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SIMULATION OF THE 1755 TSUNAMI FLOODING AREA IN THE ALGARVE (SOUTHERN PORTUGAL): THE CASE-STUDY OF PORTIMÃO

Fantina Tedim, **João Gonçalves**
Faculdade de Letras, Universidade do Porto
fpedrosa@letras.up.pt

RESUMO

O terramoto de 1 de Novembro de 1755 continua a ser o mais poderoso e destrutivo que afectou a Europa. Apesar de ter ficado associado a Lisboa, uma das mais importantes cidades europeias nessa época, este sismo originou um número de vítimas e um cenário de destruição igual, senão mesmo superior, no Algarve, onde a intensidade sísmica foi estimada em IX-X na escala de Mercalli. Alguns minutos depois um tsunami aumentou a dimensão da catástrofe. Recorrendo a técnicas simples de simulação, estimaram-se os potenciais impactes da repetição nos nossos dias de um tsunami semelhante ao de 1755, na área de Portimão.

Palavras chave: Sismo de 1755, tsunami, Algarve, catástrofe, simulação, sistemas de informação geográfica (SIG), planeamento de emergência, avaliação de impactes.

ABSTRACT

The November 1st 1755 earthquake remains the most powerful and destructive to hit Europe so far. Although frequently associated with the city of Lisbon, this earthquake caused similar or greater damage and casualties in the southwest of the Algarve, where the seismic intensity was estimated at IX-X Mercalli Intensity Scale. Some minutes later, a tsunami increased the dimension of the disaster. Using simple techniques of simulation, we estimated the potential impacts of the occurrence of a similar event to the 1755 tsunami nowadays in Portimão.

Key words: 1755 earthquake, tsunami, Algarve, disaster, simulation, GIS, emergency planning, impacts assessment.

RÉSUMÉ

Le séisme du 1er Novembre 1755 est jusqu'au moment le plus destructif à affecter l'Europe. Malgré associé souvent à la ville de Lisbonne, le séisme a provoqué dommages, semblables ou même plus grands, dans le sud-ouest de l'Algarve, où l'intensité séismique estimé est de IX-X dans l'échelle de Mercalli. Quelques minutes après le séisme, un raz de marée a augmenté la dimension de la catastrophe. En utilisant des techniques de simulation nous voulons évaluer les conséquences de l'occurrence aujourd'hui d'un phénomène pareil au de 1755 à Portimão.

Mots clé: Séisme de 1755, raz de marée, Algarve, catastrophe, simulation, SIG, planification d'émergence, évaluation de dégâts.

Introduction

The 1755 earthquake, which reached a magnitude of 8.5, remains the most powerful and destructive to hit Europe so far. Within minutes, many lives were lost, populations displaced, livelihoods, homes and infrastructures were destroyed.

Shortly after the earthquake, a tsunami increased the death toll and the amount of damage. The tsunami hit both coasts of the North Atlantic. It reached the London harbour and it is reported from Norway, as well as from the African coast. However, the more destructive damage occurred in the Portuguese coast, south from Lisbon, in the Moroccan coast and in the Gulf of Cadiz. The downtown of Lisbon was hit by waves 6 meters high and at Cape São Vicente (Southwest of Portugal) the run-up height, evaluated from historical data, was greater than 15 meters (Baptista *et al.*, 1998). The data from Spain and Morocco reported waves greater than 10 meters high. In the Spanish coastal towns of Huelva and Cadiz the tsunami was also violent and the greatest part of the estimated 2,000 victims was due to the tsunami, which was known as the "maremoto de Cádiz" (Martinez Solares and López Arroyo, 2004).

The 1755 earthquake marked a significant milestone in the way Portuguese society perceived not only this type of geological phenomenon but also the subsequent disaster response. Throughout Europe, the disaster was vigorously explained by Enlightenment philosophers as a natural phenomenon that could be scientifically understood rather than an Act of God that served only to punish the sinful. In contrast, a deeply religious Portuguese society was willing to consider the earthquake as God's punishment. Facing stiff social opposition to mitigate this perceived punishment Prime Minister Sebastião José de Carvalho e Melo, later made Marquis of Pombal, launched a disaster response operation that was extremely complex for the time. The operation was set up despite the lack of socio-political experience in dealing with such an unprecedented disaster and the non existence of any previous emergency planning. Although his priorities were to bury the dead in the face of threatening epidemics and to take care of the living by means of food and shelter, the Marquis of Pombal preserved public order, allocated a workforce for reconstruction, and relaunched the Portuguese economy both at the microeconomic and macroeconomic scales. The reconstruction effort followed an assessment of several possible reconstruction models and the search for structural measures of hazard mitigation.

