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Identification of Earthquake Shake Levels in Palu City Based on Mw 6,8 Shakemap Scenario by Palu Koro Fault

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Abstract

Palu city is an active earthquake region, mainly sourced from the activity of the Palu Koro Fault. Refer to the Mw7.4 Central of Sulawesi earthquake on September 28th, 2018 with ground shaking intensity reached VII-IX MMI level in Palu. As a support data and preparation of an earthquake contingency plan document in Palu City, we proposed 3 sources of earthquake scenarios in the Palu Koro fault at a depth of 11 km, namely Mw6.8 in the Palu City Segment with coordinates 119.830 E – 0.800 S, Mw 6.9 in the Saluki segment with coordinates 120.010 E - 1,250 S and Mw 7.1 in the Makassar Strait segment with coordinates 119.750 E – 0.380 S. The worst-case scenario is that the Mw6.8 earthquake in Palu City can reach VI-VIII MMI.

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1. INTRODUCTION

Central Sulawesi Province is one of the regions in Indonesia which has very high tectonic earthquake activity, this is due to the strategic location of the tectonic geodynamics of the province which actively moves in a complex manner from its constituent plates. This island is tectonically a complex area because it is the meeting place of three plates, namely: the Indo-Australian continental plate which is moving northward, the Pacific Ocean plate which is moving westward and the Eurasian continental plate which is moving south-southeast and the Philippine plate. On the other hand, regional waters along the coast of this province have potential sources of tsunami threats, both local tsunamis and tsunamis and/or with natural tsunami generating sources that are known to the people of Indonesia, namely the potential for tectonic earthquakes in the mega-thrust zone. subduction of northern Sulawesi and due to the effects of earthquake events with shock levels that cause material dislocations (slides) on underwater cliffs such as the Mw 7.4 Central Sulawesi Damaging Earthquake on 28 September 2018 and the potential for the eruption of the Colo Volcano formed in the article Wikipedia is due to the process of subduction rollback cracking/expansion or stretching of the crust under Tomini Bay due to changes in the angle of the subducting plate so that the crust becomes thinner which is a weak zone in the rock layer, so that it can be intruded by magma or earth's mantle material.

The provincial capital of Central Sulawesi is Palu City with an area of 395.06 km² with a population of 372,218 people in 2020 consisting of 8 Districts and 46 Villages [1]. Climatologically, Palu City is included in the Non-Seasonal Zone (NON-ZOM) region category which includes Palu City (N46) and other districts based on the Seasonal Zone and Non-Season Zone Map of the Central Sulawesi Region (GAW Palu Station; 2019) with the main characteristic being a tropical area. The meaning of an ZOM category area is an area with clear boundaries between the rainy season and dry season, or a typical monsoon pattern, with a certain ZOM area code according to BMKG standards and for non-ZOM areas it is the other way around.

According to Sompotan [3], based on the lithotectonic structure, Sulawesi Island can be divided into 4 (four) mandalas, namely the West Mandala which is the western and northern parts of Sulawesi Island which are the Plutonic Volcano Arc area with magmatic pathways at the tip of the Sunda Shelf. Central Mandala which is the Metamorphic Belt of Central Sulawesi, composed of metamorphic rocks overlaid by bancuh rocks from Australian blocks, East Mandala which is known as the Eastern Sulawesi Ophiolite Belt composed of imbricated oceanic crust segments of ophiolite and Triassic-Miocene sedimentary rocks and finally Fragments The continent of Banggai – Sula – Tukang Besi, in the eastern and southeastern parts of Sulawesi Island which is a fragment of the continental structure that has moved westward due to the motion of the strike – slip fault from the island of Papua (New Guinea). Specifically, for the Central Mandala section, Palu

City is composed of quaternary sedimentary rocks, to be precise, alluvial areas, coastal deposits and Molasa Celebes [4][5]. According to Supraptoyo, [6, 7], quaternary sediment deposits are generally loose, loose, soft and not yet compact, when subjected to earthquake shocks they can be deformed easily. The western part of Palu is composed of sandstone, shale, conglomerate, limestone, chert, phyllite, slate and volcanic rock as well as 35 million-year-old granotoid intrusions, while the eastern part is composed of 3 million year old phyllite metamorphic rock, schist, gneiss intruded by granotoid type S is 2.4 million years old accompanied by the Molasa Celebes Sarasin deposit which is composed of conglomerate, sandstone, mudstone, coral limestone, marl and alluvial deposits and beaches. The size of the constituent material is not uniform with the depositional environment of deltas, rivers and shallow seas [8].

Due to the complicated tectonic processes, there are at least 48 active faults that trigger earthquakes in Sulawesi. The North Sulawesi subduction zone needs to be watched out for, because a large earthquake with a magnitude of Mw 8.5 is predicted to occur which can trigger a potential tsunami along the coast of the northern part of Sulawesi [9, 10]. The impact of earthquake shaking for Palu is generally dominated by shallow earthquakes that occur along the plane of the shear fault along the Palu Koro Fault. The fault area consists of 4 segments, namely the 130 km long Makassar Strait segment with the potential to trigger a 7.1 magnitude earthquake (in fact Mw7.4 in 2018), the 31 km long Palu segment with a potential of Mw 6.8, the Saluki and Moa segments along 44 km and 66 km with potential Mw 6.9 and Mw 7.1. The potential for liquefaction and avalanche tsunami events has been described by Ramadhani (2011), that the impact of strong earthquake shocks can cause cliff slides and trigger tsunamis and liquefaction in water-saturated sandy soil structure conditions as a secondary disaster, if correlated with natural landscapes such as topography, geotechnical, geohydrology and social conditions of the people.

