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Mapping Of Tsunami Risk Zones On Lombok Island To Support Military Operations Other Than War (OMSP)

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Abstract

Indonesia's existence at the meeting point of three major plates has resulted in the creation of tectonic complexes, especially at plate boundaries located in eastern Indonesia. Lombok Island and its surroundings have an active seismicity zone, namely the Flores back arc and the subduction between the Indo-Australian and Eurasian plates. The existence of active seismicity zones can produce earthquake events. If an earthquake occurs in a marine area, there will be high, destructive sea waves called a tsunami and can endanger safety, for this reason it is necessary to carry out tsunami simulations to map vulnerable areas around the coast. This information can then be used to increase community preparedness so that it can support the government in carrying out Military Operations Other Than War (OMSP). The simulation was carried out by integrating modeling software, namely WinITB v.6.52 and ArcGIS mapping software. The simulation results show that the tsunami in the north of Lombok Island and its surroundings spread towards an azimuth angle of 61° and the tsunami in the south of Lombok Island and its surroundings spread towards an azimuth angle of 80°. The estimated height resulting from the tsunami in the north of Lombok Island and its surroundings is as high as 1.9 m with a dangerous classification, while the height resulting from the tsunami in the south of Lombok Island and its surroundings is as high as 4.7 m with a very dangerous classification. Tsunamis can be generated from active seismic sources, with earthquakes with depths of less than 60 km, dip-slip plate faults and earthquake magnitudes greater than M6.5.

Keywords: Earthquake, Lombok Island, OMSP, Tsunami, Wave Height Estimation

INTRODUCTION

Indonesia is a country located in the ring of fire zone, Indonesia's geographic location is between the Australian Continent and the Asian Continent, and between the Pacific Ocean and the Indian Ocean. Geologically, Indonesia is located at the meeting point of three plates, namely the Indo-Australian plate, the Eurasian plate and the Pacific plate. These three plates are active plates which, if they meet, can create interactions, one of which is collision interactions between plates. This interaction can result in active seismic zones in Indonesian territory, resulting in frequent earthquakes.

Lombok Island is part of West Nusa Tenggara Province, geographically surrounded by the sea. The western region borders the Lombok Strait which separates Bali Province, the eastern region borders the Sape Strait which separates NTT Province, the southern region borders the Indian Ocean, the northern region borders the Java Sea and the Flores Sea. The border in the southern region is in the subduction zone of the Indo-Australian plate and in the northern region is in the Flores Back arc thrust zone (Darman & Sidi, 2000) (Maipark Indonesia, 2019). The existence of this zone means that Lombok Island and its surroundings occupy an active seismicity zone. It is proven that Lombok Island and its surroundings have a history of quite a lot of earthquakes. If an earthquake occurs due to the activity of tectonic plates and is on the seabed, it will cause sea waves to become tidal waves with maximum height and move towards land at high speed.

The active dynamics of plates and faults on Lombok Island and its surroundings has recorded a series of earthquakes which have resulted in destructive sea waves at high speed.

Starting from 416 - 2018, there were approximately 30 earthquakes that triggered sea waves (BMKG, 2019). Lombok Island is one of the areas that has a tsunami-prone zone in Indonesia, with more than 10 incidents since 1818. BMKG data shows that tsunamis occur due to earthquakes with an average strength of 6.12 SR, with the largest tsunami incident being caused at a strength of 7 SR. in 2018 (Nugroho, 2018). An earthquake is an event where the earth vibrates or shakes, due to sudden movements or shifts experienced by layers of rock on the earth's crust due to the movement of tectonic plates (Sunarjo, Gunawan, & Pribadi, 2012). Ocean waves resulting from earthquakes are long waves that can be modeled as shallow water flows. The wavelength can be longer than the depth of sea water (range of several meters). Sea waves that propagate towards land are destructive, because they have a very high amplitude. This amplitude is produced because sea waves enter shallow water and are influenced by the presence of several objects on the coast, such as the presence of ships, buildings, breakwaters on the coast, and others (Pawirodikromo, 2012).

The risks posed by a tsunami will be detrimental to the country and become a concern in the country's defense system. Therefore, it is necessary to map the level of tsunami vulnerability that occurs due to earthquakes on Lombok Island by simulating sea waves due to earthquakes. This activity will provide an alert attitude among the public to find out natural disaster mitigation patterns and can support the government in carrying out Military Operations Other Than War (OMSP) which are in line with Law No. 34 of 2004 concerning the Indonesian National Army, with the aim of, among other things, assisting the government in carrying out its duties. -governmental duties, such as development, disaster management and law enforcement, protecting the nation and state from non-military threats, such as natural disasters, social unrest and maritime security threats, and assisting other countries in the context of upholding international peace and security.

RESEARCH METHODS

This research uses quantitative research methods, namely a systematic, planned and structured type of research with variables measured using research instruments that can be analyzed (Kusumastuti, 2020). Quantitative approach method research is carried out with the number of samples determined based on the number of samples carried out using a certain formula. The data obtained is empirical data that is valid, reliable and objective. The data obtained is in the form of parametric numbers so that the magnitude can be determined which is then referred to as quantitative data (Priadana & Sunarsi, 2021). The research samples were carried out in areas with high seismicity, namely in the North of Lombok Island and the South of Lombok Island. The data obtained is the height of the waves caused by the earthquake and the travel time of the waves. The research phase begins with a literature study, wave simulation, and validation phase.

The wave simulation stage was carried out by integrating WinITDB v.6.52 software and ArcGIS software. The WinITDB v.6.52 application is a comprehensive tsunami database application for the world's oceans which is compiled in the form of a basic Pacific tsunami data base catalog which was carried out in conjunction with the IUGG/TC and ICG/ITSU projects. ArcGIS software is software developed by ESRI, with a compilation of functions from various types of GIS software. This software can process data in the form of mapping and analysis, and can carry out editing and geoprocessing analysis needs. The Validation Stage is a stage carried out before carrying out the simulation process, which aims to determine the level of accuracy of the WinITDB v.6.52 application. At this stage, we compare the EWH data resulting from simulations using WinITDB v.6.52 with run-up data from field observations and research data, namely research data from (Borerro, LeVeque, Greer, O'Neill , & Davis, 2015), field data from NOAA's NCEI, and NDBC's BUOY. The field data used are tsunami events that have occurred in Indonesia and Japan, tsunami events in Indonesia, namely the 1994 Banyuwangi tsunami and tsunami events in Japan, namely the 2011 Tohoku tsunami. The selection of the 1994 Banyuwangi tsunami tsunami event can represent the tsunami event in the southern part that occurred in the zone subduction of the Eurasian and Indo-Australian plates adjacent to Lombok Island and its surroundings, while the 2011 Tohoku tsunami was chosen because it compares with data fromBOIL NDBC in the middle of the sea and research field data from Jose C. Borrero. The data was then simulated using WinITDB v.6.52

