunamis to buildings. This would be an important added value to Disaster Risk Management for the reason that may offer a basis for the prevention of tsunami disaster through appropriate long-term preparatory actions undertaken by civil protection authorities and other decision makers. In addition, such a service would be of particular value to insurance and re-insurance stakeholders. Moreover, the methodology would be applicable, after appropriate modifications, to other types of hazards, such as earthquakes and floods.

The proposed Service aims to test methodologies for the estimation of the expected damage level and economic losses to buildings due to tsunami impact. Since such estimations should be reliable for practical implementation, emphasis will be given to test the dependence of the results on the several parameters and assumptions inserted in the method. The methodological steps to follow include (a) selection of worst case scenario in the study area, (b) numerical simulation of the tsunami and determination of the inundation zone, (c) application of the DAMASCHE empirical tool, produced by the SCHEMA EU-FP6 project, for the calculation of the damage level expected at each one of the buildings as a function of the water depth in the inundation area, (d) calculation of the buildings that would need reparation after partial damage and of those that would need reconstruction after total destruction, (e) calculation of the cost implied for reparation and the cost implied for reconstruction.

The several data sets which are needed for the execution of these steps, are susceptible to many uncertainties and, therefore, the final results are quite sensitive to changes of the data sets, such as the parameters of the tsunami source inserted in the scenarios, the bathymetry, the Digital Elevation Model (DEM) in the inundation zone, the building data as well as the building-damage cost functions adopted for the calculation of the economic losses.

**Selection of Rhodes city (Greece) as test-site**

For a number of reasons, the test site selected is the Rhodes city of Rhodes Isl. in Greece. The entire island (Fig. 1) has a permanent population of about 130000, while the city of Rhodes has a permanent population of about 40000. However, since it is an international tourist destination the built environment of the city has been highly expanded to facilitate hundreds of thousands of visitors every year. On the other hand, from the earthquake and tsunami history of the area it results that the city of Rhodes was hit by several powerful tsunamis in the past. Therefore, the built environment is highly exposed to future tsunami threat. In addition, the Rhodes city was one of the main test-sites of the EU-FP6 TRANSFER tsunami
project and of the DG-ECHO NEARTOWRN project (2012-2013), thus offering appropriate data as regards the selection of tsunami scenarios. The Civil Protection Office of the Rhodes Municipality is in constant collaboration with the Hellenic National Tsunami Warning Center (HL-NTWC) of NOA offering administrative support.

However, the coastal zone of the city of Rhodes and its surrounding areas (Fig. 1) is of a total length of about 25 km. Therefore, there is need to select an appropriate coastal segment which is suitable for the application of the methodology proposed. Some of the coastal segments are unsuitable for the reason that their built environment is dominated not by regular buildings for resident and commercial use but by specific engineered structures such as harbor and large breakwater walls for the protection of marinas. A particular coastal segment was selected as shown in Figures 1 and 2 for the reason that it is dominated by regular buildings and, therefore, it is suitable for the application of the methodology developed.
Figure 1. Map of the island of Rhodes. The capital city and its surrounding areas is marked by the rectangular at the NE side of the island. (see detailed topography map in Fig. 2).
Figure 2. Digital Elevation Model (DEM) of the bay of Phaneromeni area.

**Tsunami Scenario Selection**

The deliverables expected to be produced within this contract and their corresponding deadline for delivery are listed in Table 1. The first concerns the Tsunami Scenario Selection and the Data Collection.
Table 1. List of deliverables to be produced within this contract and their corresponding deadline for delivery.

<table>
<thead>
<tr>
<th>Task</th>
<th>Deliverables</th>
<th>Title</th>
<th>Type of deliverable</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Tsunami Scenario Selection - Data Collection</td>
<td>Data to be sued for the study</td>
<td>M1</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Determination of Inundation Zone</td>
<td>Maps and methodology</td>
<td>M2</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Ex-ante Loss Assessment: People Affected and Economic Losses due to damaged buildings.</td>
<td>Results and methodology</td>
<td>M2.5</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Results Evaluation - Applicability to other Hazard Types</td>
<td>Results and proposed methodology</td>
<td>M3</td>
</tr>
<tr>
<td>5</td>
<td>D1</td>
<td>Identification of the key recommendations</td>
<td>Final Report</td>
<td>M3.5</td>
</tr>
</tbody>
</table>