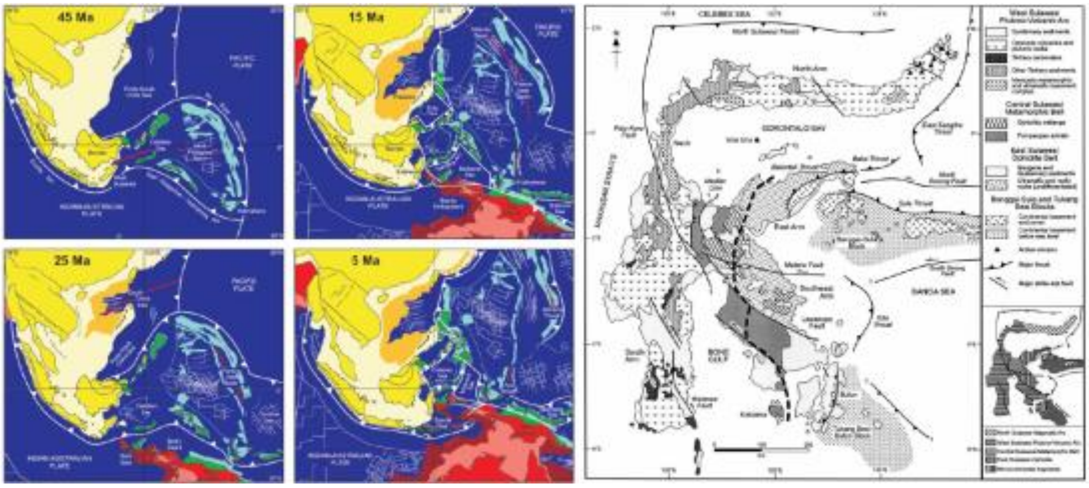


Figure 1. The tectonic development of Sulawesi (2008) and the geological map of Sulawesi [2] in the Geological Structure book

2. THE HISTORY OF THE DESTRUCTIVE EARTH GENUINE IN PALU AND THE CHARACTERISTICS OF THE MW 7 EARTHQUAKE (28 SEPTEMBER 2018)

For earthquakes with a magnitude above 5.7 that impact Palu City, they generally occur in the Palu Koro fault area with a shallow earthquake type. Based on the history of destructive earthquakes from 1907 to the present, such as the 1907, 1909, 1927 (tsunami), 1968 (tsunami), 1998, 2005, 2012 earthquakes, and a series of 2018 earthquakes (tsunami), as well as earthquake activity on other faults in 1938 (tsunami), and 2017. [9], [10] noted that the speed of the Palu Koro fault was 20-40 mm/year with an estimated repetition of large earthquakes potentially occurring around 130 years with a strength above 7.0. The case of the 28 September 2018 earthquake for 25 minutes after the Mw7.4 earthquake occurred, followed by an earthquake at 18.14 WITA (Mw5.8) in the northern part of Mw7.4, a Mw5.8 earthquake at 18.16 WITA in the eastern part of Palu, and at 18.25 WITA (MW 5 , 7) the southeastern part of Palu caused the liquefaction of residents' houses in Balaroa to get worse, increasingly shifting and sinking with the process of moving up and down and leveling off. In Figure 2 and Figure 4, the colored circle marks indicate the position of the epicenter of the earthquake, and the asterisk in Figure 3 represents an earthquake scenario.

According to Supendi [11] based on the results of the relocation of the Mw7.4 aftershock, the earthquake was predominantly in the east of the Palu Koro fault plane with a depth of less than 20 km with a fault length of about 200 km in a northwest-southeast direction and a width of about 50 km. [12], it is likely that the Moho layer immediately beneath the Palu Koro fault plane is at a depth of over 25 km. The earthquake resulted in a combination of changes in soil and seabed deformation accompanied by avalanches that triggered a tsunami, massive liquefaction in Balaroa, Petobo, Sibalaya, Jono Oge with 4,340 fatalities including missing, 175,000 people displaced, and 68,451. Damaged houses with an estimated total loss of Rp. 2.9 trillion and the impact of damage reached Rp. 15.6 T by BNPB (2019). [13] The slip rate of the Palu Koro Fault is predicted to reach 35+8 mm/year and based on GPS measurements it is 32-45 mm/year which is a relatively fast-moving fault with a relatively low level of seismicity.

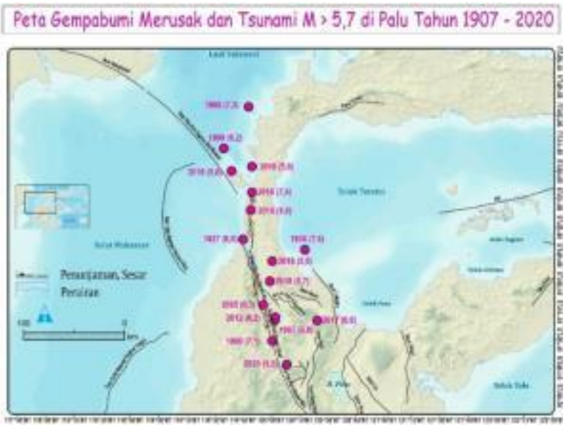
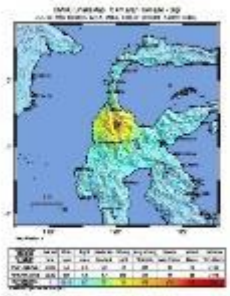
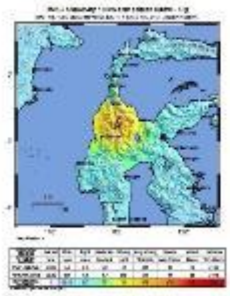