RESULT AND DISCUSSION

Simulations of the propagation of sea waves due to earthquakes were carried out on Lombok Island and its surroundings, based on earthquake parameter data. The sea wave simulation is in two places, namely the southern and northern parts of Lombok Island and its surroundings. The results of sea wave simulations are in the form of recorded data from each observation point, which is called mareogram data. The data consists of estimated wave height (EWH) and estimated arrival time (ETA) of waves. The form of sea wave propagation can be determined based on the parameters of the earthquake that caused the wave. Interpretation of the level of danger produced by sea waves can be determined based on the resulting EWH and ETA data. to determine the level of accuracy of the application in carrying out wave simulations. This process is carried out by comparing wave height field data with the results of simulations in the WinITDB v.6.52 application.

Software Validation

The 1994 Banyuwangi and Tohoku, Japan 2011 tsunami field data originating from NCEI NOAA and BUOY NDBC were compared with simulation results data in the WinITDB v.6.52 application, this was done to validate or test the application in simulating the tsunami that occurred on the island of Lombok. So that the results of the simulation will be accurate.

Table 1. Data Comparison of Sea Wave Height Simulation Results in WinITDB v.6.52 with NOAA NCEI Data for Sea Waves Due to the 1994 Banyuwangi Earthquake

Station Point	*Latitude*	*Longitude*	Sea Wave Run-up Field Data (Meter)	Sea Wave Run-up Simulation Results WinITDB V.6.52 (Meter)	Error Rate
1	-8.40500	114.7672	2.70	0.16	94%
2	-8.61983	115.0858	2.00	2.47	24%
3	-8.61517	114.1138	1.30	0.25	80%
4	-8.38038	113.4466	5.80	1.70	71%
5	-8.73033	114.351	4.20	2.46	41%
6	-8.73083	114.3475	5.50	3.77	31%
7	-8.73217	114.3488	5.10	5.44	7%
8	-8.73950	114.3427	5.60	5.44	3%
9	-8.74583	114.3558	4.40	4.63	5%

Station Point	*Latitude*	*Longitude*	Sea Wave Run-up Field Data (Meter)	Sea Wave Run-up Simulation Results WinITDB V.6.52 (Meter)	Error Rate
10	-8.65683	114.3607	4.90	5.53	13%
11	-8.65700	114.3607	3.60	2.68	26%
12	-8.43443	113.5823	7.60	6.27	17%
			Average error rate		34%

Table 2. Comparison Data of Sea Wave Height Simulated in WinITDB v.6.52 with Field Data (Source: Borrero, 2015) and BUOY NDBC Data for Sea Waves Due to the 2011 Japan Earthquake

Station Point	Latitude	Longitude	Sea Wave Run-up Field Data (Meter)	Sea Wave Run-up Simulation Results WinITDB V.6.52 (Meter)	Error Rate
1	38.735	148.655	1.46	1.46	0%
2	30.553	152.132	0.80	0.80	1%
3	11.929	153.909	0.29	0.29	0%
4	48.968	178.219	0.35	0.35	1%
5	49.662	165.1509	0.19	0.19	2%
6	44.435	165.1509	0.72	0.72	0%
7	50.164	171.93	0.21	0.21	1%
8	53.726	170.5427	0.06	0.06	7%
			Average error rate		2%

Based on the results of Table 1 and Table 2, the average level of comparison from research data by Jose C. Borrero (2015) and BUOY NDBC for the occurrence of sea waves due to the 2011 Japanese earthquake, is 2%. Comparative data with NOAA NCEI data for sea wave events caused by the 1994 Banyuwangi earthquake, with a magnitude of 34%. The WinITDB v.6.52 application has the ability to record data resulting from wave propagation in sea areas, whereas sea wave propagation that has reached land areas that form inundations cannot be recorded by WinITDB v.6.52. So the comparative data on sea waves caused by the 1994 earthquake in Banyuwangi has an average with a large percentage. Because some of the field data was obtained from the propagation of waves that had reached land, therefore, when compared with the data from WinITDB v.6.52, the results did not show a small percentage, and there were discrepancies. Meanwhile, based on research data from Jose C. Borrero (2015) and BUOY NDBC on sea waves caused by the earthquake in Tohoku, Japan in 2011, there is a small error rate, because the BUOY data was obtained in the open sea area, so the WinITDB v.6.52 application can carry out matching. . Apart from reviewing the area where sea waves propagate due to earthquakes, the WinITDB v.6.52 application also reviews the type of bathymetry that exists in the sea or on the coast.

Tsunami Simulation on Lombok Island and Its Surroundings

Simulation of sea waves due to earthquakes in the south and north of Lombok Island and its surroundings can be determined based on earthquake parameter data. Then the length and width of the fracture can be calculated. The parameter data can be shown in the following table.

Table 3. Data on Earthquake Parameters that Trigger Sea Waves on Lombok Island and its surroundings

Location of Wave Propagation	**Earthquake Parameters that Trigger Ocean Waves**							
	Magnitude	**Latitude**	**Longitude**	**Depth**	**Azimuth**	**Strike**	**Fault Length**	**Fault Width**
North	M7.4	-7.99 °S	117.64 °E	10 Km	61°	299 °	48.9778	28.1838
South	M8.5	-10.744 °S	116.28 °E	30 Km	80 °	280 °	173.7800	68.39116

Magnitude is used as input in calculating the length and width of the fault and depth is a condition for the occurrence or emergence of sea wave propagation events due to earthquakes, namely it must be less than 60 km below sea level. To find out the EWH and ETA of a propagating wave, that is by determining observation points. In this research, 96 observation points were placed along the coast of Lombok Island and its surroundings, with details of 40 observation points located in the north of Bali Island, Lombok Island and Sumbawa Island, and 56 observation points located in the south of Bali Island, Lombok Island, Sumbawa Island and Sumbawa Island. Sumba. The location of these observation points can be shown in Figure 1.

