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Tsunami Generation and its Characteristics Due to Land Slide in the Caspian Sea

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ABSTRACT: Tsunami waves can be generated in any coastal area, including inland seas and large lakes. Although there exists enough information about the generation and propagation of tsunami in the ocean environment, the assessment of such phenomenon in lakes with finite depth still suffers from the lack of theoretical work and sufficient measured data. The Caspian Sea is the largest lake in the world and has gone through different historical tsunami events. A numerical study for prediction of tsunami wave height time series for ten locations in the Caspian Sea is presented in this work. Unlike tsunamis generated by earthquakes, submarine landslide tsunamis generated in shallow waters were more destructive compared to those generated in deep water. This is due to the higher energy that can be converted from the slide to the water in shallow areas. Moreover, shallower waters were usually closer to the coasts and thus a shorter available distance exists for radial damping. The dispersion of short waves and also radial spreading decrease the far-field effects of landslide tsunamis in contrast to tsunamis of seismic origins. However, shorter waves were more prone to coastal amplification with higher local effects. The results of predictions were consistent with the previous finding reported in the literature indicating the possibility of tsunami occurrence in large lakes due to landslide which can affect the neighboring ports and area located particularly in the central and southern areas of the Caspian Sea.

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1. INTRODUCTION

Tsunami waves can be generated in any coastal area, including inland seas and large lakes. Although there is enough information about the generation and propagation of tsunami in the ocean environment, the assessment of such phenomenon in lakes with finite depth still suffers from the lack of theoretical work and sufficient measured data. The Caspian Sea is the largest lake in the world and has gone through different historical tsunami events. The reported tsunamis were generated due to earthquakes and landslides particularly in the middle zone of the sea. It should be noted that the seismicity of the Caspian region has been studied in some detail, but the manifestation of a tsunami in the Caspian Sea and the degree of risk for the coast remain poorly understood. Similar to the other coastal regions around the world, the increase of the population along the coasts of the Caspian Sea highlights the urgent need to assess tsunami hazards in the region [1, 2].

2. THEORETICAL DEVELOPMENT

Tsunami wave has behavior like a solitary wave as shown in Figure 1. The equation of Boussinesq solitary wave is as follow:

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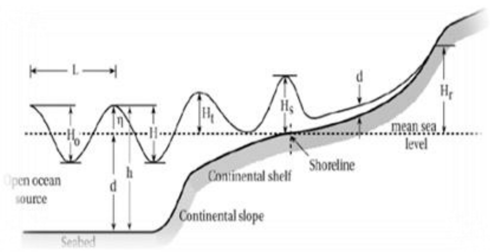

Fig. 1. Tsunami wave height [4].

$$\eta = a\,sech^2\sqrt{\frac{3}{4}\frac{a}{h^3}}x \quad (1)$$

Where a: wave height, h: depth at infinity, η: wave profile.

The whole profile of solitary waves is positive and there is no negative η. So, 'a' presents wave height and 'h' is depth in infinite [3].

3. MODELING

In this study, some submarine landslides were assumed in 7 different points of the Caspian Sea (Figure 2) with parameters mentioned in Table 1 and 2. The GEOWAVE software was used to simulate.

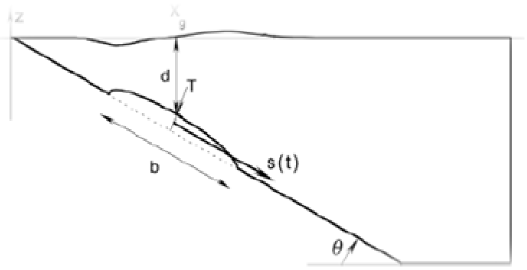

Fig. 2. Definition sketch of the simulation domain for underwater slides [5].

Table1. Parameters of the Caspian Sea probable submarine landslide [2].