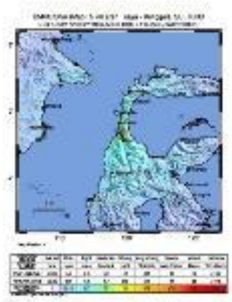
Figure 2. Map of the damaging earthquakes and tsunamis in Palu for the period from 1907 to 2020



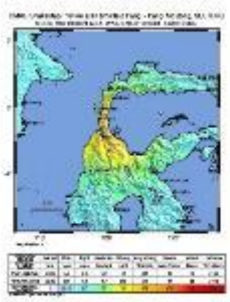
30071907
Sigi VI-VII MMI, Palu V-VI MMI



18031909-065310 + 8 UTC
Kulawi VII MMI, Palu V-VI MMI



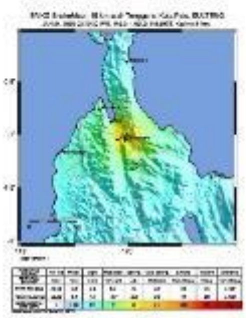
01121927-123727 + 8 UTC
Palu VII MMI (Tsunami, Magnitude of Tsunami Iada 3,9 with run up 15 m, liquefaction occurs)



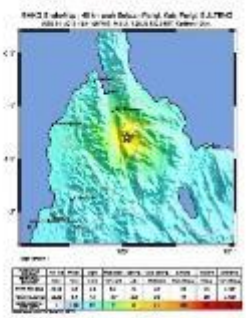
20051938-010821+ 8 UTC
Parigi VIII MMI, Palu VI MMI (Parigi 942 houses collapsed, 184 were damaged, one school building collapsed. Tsunami in Parigi)

15081968-061420+ 8 UTC
A tsunami that reached a height of 10 m and a creep of 100-300 m in Mapaga, Tambu. Resulting in 200 people died, 40 people missing, 58 injured, 800 houses damaged, the tsunami also damaged coconut plantations along the Kambayan coast

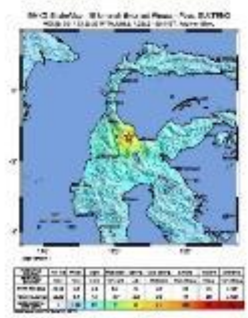
21051998-133426+ 8 UTC
Donggala IV-V MMI, Palu IV-V MMI, Poso and Toli-Toli III-IV MMI



21012005-041012+ 8 UTC (FM: 321, 61, -59) Palu V MMI, Parigi III MMI

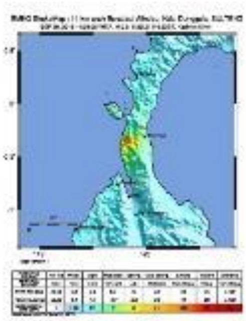


18082012-174151 + 8 UTC (FM:340, 69, -2) Lindu VI-VII MMI, Kulawi VI MMI, Palu IV-V MMI, Parigi IV MMI

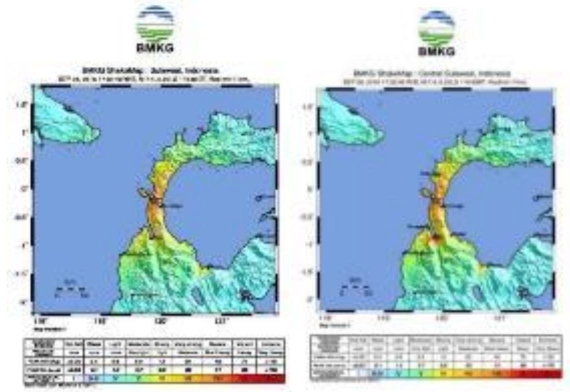


29052017-223522+ 8 UTC
Torue dan Poso V MMI; Palu dan Sigi III-IV MMI; Toli-Toli, Pasang Kayu and Tana Toraja III MMI; Palapo, Masamba, Balikpapan, Gorontalo, Bone Bolango and Soroako II-III MMI

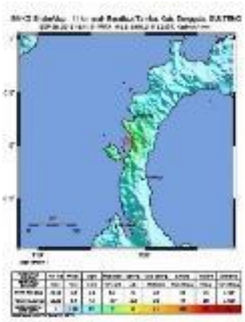
Figure 3 continued…..



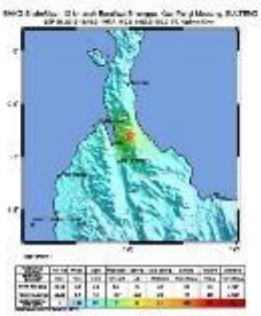
28092018-145956+ 8 UTC
Donggala IV MMI, Palu III MMI, Poso II-III MMI



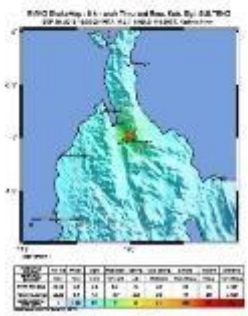
28092018-180243+ 8 UTC (FM: 350, 67, -17)
Donggala dan Palu VIII-IX MMI, Sigi VII-VIII MMI, Parigi, V-VII MMI, Poso V MMI, Morowali, Kendari, Kolaka, Toraja, Palopo, Makassar II-III MMI Tsunami and massive liquefaction 4 locations (right, corrective)