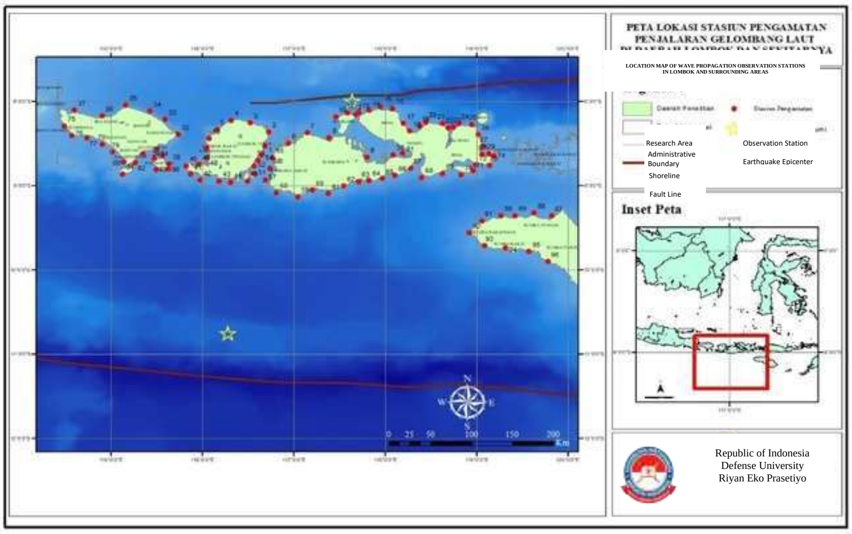

Figure 1. Estimated height of sea waves due to earthquakes on Lombok Island and its surroundings at each station in the south of Lombok Island and its surroundings Lombok Island and its surroundings

The waves depicted are the waves that first appeared, namely at the epicenter of the earthquake. With a color spectrum index that shows the estimated height of the wave that first propagated at the epicenter of the earthquake. The shape or profile and direction of propagation of sea waves caused by earthquakes on Lombok Island and its surroundings can be shown in Figure 2 and Figure 3.

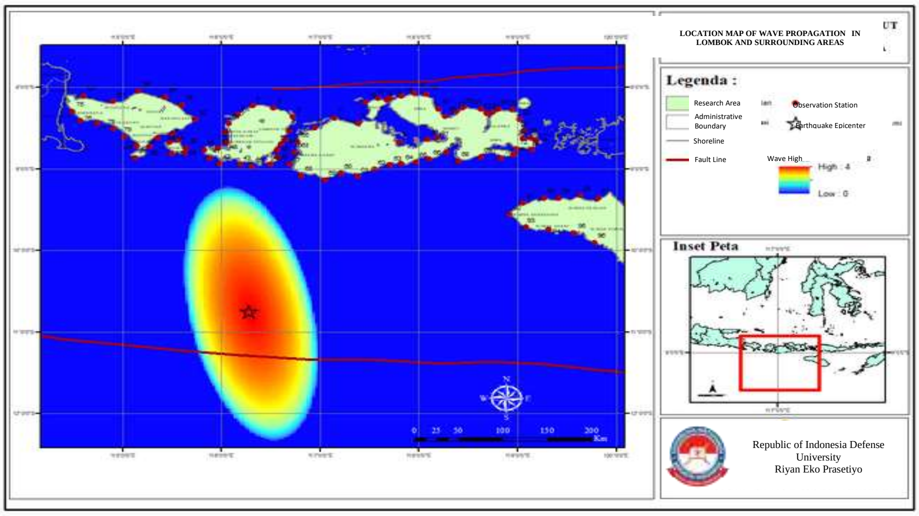

Figure 2. Map of the shape of sea waves propagating due to earthquakes in the south of Lombok Island and its surroundings

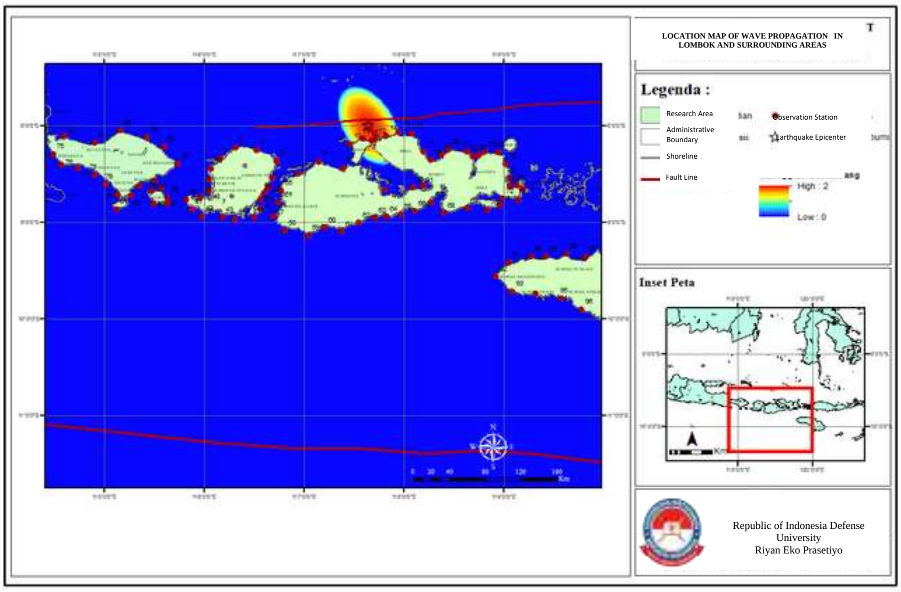

Figure 3. Map of the shape of sea waves propagating due to earthquakes in the north of Lombok Island and its surroundings

On the map of sea wave propagation due to the earthquake in the south of Lombok Island and its surroundings with a maximum height of 4 m, the direction of propagation is towards Sumba Island with an azimuth angle of 80°. Sea waves also hit Lombok Island, Bali Island and Sumbawa Island, while the sea wave propagation map due to the earthquake in the north of Lombok Island and its surroundings with a maximum height of 2 m, the direction of propagation is towards Sumbawa Island, Lombok Island and Bali Island, at an angle azimuth 61°. The sea waves that occurred first hit Sumbawa Island and Bima Island. The direction of wave propagation is determined based on the azimuth angle of the earthquake event. Sea waves are generated from earthquakes that occur in fault areas, namely the southern part which occurs in the subduction fault area of the Eurasian and Indo-Australian plates, which are along the southern region of Indonesia, as well as the Flores back arc fault in the northern part of the islands of Lombok and Sumbawa. This event occurred because the island of Lombok was formed from a volcano resulting from the subduction of the Australian plate which subducted northward under the Eurasian plate (Pamumpuni, Sapiie, Marshal, Apriansyah, & Anisprawoto, 2018). Lombok Island is one of the islands in the Nusa Tenggara archipelago. Geologically, Lombok Island has relatively young rocks, dominated by volcanic rocks (volcanic breccia, lava and sandstone) (Agustawijaya, et al., 2005, 2006; Agustawijaya & Syamsuddin, 2009).

