

USE OF INNOVATION MAPS FOR ASSESSING THE IMPACT OF TSUNAMIS ON THE COASTAL LINES OF ISTANBUL

D. Z. Seker¹, S. Kabdasli², A. I. Ulusoy³ and A. C.Yalciner⁴

Abstract: In this study to produce innovation maps of study area, different types of data such as elevation and bathymetry of study area and Geographic Information Systems (GIS) have been used to determine risks areas on the coastline under the threat of tsunami.

INTRODUCTION

Innovation maps dedicated itself to the most advanced aesthetic strategies in the audiovisual sphere; a challenge to map the gray area between technological innovation and poetic imagination. Tsunami is the sea wave that is caused by vertical displacement at the bottom of the sea. “Tsunami” is a Japanese word, which can be translated as “harbour wave”; now used internationally to refer to a series of extremely long waves travelling across the ocean. In other words, a tsunami is a series of waves that may be dangerous and rather destructive. Tsunamis are large water waves, typically generated by seismic activities that have historically caused significant damage to coastal communities throughout the world.

Most of the Tsunami events occurred in The Pacific Ocean. According to Gusaikov, 800 Tsunami events were recorded between the year 684 and 1994 in the Pacific. 3000 persons have been reported missing or dead because of Papua New Guinea Tsunami in 1998. Average height of this Tsunami was about 7-10m. Destructive tsunamis have also occurred in Indian and Atlantic Oceans. (Altinok, 2000)

More than 90% of countries in the world are located around the coastlines. Reason of this situation is that these countries are under effects of natural disasters

¹ Assoc. Prof. Dr. ITU Civil Engineering Faculty 80626 Maslak Istanbul, Turkey, dzseker@srv.ins.itu.edu.tr, seker@itu.edu.tr

² Prof. Dr. ITU Civil Engineering Faculty 80626 Maslak Istanbul, Turkey, skabdasli@srv.ins.itu.edu.tr

³ Civil Engineer, ITU Civil Engineering Faculty 80626 Maslak Istanbul, Turkey, aliilkeru@ixir.com

⁴ Assoc. Prof. Dr. METU Civil Engineering Faculty, Ankara, yalciner@metu.edu.tr

related to coastal zones such as tsunamis. Turkey is one of these countries which have several severe environmental and natural problems related to coastal zone. Earthquake and tsunami are among these natural disasters. The Anatolian peninsula is one of the well-known areas threatened by such natural disasters. Parts of North Anatolian Fault Zone (NAF) in Marmara Region can be seen in Figure3. (Musaoglu et al. 2000, Seker, et al. 2001).

TURKEY and TSUNAMIS

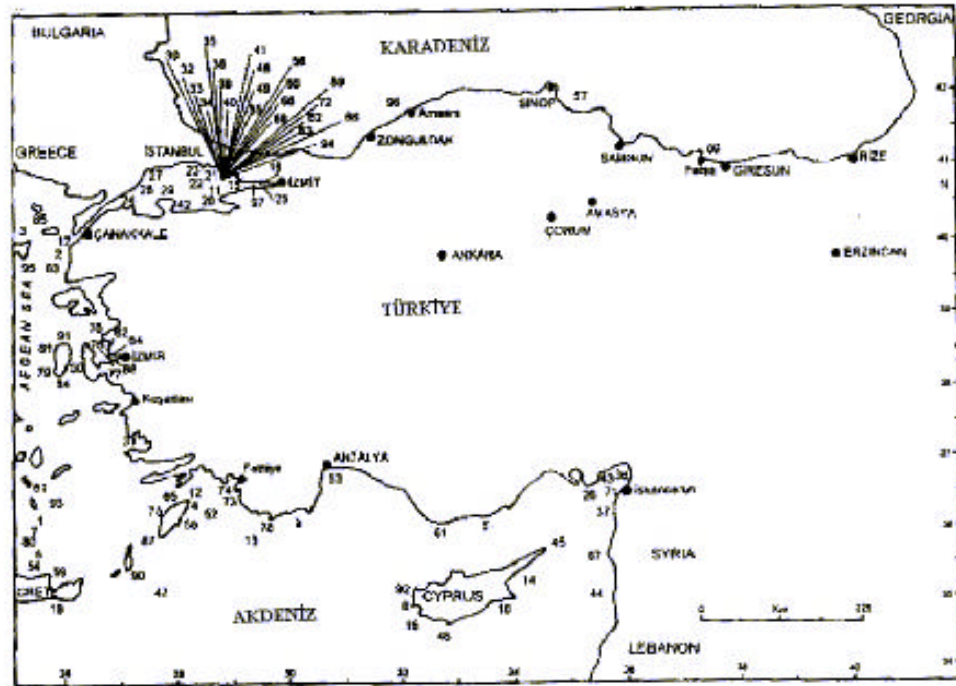
Turkey has a coastline of about 8333 km long. During the course of history, many dramatic examples of both earthquakes and tsunamis have occurred around the coastlines of Turkey. According to the records, more than 90 tsunamis occurred between the year BC 1410- AC 1999 , 3000 years. Figure 1 shows the locations of these tsunamis on Turkey Map. And chronological list of the same tsunamis can be seen in Figure 2. The most known example near Anatolian Peninsula occurred after the eruption of Thera Volcano in BC 15th century. Thera is known Santorini Island today. Minoan civilisation in Crete was wiped out because of this Tsunami. A lot of Tsunamis in Mediterranean Sea caused casualties.