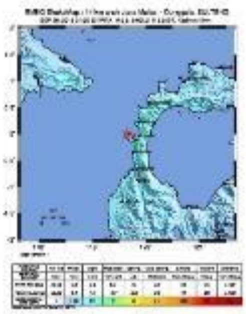
28092018-181421+ 8 UTC
Donggala and Palu V MMI



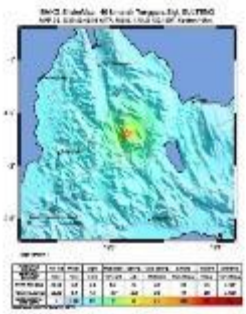
28092018-181651+ 8 UTC
Palu IV MMI, Sigi and Donggala III-IV MMI



28092018-182505+ 8 UTC



28092018-213532+ 8 UTC
Palu, Sigi and Donggala III-IV MMI



28032020-234317+ 8 UTC
Poso, Pasang Kayu IV MMI, Sigi, Sausu, Palopo, Masamba, Mamuju, Topoyo, Kalukku, Luwu Utara, Sanggata Kutai Timur III MMI

Figure 3. Damage and tsunami shakemap maps in Palu for the period from 1907 to 2020

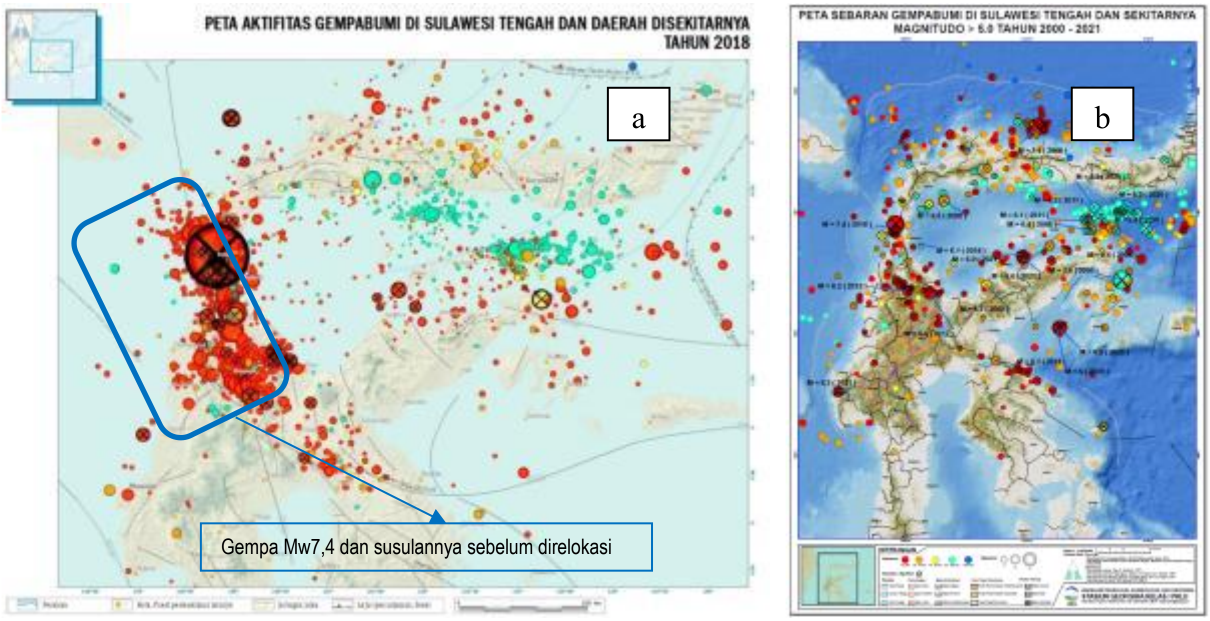


Figure 4. (a) Earthquake distribution map in Central Sulawesi and its surroundings in 2018 and (b) with a strength above 5.0 for the period 2000 to 2021

This Mw7.4 earthquake not only broke off in the north with a left-hand shear pattern, but there was a trend in the northwest segment off the coast with a maximum slip of up to 6.3 meters in a downward pattern which triggered a tsunami in Palu Bay (Figure 5). The Mw7.4 earthquake tsunami wave reached 10 meters in Palu Bay, Tondo and the farthest inudation reached 460 meters with the intensity range of the earthquake shock level reaching the VI-IX MMI range in Palu City, Sigi and Donggala [14]. A map of the results of tsunami measurements can be seen in Figure 5. Liu emphasized that the findings of the large number of landslides on the coastal cliffs triggered the tsunami in Palu Bay [15]. Based on the measurements of the magnitude and configuration of the avalanches along with the characteristics of the generated tsunami waves, the effect of the meeting of the many tsunami waves from several avalanche sources resulted in a wave resonance process that strengthened or amplified each other to the south of Palu Bay. However, it is possible that the combination of the deformation effect of seafloor fractures and several avalanches during the earthquake triggered the tsunami in Palu Bay. According to Hermann Fritz's presentation in an initial meeting with the writing team at the Palu Geophysics Station Office before the tsunami survey was carried out by their survey team in November 2018: "The characteristic of a tsunami due to an avalanche from one source is that it is sudden (the time duration is very fast) with the wave amplitude spilling over short period in the coastal area, it is not yet clear for the combination of landslides". Udrekh Al Hanif to the BBC (2018), the results of a comparison of bathymetry data / depth of the seabed before and after the tsunami occurred, it can be seen that almost all parts of the seabed in the bay have fallen. In addition, movement to the north can be monitored. So that there are vertical and horizontal shifts when the earthquake occurs, with data evidence of several underwater landslides. Finn told the BBC (2018), the chances of this happening are very uncommon, but tectonics has told us that this could happen again in the future. Tracing the team of authors, the tsunami pattern is similar to the 1998 Aitape – Papua New Guenea Tsunami, Ransiki, Papua – Indonesia 2002, and this is clearly seen in the occurrence of the collapse of limestone cliffs on the east side of Yapen Island when the 2010 Yapen earthquake shook which triggered the water to rise by about 50 cm on the coast, and the same possibility if associated with an earthquake that triggered an avalanche and then generated a tsunami in Donggala 1927, Parigi - Tomini Bay 1938, West Coast - Tompe 1968 and Tonggolobibi - Toli-Toli 1996. Based on the results of research [9], the level shaking in the city of Palu can reach 0.8-0.9 g or with an intensity of IX-X MMI at peak acceleration in bedrock for a 2% probability of exceeding in 50 years and according to the results of the microzonation survey of earthquake vulnerability index maps in Palu City carried out by Stageof Palu before September 28 2018 [16] reached a value of 0.5 g or as large as VII-IX MMI. The research results for the acceleration of the response spectrum of 0.2 seconds and 1 second with a 5% immersion ratio in bedrock for a 2% exceedance probability in 50 years are 1.2 g and 0.9 g [9].