Although frequently associated with the city of Lisbon the 1755 earthquake caused similar or greater damage and casualties, in the southwest of the Algarve, where the seismic intensity was estimated IX-X Mercalli Intensity Scale (Sousa, 1919; Baptista *et al.*, 1998; Chester, 2001).

It is our purpose to delimitate the area flooded by the 1755 tsunami in the municipality of Portimão, which was one of the most devastated in the Algarve, and to assess the impacts of the occurrence of a similar event nowadays. The study area corresponds to a coastal strip well delimited, extending from river Alvor to river Arade. It is characterised by an average altitude of 25 meters high, the highest point being at 71 meters, displaying gentle slopes, with the exception of some cliffs in the area of Praia da Rocha (Figure 1).

We want to show that the determination of the flooded area is an important instrument not only in terms of disaster preparedness but also for the integration of mitigation measures in the strategy of development and land planning of the coastal area.

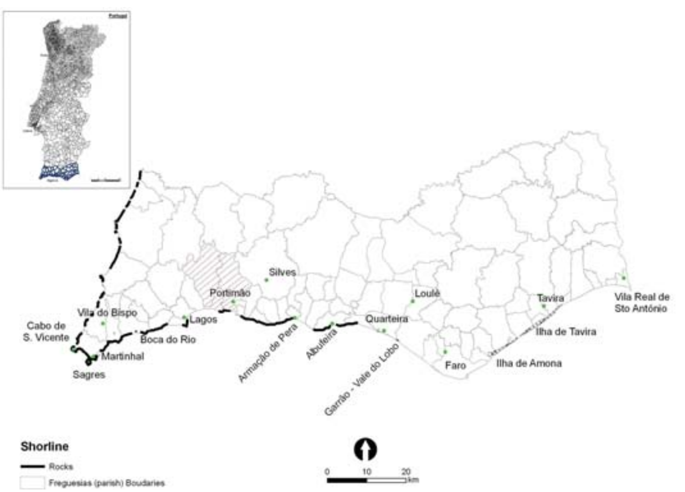

Figure 1 - The localisation of the municipality of Portimão.

Data and methodology

Taking into consideration that the earthquake occurred in 1755, the devastation is well documented in engravings, reports in newspapers of the time, and letters between several distinguished people. Prime Minister Melo ordered a survey to be answered by the priests of all parishes of the country, known as the *Marquis of Pombal Survey*, which contributed immensely to a scientific analysis of the disaster response. In fact, this survey is extremely scientific considering it was written in the 18th century. From it we can identify the moment the earthquake started and how long it lasted as well as the extension of the area affected; characteristics of the event and physical impacts including aftershocks, direction of the waves, disaster response and recovery efforts. Two of the questions focused specifically on tsunami[1].This was not only an important intervention at the political level but it also was a significant initiative from a scientific perspective. The observation network that was thus established to document the effects of the earthquake was therefore extremely extensive and specific (Pedrosa and Richards, 2005).

Another fundamental source is the *Dicionário Geográfico* [Geographical Dictionary] which contains vital information regarding several aspects of the geography of the Kingdom of Portugal in the 18th century. Although the process of collecting information by sending the survey to the priests, of all the parishes, began in 1721, several problems made it necessary to send a new survey in 1758 (Costa *et al*. 2005). The questionnaire included a question[2] regarding the devastation level caused by the earthquake and the state of current reconstruction. Despite the fact that it did not include a question directly related with the tsunami, the priests mentioned, in their answers, the damage caused by the phenomenon. This survey is much more limited for the study of the 1755 earthquake than the earlier *Marquis of Pombal Survey*, but the answers to the latest regarding the South of Portugal remain unknown. For this reason the main support of our research is the *Dicionário Geográfico* of 1758.

The information collected in historical documents about the height of the waves and the extension of penetration of the tsunami on land provided a base to the delimitation of the flooded area. However, we are not entirely sure of the exact coastal morphology of the time, so it is particularly important to determine the location of churches and other buildings damaged by the force of the waves, inside of which the maximum height of the water is known, in order to validate our methodology. A good example is the Igreja da Misericórdia, located ten meters above sea level. The water, inside this building, is said to have reached 2.64 meters high. So the height of the wave was determined based in three types of information: historical description of the wave height, extension of penetration of the tsunami and reports of destroyed buildings.

Also important was the Digital Terrain Mode (DTM) built for the municipality of Portimão. The determination of the flooded area depends on the accuracy of this model. The DTM was built based in topographic information at 1/5000 scale, resulting in a Triangulated Irregular Network.