Records also show that one third of tsunamis happened in the Marmara Sea, coastline of Istanbul and Izmit. 10 September 1509 earthquake is one of the most destructive ones in the last five centuries. Maximum damage of the earthquake occurred in Istanbul. 4000-5000 people died and 1000 houses destroyed. After the earthquake a Tsunami occurred and the waves overtopped city walls in Yenikapi and Aksaray wave height was more than 6,0 m. On 10 July 1894, another earthquake and tsunami damaged Istanbul again. The earthquake killed 474 people. Many distributions were seen along the coast, sea receded up to 50 m and then returned. According to Miahilovic (1927) inundation distance of sea was about 200 m. Doubtless a tsunami occurred and its height was less than 6 m. (Altinok 2000)

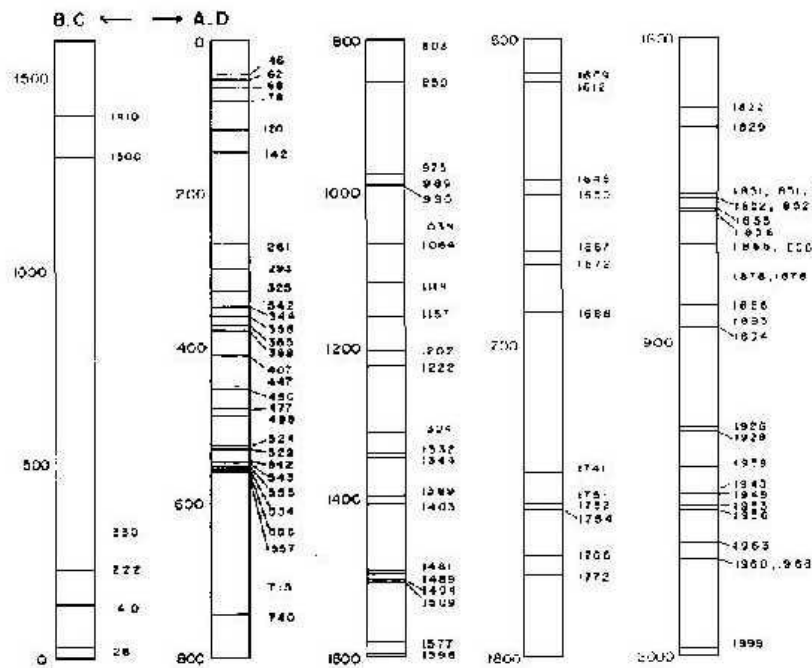
Last Tsunami event in the coast of Turkey is, Kocaeli Earthquake 17 August 1999 in Izmit Bay. Kocaeli earthquake is occurred on the north arm of North Anatolian Fault (NAF) in Marmara Sea. Fault zone in Marmara Sea can be seen in Figure 1. According to findings; sea level decreased on both sides of the bay first. North side of the bay, maximum run-up of tsunami was 2.5 m (Yalciner 2000). Because of these facts, effects of tsunamis should be considered and examined as much as possible especially in the Marmara Region and Istanbul Coastline for a possible earthquake. This will surely be beneficial in coping with the grave consequences likely to be seen immediately after an earthquake and/or tsunami.