According to Pakpahan [17], in a study of the M6.2 earthquake (2012), it gives an illustration that the layers of hard and rigid rock below the surface are in the range of 7 km and deeper. Hendra *et al* [5] found the character of the type of rock layers that make up the soil on the surface with a depth of up to 30 meters has a Vs30 value range between 260 – 330 ms-1 which means it is composed of alluvial medium layers of soil and the Palu BPBD ranges from 250 – 440 ms-1 which means variation Palu City's surface soil layer consists of dominantly medium to hard soil (Type Class D) [16]. The impact is that there will be an amplification process of strengthening the force of earthquake shocks against earthquake loads on the surface, especially for bridge infrastructure, house buildings, shops or offices and in the future, it must be built according to building code standards that are safe, adaptive and earthquake-friendly. This amplification factor will be different in every corner of Palu City.

Figure 5. Map of tsunami measurement results [27]

Based on the Strong Motion Accelerometer data installed in the Earthquake Equipment Bunker of the BMKG Palu Geophysics Station, which is 80 km from the epicenter of the Mw7.4 earthquake, a value of 0.34 g or around VII-VIII MMI was obtained [18]. Based on empirical calculations using the ground-motion equation [19] [20] as follows:

$$\ln y = C1 + C2M + C3\ln[R+C4\exp(C5M)] + C6H + C7(Vs,30/1130) \quad (1)$$

where y is in g units and the coefficient value is C1 = -5.60, C2 = 1.63, C3 = -1.70, C4 = 0.51552, C5 = 0.63255, C6 = 0.0075, C7 = -0.27 and σ = 0.61, then the overall earthquake estimates in Palu it reached 0.41 g or the equivalent of VIII MMI. This Mw7.4 earthquake is also known as the Palu Koro supershear earthquake with a rupture speed or magnitude of earthquake slip of around 4.1 kms-1, faster than the shear waves that occur [21]. Fang *et al* [22] estimated a total seismic moment of 2.64 x 1020 Nm in less than 40 seconds after the earthquake energy was released which could trigger potential liquefaction on the surface. The Governor of Central Sulawesi is a provincial level disaster, known as the Central Sulawesi Earthquake and Tsunami Disaster of 28 September 2018 [23]. [24] found an offset surface rupture point of 5.1 meters with a direction of 348o on Jalan Padanjakaya - Palu. TSM-BMKG [25] found a lot of damage to road infrastructure, bridges and houses with an MMI VII-IX range. Sulistyawa [4] found a horizontal offset of 4.3 m on Jalan Cemara, 5.1 m in Tolambu and others and not including vertical land subsidence which could reach 5 meters in Balaroa due to liquefaction. Socquet *et al* [26] stated that the fault is active approximately 180 km from north to south, a clear fracture is visible about 30 km south of Palu in a linear manner with slip on the surface ranging from 4 to 7 meters with inferring supershear velocities (Figure 6).

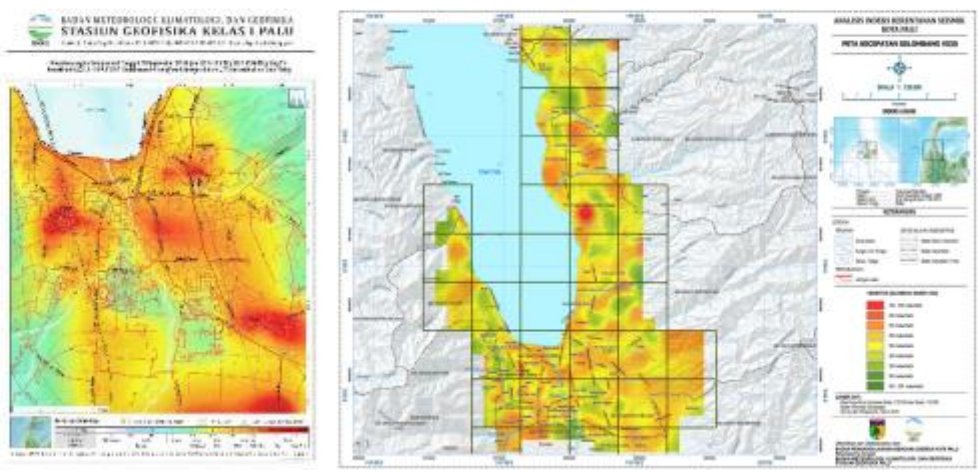


Figure 6. Macroseismic survey map of the level of damage to the Mw7.4 earthquake on September 28 2018 in Palu City [18] and the VS30 wave velocity map in Palu City [16]