After determining the probable height reached by the wave in certain areas of the municipality, we used the analysis capacity of Geographical Information Systems technology to determine the area likely to have been flooded in the 1755 tsunami. The next step was cross-referencing this information with the current data available regarding population, built-up area, and equipments using overlay operations in order to evaluate the impacts of a tsunami similar to the one of 1755, nowadays.

Seismic hazard in the Algarve

In Portugal the Algarve is one of the regions most susceptible to the occurrence of earthquakes. The first known earthquake to have been felt in the Algarve dates back from 63 B.C. (Oliveira, 1986), but over the centuries other events more or less intense have occurred in that area (Table 1).

In the 18th century three earthquakes hit the Algarve causing great destruction. The 1719 earthquake had its epicentre off the coast of Portimão and reached an estimated magnitude of 7. The 1722 earthquake, with a probable epicentre off the city of Tavira caused great damage in the villages of Portimão, Albufeira, Loulé and in the cities of Faro and Tavira causing many deaths and the ruin of churches, convents, wall towers, and uncountable houses, which were left completely destroyed and uninhabitable (Anno Histórico, Tomo III. fl.546, apud Sousa, 1915).

The 1755 earthquake was even more destructive than the previous ones, being considered the greatest earthquake of the entire Christian era to have occurred in the Algarve (Costa *et al*. 2005). This earthquake

[1]The questions formulated are the following: 5th Did you notice what happened to the sea, to fountains and to rivers ?; 6th Did the sea rise or fall first, and how many “meters”.

[2]The formulation of question 26 of part I is: If the parish suffered damages caused by the 1755 earthquake, what where they and if they have been repaired? The question 27 of part I of the survey suggests that it should be mentioned everything important not contemplated in this questionnaire (27th And everything else worthy of memory, not contemplated in this questionnaire.). This question was used by some priests to refer the tsunami as the priest of Budens (Vila do Bispo) did.

caused a high death toll. The probable number of more than 1,000 deceased in all of the Algarve to an estimated population of 80,000 inhabitants clearly reveals the violence of the earthquake and subsequent tsunami which occurred in this region (Costa *et al*, 2005). Nevertheless, in some local communities the proportion of deceased was much higher, for instance in Albufeira and Boliqueime, affecting, respectively, 10% and 7% of the inhabitants (Sousa, 1919).

In the latter the majority of the deaths resulted from the earthquake, unlike Albufeira where the majority of the population died as a consequence of the tsunami. Here, few were the houses that were left standing and those which resisted were uninhabitable; the sea flooded the land by the outskirts of the village and washed out the Bairro de Santa Ana, which had seven streets, and many other houses without sign of the water flux and reflux or of the houses location (Dicionário Geográfico, 1758).

In other areas the death toll was not as high but the destruction was nonetheless enormous. For example in Vila do Bispo, although only 13 people died (Relaçam, 1755) the village was devastated by the 1755 earthquake, since all houses, except for one, were in ruins. The homeless population had to live outdoors in cold weather deprived of the supplies they had stored, lost under the ruins of the same earthquake (Dicionário Geográfico, 1758). Also all the houses of the village of Aljezur were in ruins, the taller ones completely destroyed, as were the castle and the main church (Lopes, 1841).

The city of Lagos was another of the most affected. In the parish of São Sebastião all the houses of the city were in ruins and in the entire parish only a few one-storey houses were left standing. In this parish 95 people perished, some under the ruins, others taken by the sea. Furthermore in the parish of Santa Maria more than 100 people died, not to mention the people who were spending the day away from the city, which were many, given that this was a holiday (Dicionário Geográfico, 1758).

After 1755 other earthquakes have been felt in this region, but luckily with much lower magnitude. A recent earthquake that hit the Algarve in the morning of 12th of February 2007 measuring 5.8 on the Richter scale alerted to the risk that the occurrence of earthquakes represents to this region and reminded the importance of disaster preparedness.

Table 1 – The greatest earthquakes in Algarve.