It is clear that this part of the country is under the threat of tsunamis following an earthquake. According to the studies still ongoing in this region, possibility of an earthquake, whose magnitude is greater than 7, within the next 30 years is estimated to be about $62\% \pm 15$. (Altinok, 2000)

Another well-known risk of tsunamis is landslides at the bottom of the sea. There are three main basins at the Marmara Sea, which can be seen in the Figure 4.



**Figure 1. Location of tsunamis in Turkey Between BC 1410- AC 1999.
(Numbers show the sequences)**



**Figure 2 Chronological List of tsunamis in Turkey and Adjacent Areas Between
1410 BC and 1999 AD**

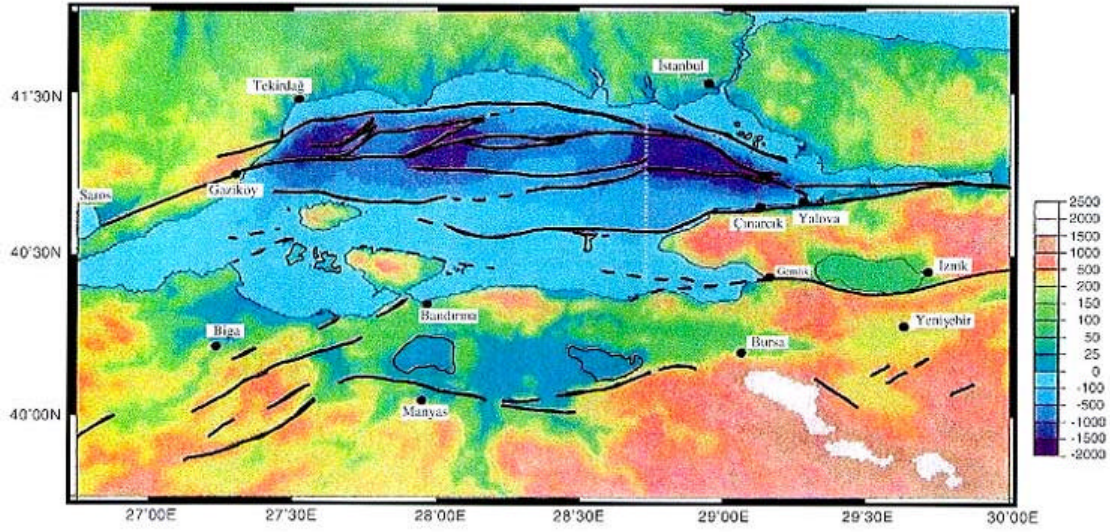


Figure 3. Fault Zone of Marmara Sea. (www.mta.gov.tr)

The Marmara Sea, which is located on the west arm of the NAF lies in a complicated closed basin, whose tectonic structure that consist of various faults has not been completely identified. The NAF zone, which extends throughout North Anatolia from west Erzincan to the Sea of Marmara, is a right lateral strike slip type. It is divided into three at the west longitude 31°E. While the south arm is located between Yenisehir (Bursa) and Edremit on the land, the middle arm follows the Marmara coastline from Armutlu Peninsula to Bandirma town and enters into Aegean Sea in Bayramic. North arm is in between Izmit Bay, deep Marmara basins and Saros Bay and is directed towards North Aegean basin.

Along the northern arm of NAF, there are three underwater depression areas with the depth more than 1100 m. These three depression areas are closer to North coast and named as Cinarcik Basin, Marmara Ereğlisi Basin and Tekirdag (Ganos) Basin.

At west of the sea of Marmara NAF intersects with Cinarcik Basin which is located at the south of Istanbul and which attracted high attention after the August 17, 1999 Izmit Earthquake. The longer axis of this basin has a direction of N 45 W. The maximum water depth in the basin, is 1289 m. Detailed information about the marine surveys, are given in Altinok et al. (1999) for Izmit Bay and Alpar et al. (2000) for the east part of the sea of Marmara.

The slopes of the continental shelf of Cinarcik Basin are very steep with a slope of 17°~23° at north and 7°~10° at south. At the skirts of the shelf the slopes reach their steepest value (35°~45°). There are mass depositions at the toe of the shelves. Underwater landslides cause these depositions and they are more developed

and clearly observable at the base of the Cinarcik Basin. It must be considered that there is a possibility of the existence slumps at he slopes of Cinarcik Basin and around.