This Mw 7.4 earthquake was preceded by 26 preliminary earthquakes with the largest magnitude Mw6.0 at 14:59:56 WITA and it turned out that the previous week there were two M4.8 scale earthquakes that occurred on September 21 and 22 2018. Figure 7 shows aftershocks where the earthquake decay was declared to have ended on November 5 2018 by the Head of the Palu Geophysics Station based on a Statement Letter Regarding Post-Earthquake Normal Conditions to the Head of the Palu BPBD with letter number UM.001/276/PLU/XI/2018 because conditions were already conducive. Based on the classification [29], the Mw7.4 earthquake is type 2 with a series of earthquakes that occur, namely the preliminary earthquake, main earthquake and aftershocks. The Mw7.4 preliminary earthquake that occurred at 14.59 WITA (Mw6.0) is in the strong category and is the same as the earthquake that occurred on Yapen Island in 2010.

Based on earthquake data for 2008-2018, a b-value range of 0.55-0.961 was obtained and an a value of 3.63-5.42 [30]. The highest b value occurred in 2015 of 0.961 with an indication of a fluctuating increase in seismic activity in the Palu area. After Mw 7.4, the b-value decreased significantly to 0.685. In 2015 it was identified that if the rocks in the Palu area experienced a period where the fragility of the rocks was very high with low stress resistance, this would have an impact on the chances of the rocks becoming brittle or break easily and impact on the elastic limit of the rocks being exceeded when a strong earthquake occurs. The resistance of rocks along the Palu Koro fault plane to stress increased from 2015 to 2018. The seismic index value for the Palu area is 0.040789 with a repetition of M 7 earthquakes is 25 years. Areas that have a large seismic index with a low return period indicate that the area is an area that is prone to earthquakes or has a high earthquake risk. It is possible to predict the values of a and b for the Palu region in the future, it is necessary to have a data series of earthquake parameters in the same range with a duration from 2019 to n-years (eg 10 years ahead, 2028) so that the values of a and b can be seen whether the fluctuations are decreasing, constant with insignificant change in value and/or increase.

Figure 7. Graph of aftershocks [28]

3. EARTHQUAKE CONTINGENCIES

A contingency is a condition that is expected to occur, but may not occur. Because there is an element of uncertainty, a plan is needed to reduce the impact that may occur. contingency planning is the process of planning ahead, in uncertain circumstances, in which scenarios and objectives are agreed upon, managerial and technical actions are determined, and systems for responding to incidents are devised in order to prevent, or better cope with the emergency situation or situation at hand [31]

4. RESEARCH METHODS

a. Literature Study and Data Collection

The data used in this study is earthquake scenario data which is predicted to occur in the worst scenario if a damaging earthquake hits Palu, based on reference [9], the maximum magnitude on the Palu Koro Fault Makassar Strait Segment M7.1, Palu M6.8 and Saluki M6, 9. As for the earthquake epicenter scenario, there are 3 earthquake parameter scenarios (Figure 8), namely:

b. Data processing

Then the author inputs these parameters into the BMKG Shakemap application to obtain a "Shakemap" shock level impact map (Figure 9). For a comparison model with scenario earthquake parameters, ground-motion empirical equations are used according to [19] in equation (1). According to [32] the equation for calculating the PGA value in units of g is as follows:

$$\ln PGA = -0,152 + 0,859M - 1,0803Ln(R+25) \quad (2)$$

5. RESULTS AND DISCUSSION

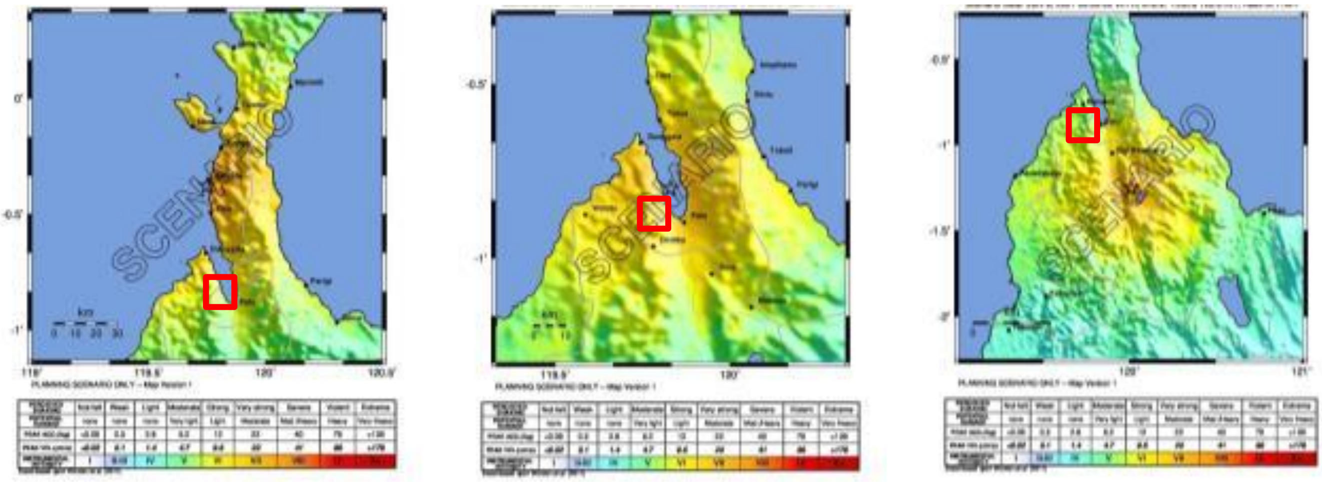
After inputting and processing the BMKG Shakemap application, the results are in the form of a map of the level of earthquake shocks (see Figure 9). Based on the results of the earthquake scenario shakemap map in the red box, for the Mw7.1 earthquake scenario the impact of the shock level in Palu is V-VII MMI. Meanwhile, Mw 6.8 is VI-VIII MMI and Mw6.9 is V-VII MMI.