The tectonic symptoms that occur can cause normal faults and strike-slip faults trending to the northwest and southeast. On the island of Lombok, apart from faults or lineaments, there are also many joints (Agustawijaya D. S., 2006). The oldest rocks on Lombok Island are located in the southern part of Lombok Island, which is tectonically right at the front (force arc). Breccia rocks and sandstone which are the result of roller formations and herd formations in several places can be found breached by basaltic igneous rocks. Then in the northern part of Lombok Island, namely around Mount Rinjani, there are rock formations consisting of volcanic rocks that are loose and quaternary in age. The thickness of the layer on the rock is quite thick, capable of covering almost two-thirds of Lombok Island (Agustawijaya & Syamsuddin, 2009).

From the explanation of the geological conditions of Lombok Island, it can be linked that the condition of these rock structures is related to earthquake events, namely that these rock structures play a role in providing paths for seismic waves resulting from earthquake events. Lombok Island has a fairly high potential for natural disasters, this is because based on the aspect of soil conditions, Lombok Island has soil conditions that are loose, thick and have aquifer. Apart from that, based on geological conditions, it has a strong structure and active and vulnerable faults, plus in the northern part there is a volcanic complex which has a sediment structure that is not compact and easily detaches (Agustawijaya & Syamsuddin, 2009). Lombok Island is located on two major faults, namely the Flores back arc and the subduction zone. The Flores back arc is located in the north of Lombok Island and is one of the main sources of earthquakes. The position of the Flores back arc is an important concern for researchers, because it is the cause of dangerous earthquakes, with hypocenter shallow and magnitude the big one. The plate subduction zone is located south of Lombok Island. The plate that experienced a subduction event in this area was the Eurasian plate and the Indo-Australian plate, so it could also potentially be a source of earthquakes (Maipark Indonesia, 2019).

Interpretation of Hazard Levels Based on EWH and ETA from Simulation Results

The wave height recorded on the propagation map is the height first generated at the epicenter of the earthquake. The speed of sea waves will experience weakening which is then converted into sea wave height. Ocean waves that propagate in the open sea initially have kinetic energy, which then, as they approach the coastline, is converted into potential energy. This can be illustrated by assuming the seabed is in the form of a straight line which is linear as shown in figure 4.

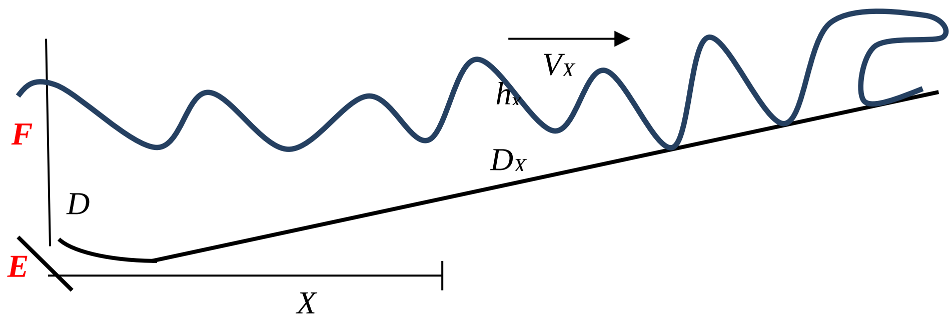

Figure 4. Model of sea waves caused by earthquakes with a linear flat seabed

After an earthquake occurs, the seabed will rise upwards/drop down suddenly which can push and pull water masses up and down suddenly (earthquake reverse fault). Then after a few minutes, the sea waves separated and divided into two, some heading towards the open sea and some towards land. Ocean waves heading towards the open sea have speed V_D and sea waves heading towards land have speed V_X. Waves heading towards the open sea have high speeds and have large wavelengths and wave energy. When the wave heads towards the open sea, the sea water on the beach will be attracted and cause it to recede suddenly. Wave energy in the open sea will remain large so that it can travel very far. Then the sea waves heading towards the coast will experience a decrease in speed because they rub against the beach topography or bathymetry, and there will be an accumulation of energy accompanied by a shortening of the wavelength. The energy will erode sand and coastal vegetation, causing strong currents. The wave height and wave arrival time will have different values for each area of land being targeted. This happens because the wave experiences a wave deformation event. Waves will experience a refraction event, namely a change in the direction of wave propagation due to the direction of arrival not being perpendicular to the contour of the seabed. This change will cause the orthogonal wave lines to bend to reach a state of balance against the shear forces of the seabed, the orthogonal lines will become perpendicular to the coastline and the wave front will become parallel to the beach face.

In a refraction event, the wave will experience changes in height and wave speed as a result of the wave entering the shallow sea and friction from the seabed. This event is called shoaling, waves entering shallow seas will experience a reduction in speed and shortening in wavelength which results in an increase in height. Waves that spread to land areas have great energy at high wave heights, until they finally break and release all the energy they carry. The release of this energy will be transferred and received by objects or objects in front of it and around it in the form of very large impulses, so that it can destroy or damage the physical condition of the object or object. WinITDB v.6.52 application in progress creates a simulation sea waves caused by earthquakes using the wave equation non-linear, which takes into account the type of sea or coastal topography, so that the friction coefficient will affect the wave height. The type of topography in question is the type of bathymetric profile that the sea or beach has. For this reason, the wave simulation process in this application can be approached using the equation non-linear shallow water. Sea wave simulations produce varying EWH and ETA, which is caused by differences in bathymetric profiles and the location of wave propagation observation points. The EWH and ETA that have been recorded by each observation point can determine the resulting level of danger. The classification of the danger level of sea waves due to earthquakes based on the maximum height of the waves is shown in the following table.