The fact that there will be an earthquake in the Sea of Marmara. Since an expected earthquake will take place at the sea bottom in the Sea of Marmara, it will also cause underwater mass movements and thus accompanying tsunamis. To obtain realistic facts about Tsunami a computer simulations with some scenarios are important.

CASE STUDY

Marmara Region is very representative of the type of coastal development. 25.8% of Turkey's population live in this region and 23% of Turkey's Gross Domestic Product is produced in Istanbul which is located on two continents, is the largest city of this region and Turkey with a population of over 12 million. It is a combination of a very rich historical background and a modern appearance. The possibility of an earthquake occurring in Marmara Region may change everything in Turkey and may have devastating effects on the country's future. In the main coastal areas of the city, the risk factor of an earthquake is very high. Because these areas are on the main earthquake zone. So the study, which will be done in this area, is of vital importance. Another reason for selecting this area is a research project that is supported by The Scientific and Technical Research Council of Turkey.

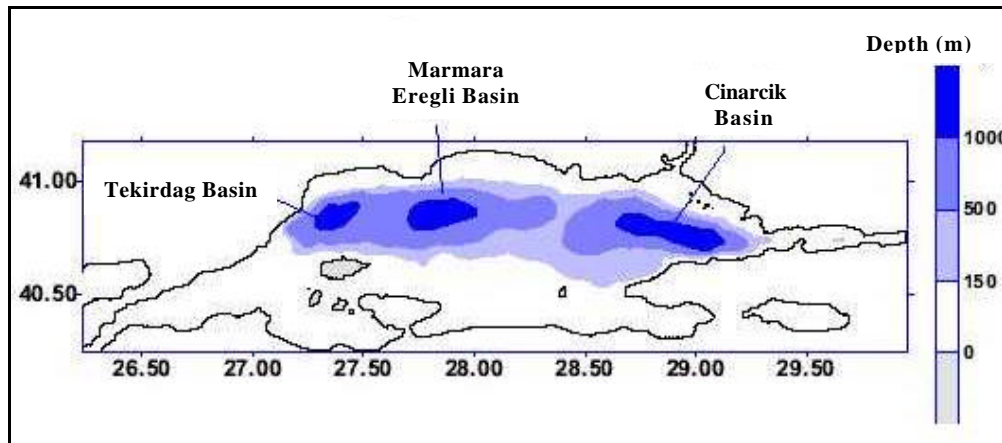


Figure 4. Three Main Basins of Marmara Sea. (Ozbay,2001)

As said before, earthquake occurrence probability in Marmara Region is about 62% within the next 30 years and historical records and experiences show that the Tsunami is an important event for Marmara Region and Istanbul Coasts.

In this study Kadikoy has been chosen as study area for preparing the tsunami inundation map using innovation maps techniques of Geographic Information Systems. Kadikoy is located at the north side of Marmara Sea and the northern arm

of NAF is very near to our study area. Study area can be seen in the Figure 5. A Tsunami that can occur after an earthquake or a submarine landslide in Marmara Sea will affect Kadıköy Region. Selected area for the pilot study is one of the most crowded areas in Istanbul.

DATA AND METHOD

After a catastrophic event like an earthquake or tsunami, there are some measures, which have to be taken immediately. Such actions require a lot of information and some tools, which are sufficient for the fast analysis in order to initiate the adequate redevelopment measures. Geographic Information Systems (GIS) is an organized collection of computer hardware, software, geographic data and personnel designed to efficiently capture, store, update, manipulate, analyse and display all forms of geographically referenced information. After the Marmara Earthquake, the most important problem was the assessment of immediate environmental effects just after the earthquake because of the lack of reliable and systematic historical data about the coastal zone. The prediction and forecast of the results of gradual effects were also very difficult because of the same problem.