Date	Latitude	Longitude	Estimated Magnitude 1	Occurrence of Tsunami
B.C. 63	36,0 N	10.7W	8.5	Probably a tsunami *(Oliveira, 1986)*
B.C. 47	-	-	8.5	
B.C. 33	-	-	9.0	
309	37.0 N	11 W	7.0	
382	36.5 N	9.5 W	7.5	There was a tsunami (Brito, 1597)
1309	36.0 N	11.0 W	7.0	
1353	38.7 N	8.4 W	6.0	
1356	36.0 N	10.7 W	7.5	
1504	38.7 N	5.6 W	7.0	
1531	38.95 N	9.0 W	7.1	
1587	37.1 N	8.0 W	6.0	
1719	37.1 N	8.5 W	7.0	
1722	36.9 N	7.6 W	7.0	Tsunami
1755	37.0 N	10.5 W	8.5	Tsunami
1856	37.1 N	8.0 W	6.0	
1858	38.2 N	9.0 W	6.0	
1909	38.9 N	8.8 W	7.6	
1910	38.8 N	7.5 W	6.0	
1915	37.0 N	10.5 W	6.6	
1941	36.0 N	10.5 W	6.0	Tsunami - intensity I
1969	36.2 N	10.6 W	7.5	Tsunami - intensity II

Source: MARTINS & MENDES VÍCTOR, 2001.

a We should point out that the estimated magnitude and epicentre localisation recorded in the catalogues should be considered as merely indicative (Oliveira, 1986, p.133).

b The earthquake epicentre is known to have been offshore but the exact location remains a controversial and debated issue. The plate tectonics of the region are complex, and there are several proposals of tectonic sources for the 1755 earthquake (Johnston, 1996; Zitelline *et al.*, 2001; Costa *et al.*, 2005; Miranda *et al.*, 2005; Gutscher, 2004, 2005).

The 1755 tsunami in the Algarve

Some minutes after the earthquake[3], the coast of the Algarve was swallowed by a tsunami, which caused a great number of deaths and vast destruction. Along the coast several fishermen were fishing, despite the holiness of the day; but those unfortunate fishermen were all killed by the powerful waves (Castro, 1786).

The 1755 tsunami was not an unprecedented event. In fact, there are references to tsunamis caused by other earthquakes which hit the Algarve. A few years earlier, in December 27th, 1722, there was also a tsunami although its effects were only felt locally (Sousa, 1915).The historical documents testify to some perplexity and lack of knowledge in people's reaction to the 1755 tsunami which contributed to a greater number of deaths in the coastal communities, as it happened for instance with the great majority of the inhabitants of the village of Albufeira, located on the top of a rock, who went down to the beach to find shelter believing the area to be safe. The water hit the beach and swallowed them all (Castro, 1786).

But the intensity of 1755 tsunami was enormous. The sea receded in parts more than 36 meters, exposing the beaches; and hitting land with such impetus, ran up inland over 5km, topping the highest rocks; it then receded again and hitting land for three times in a matter of minutes, dragging in the flux and reflux enormous masses of cliffs and buildings; and devastating almost all the coastal populations (Lopes, 1841).

[3] According to Lopes (1841) the tsunami occurred 6 to 7 minutes after the earthquake. Baptista et al (1998) presents an estimated time of 7 to 16 minutes for the *Cabo de São Vicente*.

Although the effects of the tsunami were felt across the coast of the Algarve, it was particularly destructive in the western part of the region. In fact from Quarteira to Lagos its consequences were dreadful; with great number of fatalities and damage of properties. It swallowed Armação de Pêra, the outskirts of Vila Nova de Portimão and all the low-lying neighbourhoods of the city of Lagos (Relaçam, 1756). In Quarteira, a fishing community, 87 adults and children drowned (Oliveira, 1905). The sea rose up so many meters over its surface that flooded many fields, and when it receded it took a part of the fortress and the entire village of Albufeira, leaving in the wood a large amount of fish (Mendonça, 1758).

Lopes (1841) describes that in Lagos the sea rose up to 11 meters nearly topping the city's wall; and washed away all the houses between the coast and the city's wall. It advanced inland over 2.5 km taking with it 5 boats almost to the same distance. The priest of Santa Maria parish reported that the sea destroyed part of the fortress wall and rose more than 7 meters high (Rocha, 1991). In Armação de Pêra the sea also advanced over 2.5 km, flooding everything (Lopes, 1841).

In the village of Sagres the sea rose up more than 6.6 meters on the beach and in the cliffs around the beach there are records of waves 26.4 meters high, and run up inland over 2.5 km (Sousa, 1919). The sea touched the fortress of Beliche located at 66meters (Lopes, 1841). In other locations the influence of the tsunami advanced up the rivers and was felt at distances of more than 2.5 km with an estimated height between 11 and 13 meters (Lopes, 1841).