Table 4. Classification of Danger Levels of Sea Waves Due to Earthquakes Based on Maximum Height

Maximum Wave Height	Hazard Level Classification
$H \geq 3$ m	Very dangerous
1.5 m $\leq H <$3 m	Danger
0.5 m $\leq H <$1.5 m	Quite Dangerous
$H < 0.5$ m	No danger

Source: (Latief, et al., 2000)

Based on the classification above, the following is EWH data from the results of simulating sea waves caused by earthquakes on Lombok Island and its surroundings. The EWH results analyzed are the highest EWH results from the data for each observation point, which is shown in the following diagram.

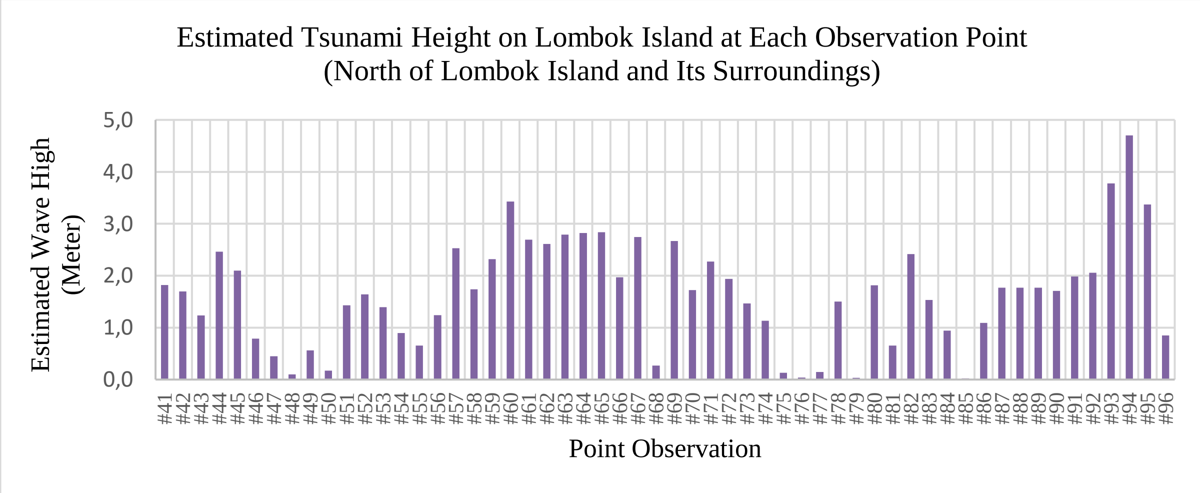

Figure 5. Estimation of sea wave heights due to earthquakes on Lombok Island and its surroundings at each station in the south of Lombok Island and its surroundings

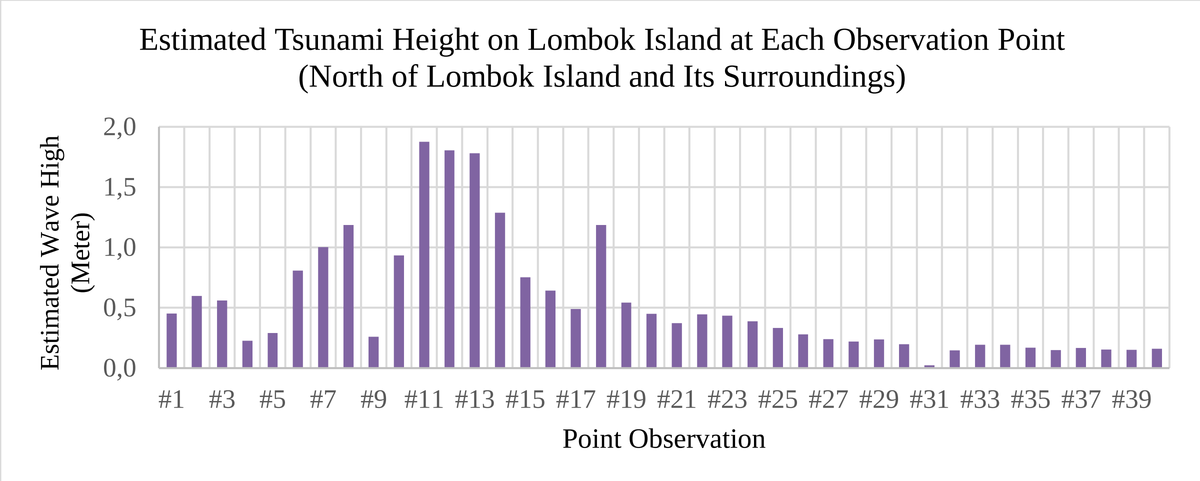

Figure 6. Estimation of sea wave heights due to earthquakes on Lombok Island and its surroundings at each station in the south of Lombok Island and its surroundings

Based on the recorded data depicted in Figure 5 and Figure 6, the highest EWH results obtained for sea wave propagation in the south of Lombok Island and its surroundings were at observation point 94 with longitude coordinates 119.3ºE, latitude -9.78ºS, the resulting EWH was as high as 4.7 meters. Meanwhile, for the propagation of sea waves due to the earthquake in the north of Lombok Island and its surroundings, it is at observation point 11 with longitude coordinates 117.6ºE, latitude -8.13ºS, the resulting EWH is 1.9 meters high. At the 94 observation point, the first sea wave that appeared after the receding sea water due to the earthquake was 0.001 meters. The location of observation point 94 is on the western part of Sumba Island which is shown in figure 7.

Figure 7. Location of station 94 observation point

Based on the location of the observation point, the western part of Sumba Island is at a distance of 354.00 km from the epicenter earthquake. The sea waves that spread towards the observation point experienced an increase in height in the 29th minute. Meanwhile, the sea waves that first appeared at the observation point epicenter The earthquake was 4 m high, then after approaching the coast, the wave height changed to 4.7 m. The process of changing wave height can be influenced by the bathymetry that the ocean waves pass through. The bathymetric profile traversed by sea waves towards observation point 94 is depicted in a one-dimensional image, which is shown in figure 8.