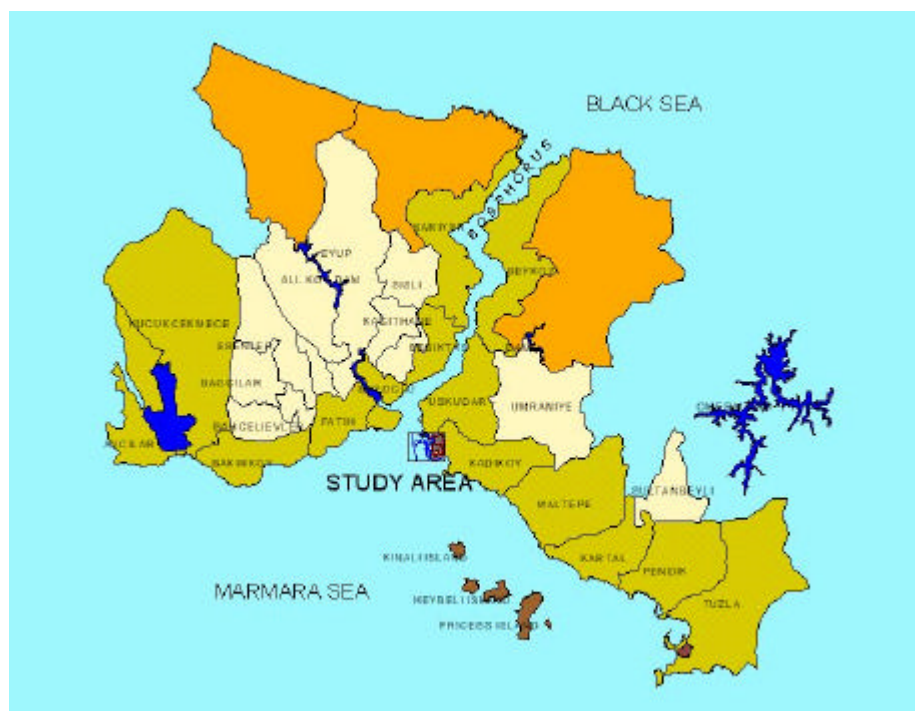


Figure 5. Study area.

In this study, 1:1000 - scale digital topographic map, which had been produced by photogrammetric technique for the Istanbul Municipality, has been used as topographic data. Bathymetric data related to same area have been taken from the Navigation, Hydrography and Oceanography Department of Turkish Navy. ArcView has been selected for the GIS software for this study. In this study, more than background information about the mechanisms of tsunami generation and

propagation, effects of tsunamis on the Istanbul coastlines are considered. Preliminary information and argue the impact of tsunamis on mankind are also given in this study. Also, recent and possible future tsunami events are examined and analysed by means of digital elevation models and innovations maps produced from Geographic Information Systems.

A set of simulation models is created so as to substantiate this study. These different scenarios will also be used and later applied to illustrate the disastrous effects of inundation upon coastal populations and coastal structures using GIS and its visualization opportunities. Also for the visual aid to examine the problem, an innovation map such as special interactive map presentation has been devised to compare various types of maps with specific sets of data. For these reasons, to find the possible effects of tsunamis on the ground several different data types were analyzed and mapped to show effects of tsunamis. Some of these different data types and coverages are; coast bathymetry, topography, landuse, buildings, elevation and population.

CALCULATION OF A TSUNAMÝ VOLUME

Mitigate the effects of a disaster, the risk area must be known before the occurrence of the catastrophe. It is important to know run-up and inundation distance of a Tsunami to know risk area and to prepare the risk map, because the effects of Tsunami can be defined with these two values. If we know the risk area before, mitigation study will be effective.

As shown in Figure 6, When a sea wave comes to the coast or a structure, runs up on it. Run-up depends on structure, shape and roughness, water depth, bottom slope in front of the coast or structure and wave characteristics. (Shore Protection Manual)

But if a sea wave comes to the coast that has a slope, which is not large, its inundation distance and run-up will be related to its volume. To calculate the run-up and inundation distance and to prepare the inundation map it must be compared with the volumes of the study area and volume of the coming Tsunami.

When the run up and inundation distances are known properly, it will be possible to prepare the risk maps under the Tsunami risk and to take measure.

Volume of Tsunami

It is can be assumed that, at the beginning, Tsunami volume is same as the total volume of the vertical displacements at the bottom of the sea. Because, the profile of Tsunami is very similar to the vertical displacement on the bottom of the sea. (Yalciner 2001).

Tsunami disperses with circular waves. (Figure 7) and its volume on unit width changes with the ratio between total length of Tsunami and the length on the study area. However, because of the dispersion feature of the wave, it will not be

able to carry the same volume on it when it reaches the shore. It can be assumed that that the tsunami will be dispersed in the form of semi-dimension and the volume it carries would be dispersed at the height of the semi-dimension. Furthermore, proportion of the volume of tsunami in the area where the risk analysis is to be made, to the volume at the time when it occurred can be assumed to be equal to the proportion of the semi-dimension formed by its dispersion.