On the eastern coast the effects of the tsunami were not so destructive. In the river of Tavira the water spread apart, in such a way that a caravel that was sailing in the river was left on dry land for a long time allowing the crew to leave the boat on foot (Mendonça, 1758). The waves washed away the huts in the beach of Monte Gordo, in which fish was traded also in Conceição de Tavira and swallowed all the islands along the coast up to the beach of Quarteira opening awful mouths, but preserving mercifully the locality of Olhão and the city of Faro (Relaçam, 1756). The little damage suffered by Faro and Olhão (Relaçam, 1756) is not entirely explained by a greater distance from the epicentre. Here the state of the tide and geomorphological configuration of the coastline were crucial factors. The sand islands located right in front of these towns are supposed to have lessened the impact of the wave on those areas. In reality, the capacity of a tsunami to flood and destroy depends largely upon the amplitude (wave height) and wavelength where they are generated but these parameters are also governed by the interaction with sea-floors and the morphology of the coastal strip the moment the tsunami hits (Costa *et al.*, 2005).

The elevated intensity of the tsunami is also confirmed by the geological records in several locations in the Algarve. One of the most important is Boca do Rio which allows us to conclude that the 1755 tsunami was both erosional and depositional and did not transport significant amounts of sediment from the offshore zone, but rather redeposited material from beaches and dunes, soils and estuarine silts and clays (Chester, 2001).

Although the return period of an event with the intensity of the 1755 earthquake is very large, we should point out that the tide gauge of Lagos recorded already in the 20th century two tsunamis: one on the 25th November 1941 measuring I and another on 28th February 1969 measuring II, both of which in the Algarve.

In 1755 run-up heights referred in historical accounts were variable at similar distances from the epicentre. No doubt some of this variance reflects imprecision in the historical data but unlike the timing of onset, run-up height is a reasonably well constrained parameter in the historical record (Mendes *et al.*, 1999). The configuration of the coast, state of the tide, and offshore bathymetry are also crucial factors.

The case-study of Portimão: historical data analysis

The municipality of Portimão comprises the *freguesias* (parishes) of Alvor, Portimão and Mexilhoeira Grande. The earthquake reached the intensity VIII Mercalli Intensity Scale in Mexilhoeira Grande and X in Alvor and Portimão (Sousa, 1919, Chester, 2001).

According to historical references in Alvor the sea inundated 660 meters inland, nearly reaching houses at 30 meters high. The chapel of Nossa Senhora da Ajuda, located on the beach by the harbour, was completely destroyed leaving no traces of its foundations (Lopes, 1841). The sea washed away fishermen who were pulling their nets. (Sousa, 1919).

The village of Portimão was one of the localities of the Algarve which suffered the most with the 1755 earthquake (Dicionário Geográfico, 1758) and it was also very much affected by the tsunami. In Portimão 6 people died under the ruins and 40 people drowned, 15 of which were female and 19 children (Livro de Óbitos de Portimão apud Sousa, 1919).

In the *freguesia* of Portimão the sea flowed inland, exceeding the natural barriers, in some areas more than 880 meters, devastating the salt ponds of this village. Since then no salt has been produced there (Dicionário Geográfico, 1758). The harbour of Portimão forms a great mouth berthed between two large rocks, in front of which are the fortresses of Santa

Catarina and São João. The first of the two was severely damaged (Dicionário Geográfico, 1758) and the latest was completely washed out (LOPES, 1841).

Through the village of Portimão flowed successively amazing waves, which advanced over 5km up the river. As the waves advanced everything was destroyed. Several boats were carried inland to such great distance that it was not possible to bring them back. Flooding occurred on the outskirts of the village, destroying all the houses and drowning many people, which had sought refuge in the river banks (CASTRO, 1786).

In the parish of Mexilhoeira the damages were not as important because the parish has no direct contact with the sea. The damages caused by the tsunami resulted from the advance of the waves up the River Alvor and other smaller water courses, but nothing worse mentioning happened (Dicionário Geográfico, 1758).

From the accounts about the height of the wave we verify that near the coast it must have got to 20 meters high. It is said that the water almost reached the village of Alvor which is located between 20 to 30 meters above sea level, reaching the Fortress of Santa Catarina (20 meters). The city of Portimão is protected by the rocks of Praia da Rocha, so it is probable that the wave did not reach the height of 20 meters. The Igreja da Misericórdia is the main source for the determination of the wave height (Figure 2).