From a variety of historical documentary sources it results that the city of Rhodes was hit by several strong tsunamis such as the ones of AD 142, 1303, 1481, 1609, 1741, 1851, all caused by large earthquakes occurring in the Hellenic Arc (Papadopoulos et al., 2007). In addition, a local aseismic tsunami, likely due to submarine landslide, was observed there on 26th March 2002. On the other hand, the generation of large earthquakes in Rhodes has been independently documented by geological observations indicating the co-seismic coastal uplift in Holocene times (e.g. Pirazzoli et al., 1989). Such a very large earthquake, measuring magnitude of up to 8.4 (Mitsoudis et al., 2012) may have generated a large tsunami in the area.

For the selection of two alternative scenarios in this study we have considered two seismic sources with fault parameters as described in Table 2. Both sources are situated to the areas east of Rhodes Isl. since this area has been considered as the most seismogenic which historically produced large earthquakes. The first scenario has fault strike of 225\(^\circ\) (with 0\(^\circ\) at north), which is nearly parallel to the coast of east Rhodes, while the second has fault strike of 285\(^\circ\) which is perpendicular to the coast of east Rhodes. These are preliminary seismic sources. After some simulation runs it is possible to modify slightly some of the parameters.

After a first wave simulation it was verified that, as expected, the scenario of fault having strike of 225\(^\circ\) is the one that produces higher tsunami amplitudes (Fig. 3) and, therefore, it would be the worst scenario for the area.
Table 2. Seismic fault parameters considered for two tsunami scenarios in Rhodes area.

<table>
<thead>
<tr>
<th>Scenario number</th>
<th>Fault locations [degrees]</th>
<th>Length [km]</th>
<th>Width [km]</th>
<th>Slip [m]</th>
<th>Centroid depth (km)</th>
<th>Strike (deg)</th>
<th>Dip (deg)</th>
<th>Rake (deg)</th>
<th>Mw</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Long(1)=28.2 Lat(1)=36.0</td>
<td>186</td>
<td>45</td>
<td>7.35</td>
<td>20</td>
<td>225</td>
<td>20</td>
<td>90</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>Long(2)=28.9 Lat(2)=36.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Long(1)=28.5 Lat(1)=36.35</td>
<td>186</td>
<td>45</td>
<td>7.35</td>
<td>20</td>
<td>285</td>
<td>20</td>
<td>90</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>Long(2)=29.3 Lat(2)=36.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3. Maximum surface elevation at all times for the case of fault with strike equal to 225 deg. (left) and 285 deg. (right).

**Data Collection**

For modelling of the tsunami which is produced by a scenario seismic source there is also need to introduce the bathymetry of the area as well as the Digital Elevation Model (DEM) of the inundation area which has been selected to study. The bathymetry file inserted for the open sea is the one which has been provided by the Hellenic Center for Marine Research, Greece. This file is of resolution of 230 m. For the near-shore domain a much better bathymetry file was obtained by digitizing the topography map of the area which contains also about near-shore bathymetry.
The Digital Elevation Model, being of resolution of 5m (Fig. 2) was provided by the National Cadastre and Mapping Agency S.A., Greece. Building data were provided by the Hellenic Statistical Survey. These data are based on the 2011 national census.

Ongoing Work – Final Report

The incorporation of all the DEM and bathymetry data into the appropriate grids as well as the determination of the inundation zone in the bay of Phaneromeni area from numerical simulation of the selected worst tsunami scenario is expected to terminate by 20 February 2017. Then, with the use of the empirical tool DAMASCHE, which was produced within the frame of the SCHEMA FP6 project and correlates tsunami water depth with damage level according to the building types, the buildings damage level will be estimated.

The damage level will be inverted to cost for building reparation and reconstruction according to the official unit costs declared by the Greek Government after the 26 January and 3 February 2014 damaging earthquakes in Cephalonia Isl., Greece. With the use of ArcGIS software we will create thematic layers in Cephalonia Isl. Greece. With the use of ArcGIS software we will create thematic layers that showing the inundation zone and the water depth, as well as the type of building block and the expected damage level in each building block after the invasion of tsunami.

The results evaluation will be executed on the basis of sensitivity analysis.

The final report is expected to be submitted before 15 March 2017.

References