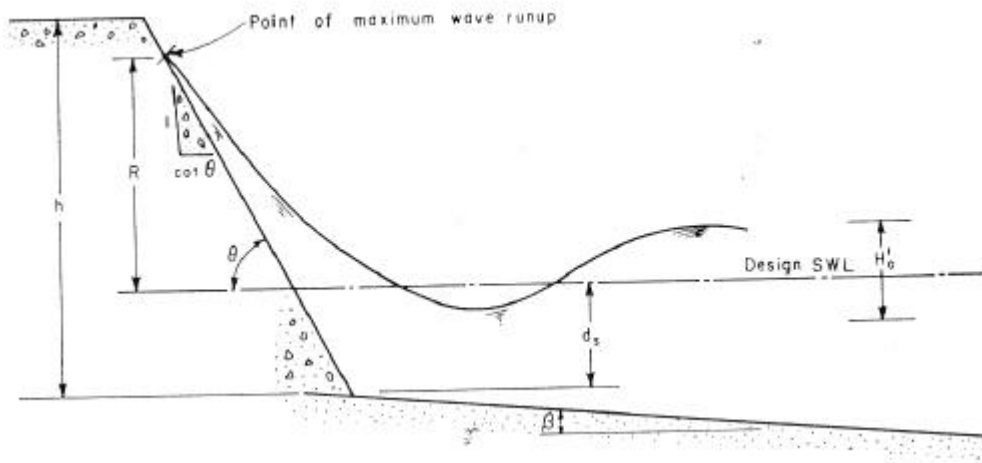


Figure 6. Run-up of Tsunami wave

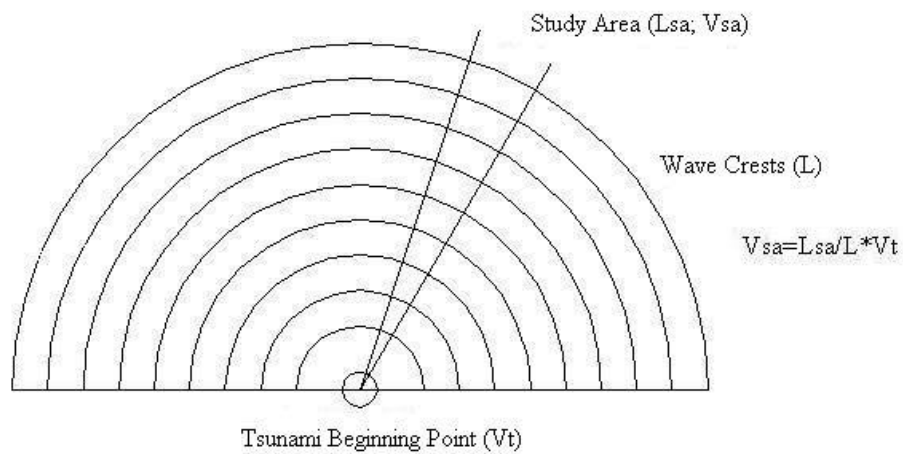


Figure 7. Wave and Volume of the Wave Dispersion

Scenarios of Different Cases

In this study, impacts of the tsunami effect that is to occur after landslide in 2 different areas as can be seen in Figure 8, on the study area will be researched. Wave period has been calculated as 9.5 minutes for first case and 14 minutes for the second case.



Figure 8. Case 1 and Case 2

In the first case (Case 1), a landslide scenario is used. The landslide is assumed to occur at the North West End of Çınarcık Basin at the south of Yenikapı coast in the area with the 28,70°E and 40,92°N coordinates. The water depth where the source mechanism occurred is 400m. An area with a width of 10 km along East-west direction and a length of 1.8 km along North-south direction is assumed to move as an underwater landslide of a layer of 6 m height towards South. It is also assumed that the slid material deposited as a layer of 3m heights to a 3.6 km long and 10 km wide area located at an approximate depth of 900m as south. For this case it is can be calculated that the total volume of the landslide is 108,000,000 m³.

In the second case (Case 2), a landslide scenario similar with the previous case is considered but at different location. The landslide is assumed to occur at the south of Silivri in the area with the 28,90°E and 40,94°N coordinates. The water depth where the source mechanism occurred is 500m. An area with a width of 10 km along East-west direction and a length of 2 km along North-South direction is assumed to move as an underwater landslide of a layer of 6 m height towards South. It is also assumed that this landslide is deposited as a layer of 3 m height to a 4 km wide area located at an approximate depth of 1000m at south. For this second case it is can be calculated that the total volume of the landslide is 120,000,000 m³.