The data in Table 2 for the PGA value unit is g Unit. In general, for the case of the Mw7.1 and Mw6.9 earthquake scenarios, an estimate of the intensity level of earthquake shocks in Palu is obtained with Wang's equation of VI MMI and for Mw6.8 of VII MMI. Based on the Cornell equation, the results of the predictions are around VIII MMI for Mw6.8, and VI-VII MMI for Mw6.9 and Mw7.1 respectively. These impacts are in the form of moderate-severe damage to buildings with solid construction, shifting of foundations, opportunities for fractures on the ground surface, landslides to liquefaction and opportunities for landslides on land and on the seabed, which can trigger a tsunami in Palu Bay.

Table 1. Earthquake parameter scenario data on the Palu Koro fault

Time	Coordinate	Depth (km)	Mw	Location
X	$0,38^0$ LS – $119,75^0$ BT	11	7,1	on land, 3 km southwest of Alindau - Donggala
X	$0,80^0$ LS – $119,83^0$ BT	11	6,8	at sea, 12 km north of Palu
X	$1,25^0$ LS – $120,01^0$ BT	11	6,9	on land, 7 km east of Pakuli - Sigi

Figure 8. Earthquake scenario map in Palu



Scenario Mw7,1 Scenario Mw6,8 Scenario Mw6,9

Figure 9. Shakemap map of earthquake shaking impact scenarios in Palu on the MMI scale with an earthquake depth of 11 km

The data in Table 2 for the PGA value unit is g Unit. In general, for the case of the Mw7.1 and Mw6.9 earthquake scenarios, an estimate of the intensity level of earthquake shocks in Palu is obtained with Wang's equation of VI MMI and for Mw6.8 of VII MMI. Based on the Cornell equation, the results of the predictions are around VIII MMI for Mw6.8, and VI-VII MMI for Mw6.9 and Mw7.1 respectively. These impacts are in the form of moderate-severe damage to buildings with solid construction, shifting of foundations, opportunities for fractures on the ground surface, landslides to liquefaction and opportunities for landslides on land and on the seabed which can trigger a tsunami in Palu Bay.

Local footprint effects on each region due to earthquakes are an important concern in infrastructure development in an area. In addition, it is important to have prevention and mitigation efforts, adaptation to life and increasing community capacity in dealing with earthquakes. Thus, the principle of benefit of having an earthquake contingency plan document must be in Palu, and evaluation and periodic updating are carried out. Cross-sectoral cooperation and coordination is enhanced. Be participatory and fulfill mutually agreed upon commitments. Build an early warning chain. On the other hand, based on the Law of the Republic of Indonesia No. 31 of 2009, BMKG works 7 x 24 hours, a positive response to BMKG information regarding Earthquake Early Information is also very necessary, in order to reduce public panic and prevent hoax news.

Table 2. Data on the estimated shock level for the earthquake scenario at a depth of 11 km based on the results of calculations using equation (1) for each sub-district in Palu City