As previously referred this church is located 10 meters above sea and the water rose 2.64 meters inside the building. Another building, the Convento de São Francisco located, approximately, 7 metres above the sea, was completely destroyed. These references were

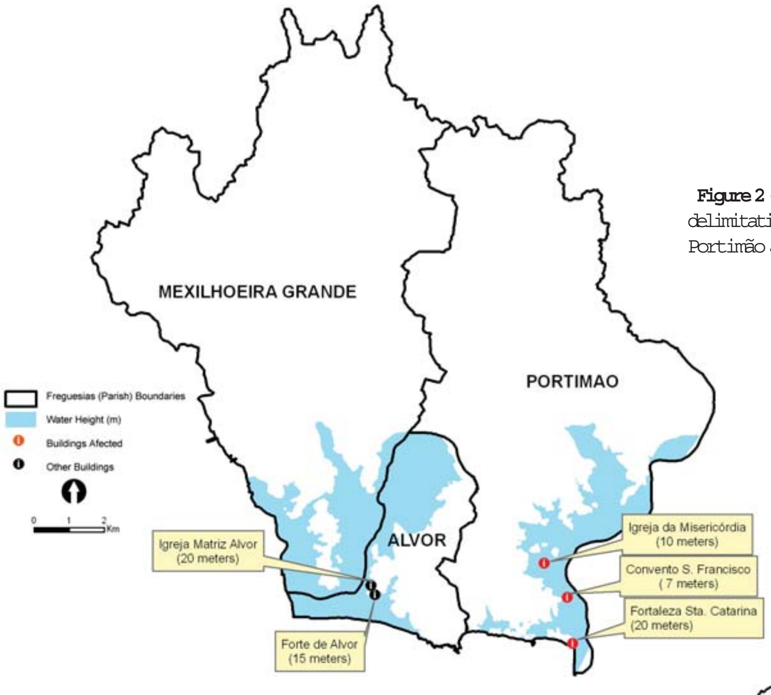

Figure 2 - Historical buildings location and the delimitation of the flooded area in municipality of Portimão as a consequence of the 1755 tsunami.

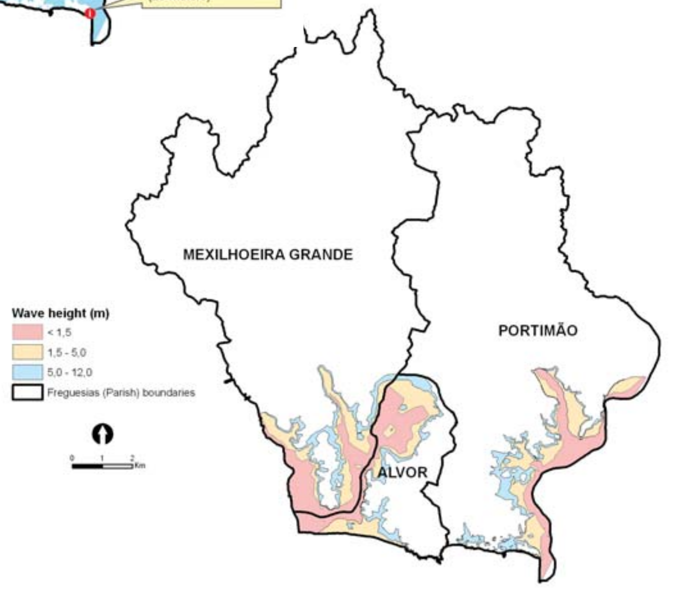

Figure 3 – The water height in 1755 tsunami: inverted model.

integrated in the map over the Digital Terrain Model (DTM). According to historical sources the height of 12 meters was considered a reliable height for most of the wave but it is possible that in small areas the wave could have reached higher heights as it happened in Fortress of Santa Catarina located on a cliff edge.

Based in the DTM, the lands with altitude below 12 meters and near the coast had been identified, eliminating isolated areas surrounded by lands higher than 12 meters, producing a new DTM of the wave height (inverted) and in a polygon the flooded area (Figure 3).

The impacts of the 1755 tsunami nowadays

The flooded area should have amounted to 23.75 Km^2, 13% of the total surface of the municipality. An extension explained by the fact that this is a sandy coast with a reduced number of cliffs and by the existence of two rivers, natural boundaries of the municipality, serving as hallways allowing the advance of the waves.

Since 1755, two key factors have increased the vulnerability in Portimão municipality. Seaside settlement is no longer solely based on livelihood but on urbanization and tourism associated with the attraction of enjoying living and holidaying literally in front of the sea.