ANALYSIS OF RISK USING INNOVATION MAPS

Calculated volumes of the study area (for the left side of the dashed line in the Figure 9) are shown in the Table 1. These volumes are calculated with software Arcview V.3.2 on the 3D innovation maps.

Table 1. Volumes of the Study Area

Heights (m)	Volume (m3)
Between 0 - 0,5	624.736
Between 0 - 1,0	1.218.432
Between 0 - 1,5	1.784.481
Between 0 - 2,0	2.333.525
Between 0 - 2,5	2.807.192
Between 0 - 3,0	3.272.619
Between 0 - 5,0	4.845.490

Table 2 Run-up on Study Area

C A S E	Distance Between Source of tsunami and Study Area (m)	Length of the Semi Circle (m)	Length of tsunami Effect on Study Area (m)	tsunami Volume at the Beginning (m3)	Effective Volume on Study Area (m3)	Run-up (m)
1	30.000	94.248	1.730	108.000.000	1.982.434	1,7
2	90.000	282.743	1.730	120.000.000	734.235	0,6

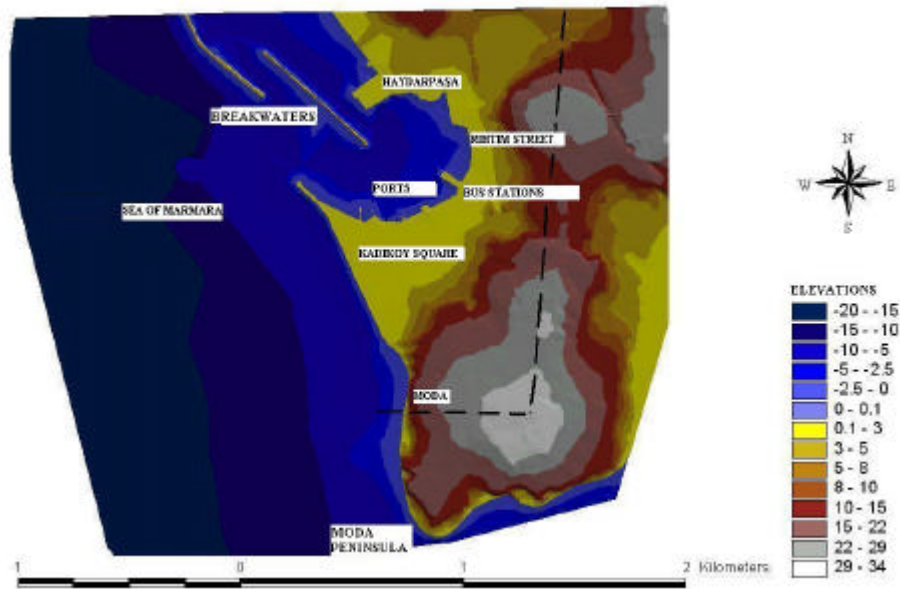


Figure 9. 3D view of study area (Kadiköy Region)

Run-up distances are calculated with interpolation. In the study area between 0 m and 1.5 m heights is 1,784,481 m³. For Case 1, coming Tsunami volume is 108,000,000 m³ at the beginning and it is 1,982,434 m³ in front of the study area. Then it can be calculated the run-up distance as 1,7m for the Case 1. Inundation Map is shown as Figure 10 for the Case 1.