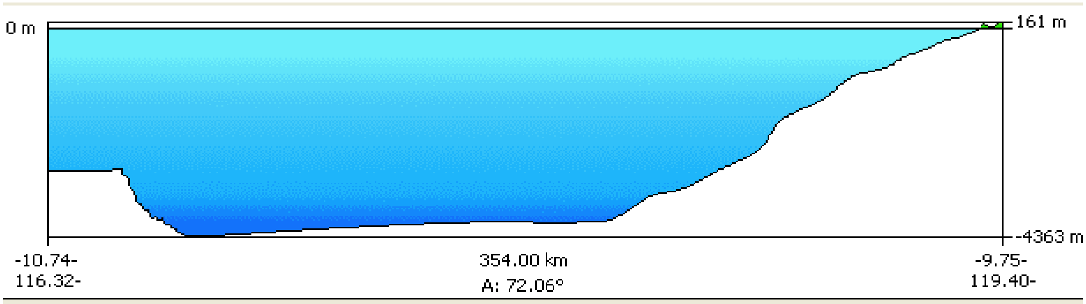

Figure 8. Bathymetric profile from the epicenter point to observation point 94

The bathymetric profile at observation point 94 is a concave type bathymetric profile. The sea waves that spread from the epicenter of the earthquake occur initially at high speed because they still have a deep depth, so they still form long waves. Then as it approaches the coast, the wave speed decreases and is converted into wave height. In this type of profile, the propagating wave is suddenly compressed due to a collision with the existing bathymetric layer, so that the resulting wave height can exceed the wave height at the epicenter of the earthquake. This height is the highest peak of the sea waves that propagate towards observation point 94. Then at observation point 11 the sea waves that first appeared after the receding sea water due to the earthquake were 1.9 meters. The location of observation point 11 is on Sumbawa Island which is shown in figure 9.

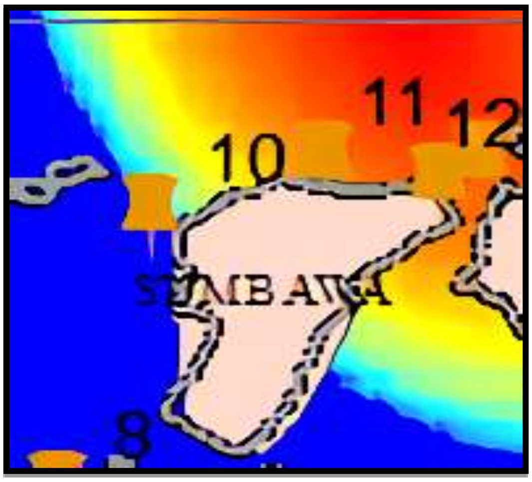

Figure 9. Location of observation point 11

Based on the location of the observation point, the eastern part of Sumbawa Island is an island adjacent to the point epicenter sea waves occurred due to an earthquake 29.00 km away, so that at minute 0 this island immediately experienced high sea waves. The first sea waves appeared at the point epicenter The earthquake was 2 m high, then after approaching the coast, the wave height changed to 1.9 m. The process of changing wave height can be influenced by the bathymetry that the ocean waves pass through. The bathymetric profile traversed by sea waves towards observation point 11 is depicted in a one-dimensional image, which is shown in figure 10.

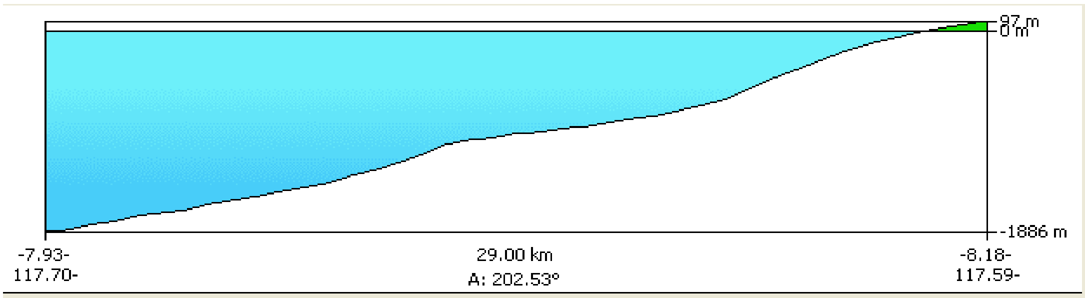

Figure 10. Bathymetric profile from the epicenter point to observation point 11

The bathymetric profile at observation point 11 is a straight line type bathymetric profile linear to the top. Ocean waves that spread from the point epcr earthquakes occur, initially at high speed, because they still have a deep level, so they still form long waves. Then as it approaches the coast, the wave speed begins to decrease and the wave begins to slowly compress, thus forming a wave height. In this type of bathymetric profile, sea waves that propagate towards the coast are confronted with the bathymetric structure, so that the waves start to get high before they reach the observation point. This causes the wave height to reach its highest point before reaching the observation point. Apart from producing EWH in the process of simulating sea waves caused by earthquakes, it also gets ETA values. The resulting ETA also has varying values from each existing observation point. The following is a bar chart, which shows the ETA from each observation point in the north and south of Lombok Island and its surroundings.

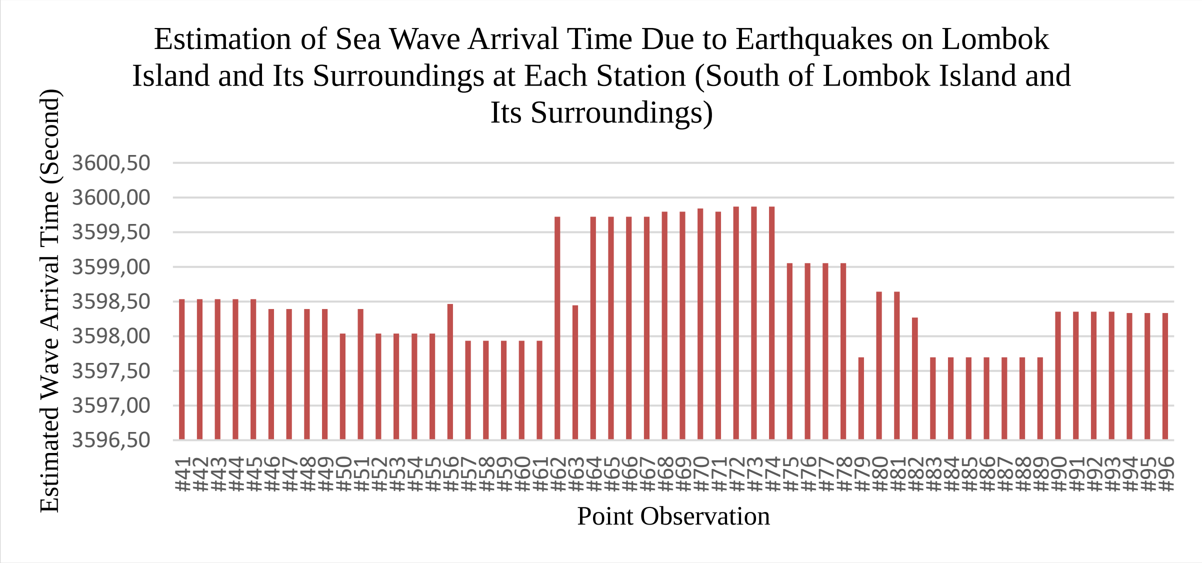

Figure 11. Estimation of Sea Wave Arrival Time Due to Earthquakes on Lombok Island and Its Surroundings at Each Station in South of Lombok Island and Its Surroundings