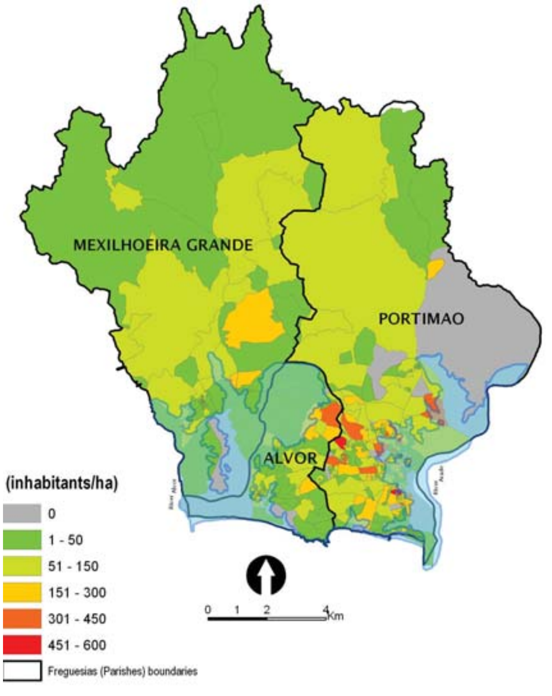

Figure 4 – Population density in Portimão municipality.

Nowadays, the potentially flooded area would put at risk, approximately, 21,845 inhabitants, according to 2001 Census data. The advance of a 12 meters wave up River Arade would affect without a doubt the low area of Portimão, where the most densely populated areas (more than 300 inhabitants/ha) are located (Figure 4). Here the population affected would amount to approximately 18,303 inhabitants. In the others parishes less inhabitants would be in danger: 2,403 inhabitants in Alvor and 1,139 inhabitants in Mexilhoeira.

Since Portimão is an area where tourism is the most important economic activity, we can conclude that the population at risk would actually be much higher. Although there is no statistical record of the temporary population and it varies tremendously during the year, if we take into consideration the water and electricity consumption in certain seasons, it is possible to say that the population doubles in some periods.

We estimate that approximately 5,000 buildings would be affected, many of which would be destroyed or severely damaged, including hotels. However, the vulnerability of the hotel units is highly variable and the units located in the low-lying parts of the city of Portimão would be the most seriously affected. We identified 67 hotels, of which 26 are located in the potentially flooded area (Figure 5).The newest resorts are located in highly susceptible areas, as it is the case of the hotel, restaurants and marina built in the mouth of the River Arade, which would represent the first structure to be struck by the waves of a tsunami (Photo 1).

In a disaster situation, the management of rescue means and security forces is essential. From our analysis, it is possible to conclude that in the established scenario the structures of civil protection agents would not be severely damaged (Figure 6). Only the police headquarter is located in a potential flooded area but fire-fighter brigades and other security forces will not be affected.

When considering the health facilities, the primary care health centres would be affected but not the hospitals. Also located in the potential flooded area are the prison, and the local building of Red Cross.

The aerodrome, important equipment allowing easy access of rescue means or the evacuation of inhabitants, is located in freguesia de Alvor in an area easily affected, since it is located at a height of 5 metres and on the bank of the Alvor River, up which the tsunami would advance.

In addition, the road network itself would be severely affected and significant stretches of essential regional routes would either be flooded or destroyed. The determination of the routes potencially affected and the routes possible to be used in case of accident is vital both for the evacuation and rescue of the populations affected.

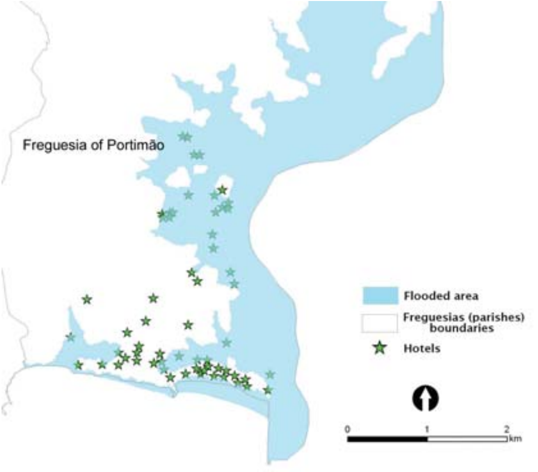

Figure 5 – Hotels affected by a potential tsunami similar to the 1755 one in freguesia of Portimão.

Photo 1 - The vulnerability of these buildings is very high.

We can thus conclude that faced with a tsunami similar to the 1755 event, the region would be considerably dependent on external rescue means.

These analyses help us to demonstrate the population's exposure to risk and the urgent need to develop protection mechanisms, including a greater attention to land management efforts, especially as far as the location of priority equipment is concerned, but also the establishment of a building code, because if there have been tsunamis in the Algarve in the past, another tsunami could occur in the region in the future. They are a summarised description of the virtuosity of our approach to emergency planning, although it is also possible to include other variables such as, water and electricity infra-structures. Also we could necessarily improve the quantitative approach.