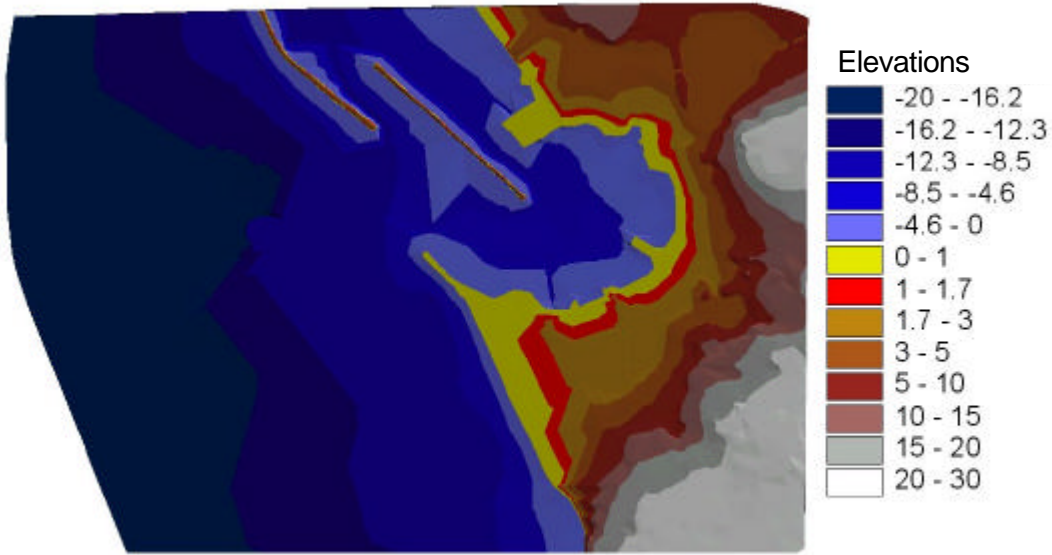


Figure 10. Inundation Map for Case 1

Same approach can be applied for the Case 2. It can be calculated the run up as 0,6m for the study area in this situation. Inundation Map for the Case 2 is can be shown as Figure 11.

CONCLUSIONS

Digital elevation model of the coastline of Istanbul has also been produced and analysis has been done using this 3D model. In this connection innovation maps can very well address to many issues which are part of the very heated debates over the size of a possible tsunami likely to affect coastlines of Istanbul, the extent to which the waves generated by such an event would reach, what proportion of the urban settlements are exposed to the disastrous effects of tsunami and a host of other relevant questions.

In this study, Kadikoy Region, a part of Istanbul that is located near Sea of Marmara, is chosen as the study area for Inundation Map for a possible Tsunami in Sea of Marmara. Inundation Map is prepared, based on comparison of the volume of Tsunami and volume of the study area. Two different cases are observed for this study. It is assumed that two different landslides occurred on different locations in both of these cases.

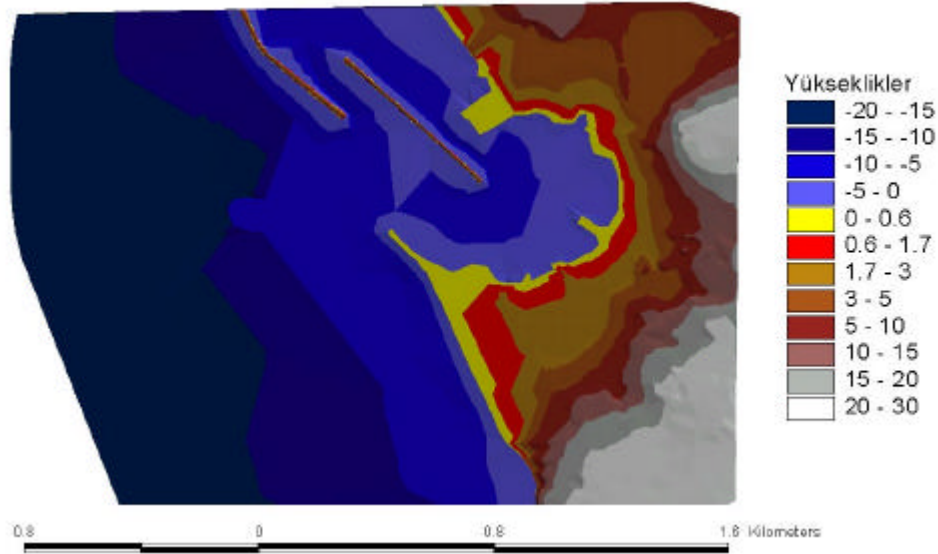


Figure 11. Inundation Map For Case 2

For the Case 1, it is calculated the Tsunami run-up distance in Kadikoy Square as 1,7 m. On the inundation map, critical buildings such as hospitals, schools etc and must be known to the population in the risk area. Depending on this knowledge, mitigation, and, if necessary, evacuation plans can be prepared before a probable catastrophe.

It must be prepared inundation maps for all parts of Istanbul, based on probable different type of cases, with similar methods. Then effective mitigation study can be applied for Istanbul coasts.

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