Estimated parameter	value
Slope (θ)	2°
Total Length (b)	5300 m
Maximum thickness (T)	1100 m
Total Width (w)	1500 m
Density	1880 kg/m^3
Initial submergence (d)	Table 2

Table 2. Characteristics of submarine landslide points

	X_0	Y_0	d (m)	CCW [1](°)
A Point	49.12	37.71	167.60	310
B Point	50.81	36.61	209.51	20
C Point	50.19	39.40	302.94	190
D Point	48.40	41.43	138.15	260
E Point	50.10	40.80	306.45	75
F Point	49.65	42.67	218.51	180
G Point	48.68	41.56	415	270

[1] CounterClockWise

Table 3. Characteristics of generated tsunamis

Source	Depth (m)	Maximum Wave Height (m)	Wave Length (km)	Effect Radius (km)
A point	167.6	20.7	19.6	60
B point	209.5	12.4	21.9	65
C point	302.9	7.1	26.4	75
D Point	138.2	35.5	17.8	50
E Point	306.4	7	26.5	75
F Point	218.5	11.7	22.4	60
G point	415	8.8	30.8	90

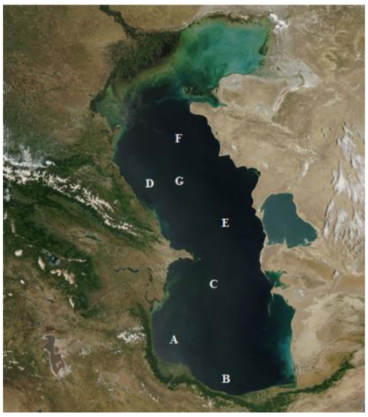

Fig. 3. Locations of submarine landslide points

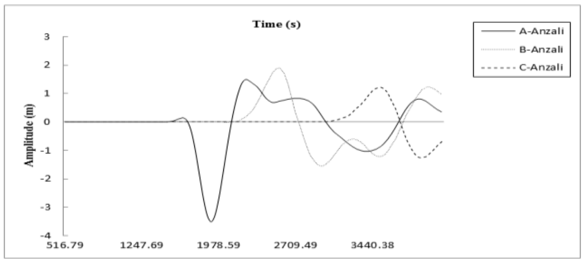

Fig. 4. Wave height time series for Anzali Station

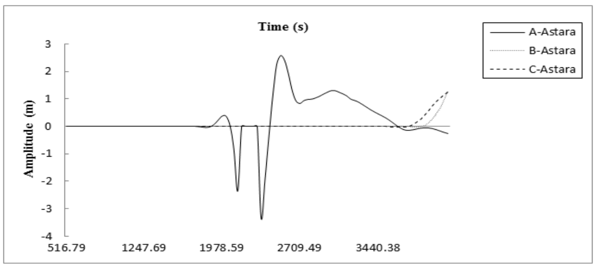

Fig. 5. Wave height time series of Astara Station

4. RESULTS AND DISCUSSION

Results of modeling listed in Table 3 show that maximum wave heights and lengths of submarine landslide tsunamis are significant. Effect radiuses express the large movement of water in the Caspian Sea scale. Figures 3 to 5 revealed that the generated tsunamis can cause a considerable run-up along the coastlines of their adjacencies.

5. CONCLUSIONS

Unlike tsunamis generated by earthquakes, submarine landslide tsunamis generated in shallow waters are more destructive compared to those generated in deep water. Based on numerical simulation results, it is inferred that a relatively high level of tsunami risk is characteristic of the Caspian coasts. Unfortunately, the incompleteness of the data prevents us from

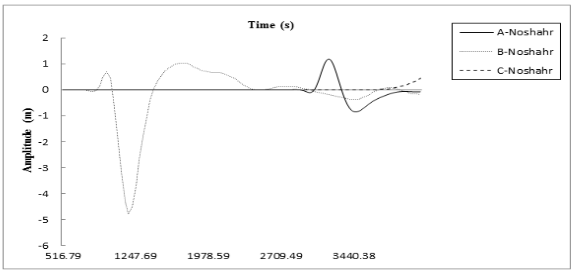

Fig. 6. Wave height time series of Noshahr Station

performing an adequate statistical analysis and assessing the probabilistic characteristics of the tsunami manifestation on the coast.

In accordance with visual observations, the heights of historical tsunamis have not exceeded 1-2 m, but it is possible to wait for tsunamis of high waves and considerable run-ups.

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