Conclusion

In the Southwest part of Algarve the waves were higher than in Lisbon and the flooded area was much larger. Although the average return period of a tsunami similar to the one that hit the Algarve in 1755 is very great, probably greater than 1000 years, it may occur at any time provided that the seismic source is totally or partially located in the sea and that the magnitude measures more than 7.5 (Costa *et al.*, 2005). In that case a tsunami would rapidly arrive, meaning that a quick perception and reaction would be necessary to minimise the damages. In the 1755 event it is

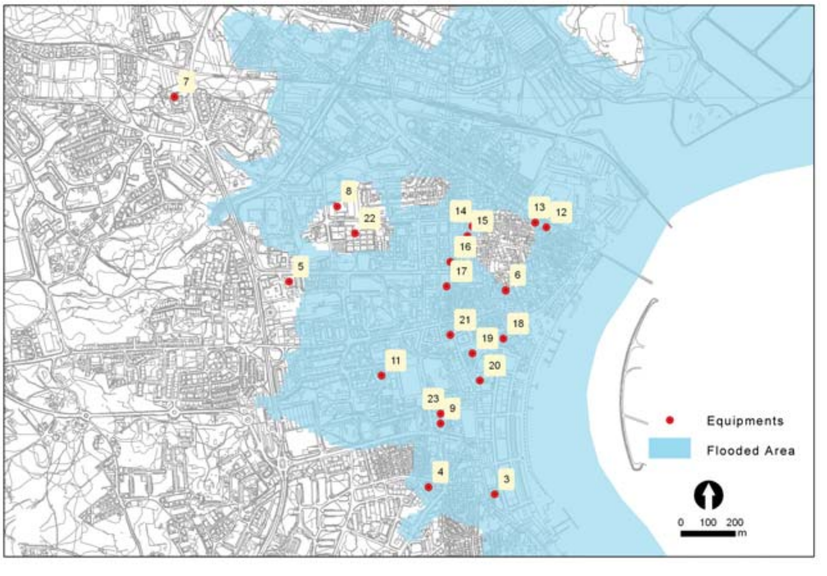

Figure 6 – Institutions: 1 - Portimão Private Hospital, 2 - Alvor Health Centre, 3 - Public Health Centre (SSP), 4 - Public Health Centre, 5 - Portimão Misericórdia Hospital, 6 - Red Cross, 7 - National Republican Guard (GNR), 8 - Portimão Volunteer Fire-fighter Association, 9 - Police Force (PSP), 10 - Water and Residues Company, 11 - Prison, 12 - Revenue Payments Office, 13 - Revenue Office, 14 - Civil Registration Office, 15 - Employment Office, 16 - Portimão Local Government, 17 - Cape Verde Consulate, 18 - Sweden/Iceland Consulate, 19 - Criminal Police, 20 - Portugal Telecom, 21 - City Hall, 22 - Graveyard, 23 - Municipal Police, 24 - Aerodrome.

supposed that the tsunami arrival time was 7±16 minutes (Baptista *et al.*, 1998, 2005). Thus, the delimitation of the flooded area is an important tool for emergency planning.

It is obvious that the simulation we present here is valid for an earthquake with the same magnitude and tectonic source of the 1755 event. Of course, other earthquakes with offshore epicentre but different magnitude and location will lead to distinct flood heights and inundated areas. In fact, the 28th February 1969 earthquake with a magnitude of 7.5 (Martins and Mendes-Victor., 2001) or 7.9 (Baptista *et al.* 1998) and epicentre at the Horseshoe Abyssal plain , south of Gorringe Bank (Fukao, 1973) generated a tsunami with weak intensity that did not put at risk the coastal communities in the Algarve.

Although we have not used modulation to assess the energy of the tsunami, the simple identification of the flooded area is fundamental because the more extensive the area affected is, the higher the height of the wave and the energy transported are (Costa *et al.*, 2005).

Also we must remember that run-up heights are not just a function of distance from the epicentre. In 1755 run-up heights were variable at similar distances from the epicentre. No doubt some of this variance reflects imprecision in the historical data but unlike the timing of onset, run-up height is a reasonably well constrained parameter in the historical record (Mendes *et al.*, 1999). The configuration of the coast, state of the tide, and offshore bathymetry are also crucial factors.

We assess the potential impacts of a wave 12 meters high but it is also possible to define other scenarios with obviously different impacts. The delimitation of flooded area besides serving as basis to the definition of scenarios and the determination of emergency planning tasks, may also serve as a guiding principle for land management.

Actually, despite the low rate of occurrence of disastrous tsunamis, their impact is so great and their consequences so dramatic that their existence should be taken into account in assessing natural risks in coastal areas (Baptista *et al.*, 2005).

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