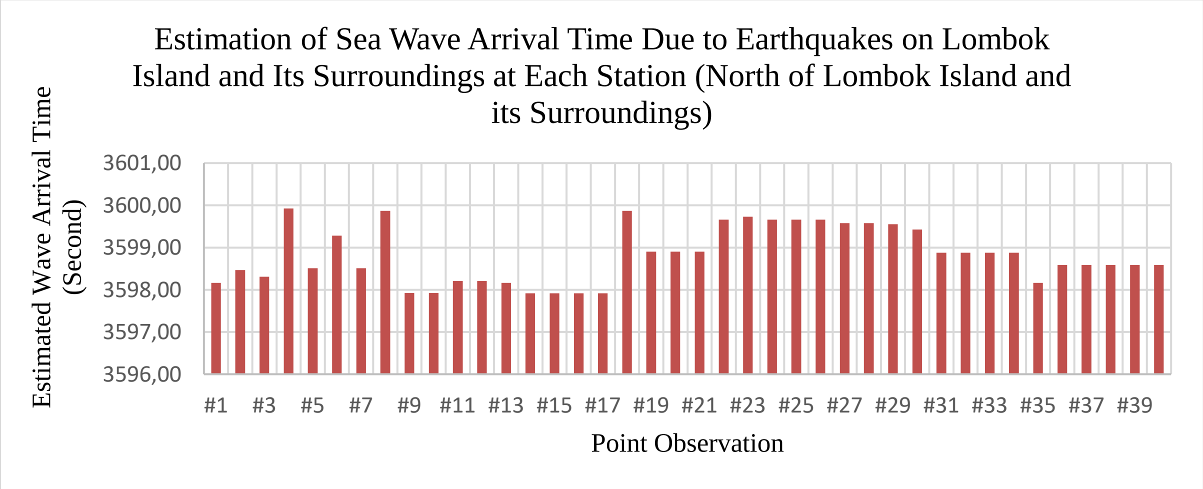

Figure 12**.** Estimation of Sea Wave Arrival Time Due to Earthquakes on Lombok Island and Its Surroundings at Each Station in North of Lombok Island and its Surroundings

The ETA shown in Figure 11 and Figure 12 is the fastest ETA recorded from each existing station. Sea waves in the southern part of Lombok Island and its surroundings have the fastest ETA of 3597.70 s or 59.96 minutes and the slowest ETA of 3599.87 s or 60.00 minutes. The fastest ETA is at stations 83 – 89 on the island of Bali, while the slowest ETA is at stations 72 – 74 on the southern island of Bima. Sea waves in the northern part of Lombok Island and its surroundings have the fastest ETA of 3597.91 s or 59.97 minutes and the slowest ETA of 3599.93 s or 60.00 minutes. The fastest ETA is at stations 13 – 17 on the northern part of Bima Island, while the slowest ETA is at station 4 on Lombok Island.

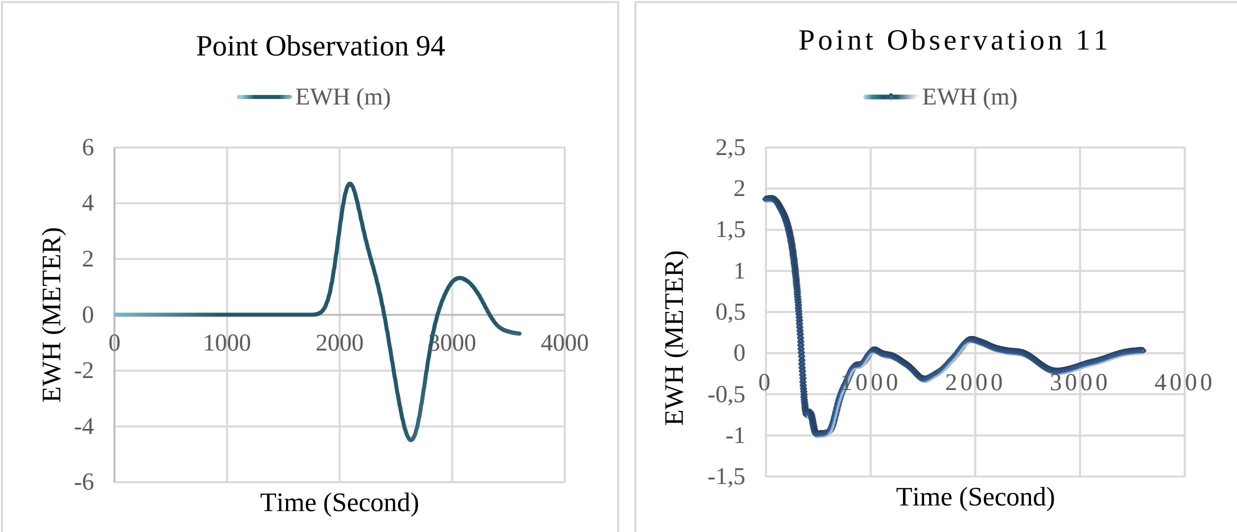

Figure 13. Relationship graph of EWH and ETA at observation points 94 and 11

In the event of a sea wave in the south of Lombok Island and its surroundings at observation point 94, it was first recorded at the 29th minute with a height of 0.001 meters, then continued to increase in height to 4.7 meters at the 34th minute. With the wave decreasing after passing the observation point, it occurred at the 39th minute. with a height of 0.03851 meters. The sea wave spread with an ETA of 59 minutes 97 seconds. Meanwhile, the sea wave incident in the north of Lombok Island and its surroundings at observation point 11 was first recorded at minute 0 with a height of 2 meters. The sea waves experienced a decrease in height after passing the observation point, which occurred in the 5th minute with a height of 0.00607 meters. The sea wave spread with an ETA of 59 minutes 97 seconds.

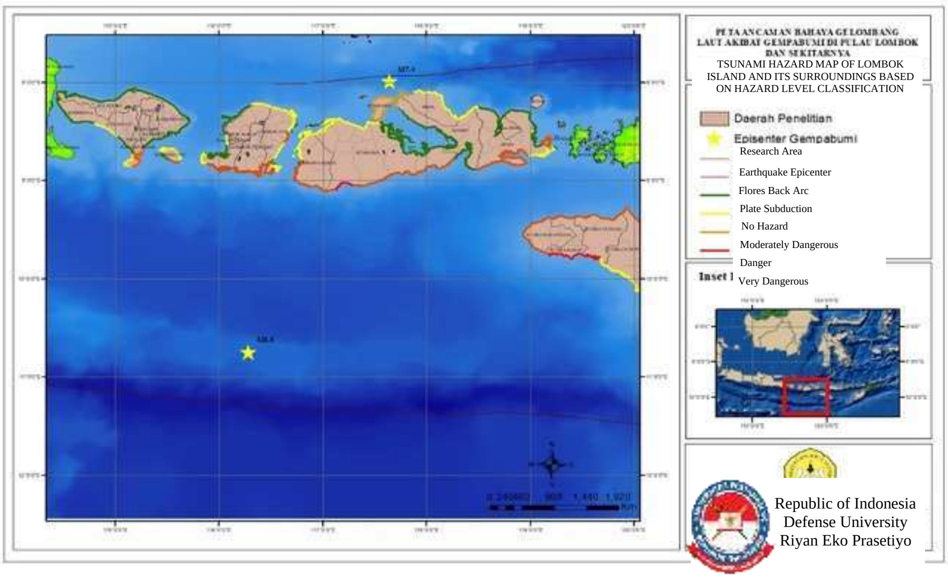

Figure 14. Mapping tsunami risk zones on the island of Lombok and its surroundings

The simulation results produced a mapping of the tsunami risk zone on Lombok Island which is shown in Figure 14. Mapping tsunami-prone areas is one of the efforts to minimize the impact of the tsunami disaster. This mapping aims to identify areas that have the potential to impact a tsunami. This information can then be used to improve community and government preparedness in facing tsunami disasters. Military Operations Other Than War (OMSP) can play an important role in mapping tsunami-prone areas. OMSP can provide technical and operational support in implementing tsunami simulations. Tsunami simulation is one method that can be used to predict the impact of a tsunami. In tsunami simulation, the TNI can use various equipment and technology to simulate tsunami waves. The simulation data can then be used to analyze the potential impact of a tsunami in an area.

CONCLUSION

The simulation results of the highest tsunami risk area on Lombok Island and its surroundings occur in the southern part of Lombok Island with a height of 4.7 meters at longitude coordinates 119.3ºE, latitude -9.78ºS. This happens because the southern part of Lombok Island borders directly on the South Sea which is an active subduction zone and megathrust site. This condition produces a concave geometric shape so that if sea waves occur at high speed there will be a collision with the bathymetric wall and will convert higher energy into wave height. Mapping results show that the area of Lombok Island and its surroundings on the south side is experiencing a red zone, which means it is dangerous if a tsunami occurs.

Military Operations Other Than War (OMSP) is an important aspect of providing technical and operational support in implementing tsunami simulations. Tsunami simulation is one method that can be used to predict the impact of a tsunami. In tsunami simulation, the TNI can use various equipment and technology to simulate tsunami waves. The simulation data can then be used to analyze the potential impact of a tsunami in an area.

REFERENCES

Agustawijaya, D. S. (2006). Aspek-aspek Geologi Teknik Geologi Teknik dan Kegempaan dalam Analisis Resiko Gempabumi. *Orasi Ilmiah dalam rangka Dies Natalis Universitas Mataram ke 44.* Mataram: Universitas Mataram.

Agustawijaya, D. S., & Syamsuddin. (2009). *Pengembangan Metode Analisis Risiko Bencana: Sebuah Studi Kasus Pulau Lombok.* Mataram: Universitas Mataram.

Agustawijaya, D. S., Sulistyowati, T., & Hadi, S. (2005). *Pengkajian Bahaya Longsor tipe Jatuhan Batuan.* Jakarta: Direktorat Jenderal Pendidikan Tinggi, Departemen Pendidikan Nasional.

BMKG. (2019). *Katalog Tsunami Indonesia.* Jakarta: BMKG, Pusat Kedeputian Bidang Geofisika.

Borerro, J. C., LeVeque, R. J., Greer, S. D., O'Neill , S., & Davis, B. N. (2015). Observations and Modelling of Tsunami Currents at the Port of Tauranga, New Zealand,. *Australians Coasts & Ports Conference.* Auckland, New Zealand.

Darman, H., & Sidi, F. H. (2000). *An Outline of the Geology of Indonesia.* Indonesian Association of Geologist.

Kusumastuti, A. K. (2020). *Metode Penelitian Kuantitatif.* CV Budi Utama. Retrieved from https://books.google.co.id/books?hl=id&lr=&id=Zw8REAAAQBAJ&oi=fnd&pg=PP1&dq=metode+kuantitatif&ots=felAyyGpHn&sig=XuR-mmr9Gr6U7i9VgLksb6NtSVE&redir_esc=y#v=onepage&q=metode kuantitatif&f=true

Latief , H., Imamura, F., & Puspito, N. (2000). Tsunami Catalog and Zones in Indonesia. *Journal of Natural Disaster Science*, 1, 22, 25 – 43.

Maipark Indonesia. (2019). *Gemuruh di Lombok, Palu dan Donggala, Senyap di Selat Sunda.* PT Reasuransi MAIPARK Indonesia.

Nugroho, B. P. (2018, 07 06). *Sederet Gempa dan Tsunami yang Pernah Guncang NTB*. Retrieved from Detiknews: https://news.detik.com/berita/d-4152068/sederet-gempa-dan-tsunami-yang-pernah-guncang-ntb

Pamumpuni, A., Sapiie, B., Marshal, M. E., Apriansyah, D., & Anisprawoto, A. (2018). *Pasca Gempa Lombok 5 Agustus 2018.* Bandung: Institut Teknologi Bandung.

Pawirodikromo, W. (2012). *Seismologi Teknik & Rekayasa Kegempaan.* Yogyakarta: Pustaka Pelajar.

Priadana, S., & Sunarsi, D. (2021). *METODE PENELITIAN KUANTITATIF* (Vol. 1). Tanggerang: Pascal Books .

Sunarjo, Gunawan, M. T., & Pribadi, S. (2012). *Gempabumi Edisi Populer*. Jakarta: Badan Meteorologi Klimatologi dan Geofisika.