No	Village	Latitude	Longitude	Mw6,8			Mw6,9			Mw7,1		
				Location	PGA value	MMI	Location	PGA value	MMI	Location	PGA value	MMI
1	Baiya	-0.723	119.860	9 km south	0.284	VII	61 km to the south	0.107	VI	40 km north	0.190	VI
2	Balaroa	-0.907	119.849	12 km to the north	0.267	VII	42 km southeast	0.150	VI	59 km to the north	0.142	VI
3	Baru	-0.893	119.856	11 km to the north	0.282	VII	43 km southeast	0.150	VI	57 km to the north	0.147	VI
4	Besusu Barat	-0.890	119.866	11 km to the north	0.276	VII	43 km to the south	0.147	VI	57 km to the north	0.148	VI
5	Besusu Tengah	-0.891	119.872	11 km to the northwest	0.273	VII	43 km to the south	0.148	VI	56 km to the north	0.149	VI
6	Besusu Timur	-0.896	119.878	12 km to the northwest	0.272	VII	42 km to the south	0.153	VI	59 km to the north	0.145	VI
7	Birobuli Selatan	-0.928	119.890	16 km to the northwest	0.244	VII	38 km to the south	0.161	VI	62 km north	0.136	VI
8	Birobuli Utara	-0.922	119.898	15 km to the northwest	0.252	VII	39 km to the south	0.165	VI	64 km to the north	0.132	VI
9	Boyaoge	-0.913	119.856	13 km north	0.269	VII	41 km southeast	0.157	VI	60 km north	0.139	VI
10	Buluri	-0.853	119.825	6 km north	0.303	VII	49 km southeast	0.133	VI	53 km to the north	0.156	VI
11	Donggala Kodi	-0.899	119.849	11 km to the north	0.272	VII	43 km southeast	0.148	VI	58 km to the north	0.144	VI
12	Duyu	-0.914	119.843	13 km north	0.270	VII	42 km southeast	0.155	VI	59 km to the north	0.139	VI
13	Kabonena	-0.893	119.836	10 km north	0.279	VII	44 km southeast	0.145	VI	57 km to the north	0.143	VI
14	Kamonji	-0.903	119.853	12 km to the north	0.272	VII	42 km southeast	0.151	VI	59 km to the north	0.144	VI
15	Kawatuna	-0.902	119.916	15 km to the northwest	0.253	VII	40 km south	0.158	VI	58 km to the north	0.145	VI
16	Kayumalue Ngapa	-0.752	119.868	7 km southwest	0.298	VII	58 km to the south	0.113	VI	47 km to the north	0.173	VI
17	Kayumalue Pajeko	-0.768	119.865	5 km southwest	0.315	VII	56 km to the south	0.120	VI	48 km to the north	0.166	VI
18	Lambara	-0.731	119.866	9 km southwest	0.290	VII	60 km south	0.110	VI	37 km to the north	0.205	VI
19	Lasoani	-0.903	119.898	14 km to the northwest	0.258	VII	41 km south	0.155	VI	61 km to the north	0.140	VI
20	Layana Indah	-0.809	119.903	8 km to the west	0.287	VII	50 km south	0.127	VI	47 km to the north	0.174	VI
21	Lere	-0.889	119.853	10 km north	0.285	VII	44 km southeast	0.149	VI	58 km to the north	0.146	VI
22	Lolu Selatan	-0.904	119.879	13 km to the northwest	0.269	VII	41 km south	0.156	VI	58 km to the north	0.144	VI
23	Lolu Utara	-0.903	119.872	12 km to the north	0.274	VII	42 km to the south	0.156	VI	59 km to the north	0.140	VI
24	Mamboro Barat	-0.790	119.873	5 km west	0.313	VII	53 km to the south	0.124	VI	45 km north	0.182	VI
25	Mamboro	-0.794	119.877	5 km west	0.308	VII	53 km to the south	0.124	VI	47 km to the north	0.173	VI
26	Nunu	-0.907	119.863	12 km to the north	0.272	VII	42 km southeast	0.156	VI	59 km to the north	0.142	VI
27	Palupi	-0.929	119.853	15 km north	0.256	VII	40 km southeast	0.160	VI	62 km north	0.133	VI
28	Panau	-0.731	119.856	8 km south	0.293	VII	60 km south	0.110	VI	41 km to the north	0.192	VI
29	Pantoloan Boya	-0.690	119.868	13 km south	0.269	VII	64 km to the south	0.104	VI	50 km north	0.162	VI
30	Pantoloan	-0.702	119.854	11 km south	0.274	VII	63 km to the south	0.104	VI	39 km to the north	0.198	VI
31	Pengawu	-0.920	119.853	14 km to the north	0.265	VII	41 km southeast	0.159	VI	61 km to the north	0.138	VI
32	Petobo	-0.936	119.900	17 km to the northwest	0.241	VII	37 km to the south	0.169	VI	61 km to the north	0.139	VI
33	Poboya	-0.888	119.897	12 km to the northwest	0.271	VII	42 km to the south	0.153	VI	60 km north	0.141	VI
34	Silae	-0.886	119.842	10 km north	0.288	VII	44 km southeast	0.147	VI	41 km to the north	0.187	VI
35	Siranindi	-0.904	119.859	12 km to the north	0.270	VII	42 km southeast	0.151	VI	60 km north	0.143	VI

Table 2 continued…

No	Village	Latitude	Longitude	Mw6,8			Mw6,9			Mw7,1		
				Location	PGA value	MMI	Location	PGA value	MMI	Location	PGA value	MMI
36	Taipa	-0.775	119.867	5 km southwest	0.315	VII	55 km south	0.121	VI	48 km to the north	0.168	VI
37	Talise	-0.884	119.878	11 km to the northwest	0.274	VII	43 km to the south	0.146	VI	57 km to the north	0.145	VI
38	Talise Valangguni	-0.883	119.885	11 km to the northwest	0.275	VII	43 km to the south	0.148	VI	58 km to the north	0.143	VI
39	Tanamodindi	-0.891	119.891	12 km to the northwest	0.272	VII	42 km to the south	0.153	VI	59 km to the north	0.143	VI
40	Tatura Selatan	-0.916	119.872	14 km to the north	0.257	VII	40 km south	0.155	VI	61 km to the north	0.137	VI
41	Tatura Utara	-0.910	119.885	14 km to the northwest	0.257	VII	40 km south	0.155	VI	64 km to the north	0.143	VI
42	Tawanjuka	-0.921	119.866	14 km to the north	0.260	VII	40 km southeast	0.160	VI	62 km north	0.136	VI
43	Tipo	-0.860	119.822	7 km to the north	0.296	VII	48 km to the southeast	0.133	VI	55 km north	0.151	VI
44	Tondo	-0.831	119.899	8 km to the northwest	0.292	VII	48 km to the south	0.135	VI	47 km to the north	0.171	VI
45	Ujuna	-0.900	119.863	12 km to the north	0.277	VII	42 km southeast	0.154	VI	58 km to the north	0.145	VI
46	Watusampu	-0.816	119.810	3 km northeast	0.312	VII	53 km to the southeast	0.121	VI	62 km north	0.135	VI

Based on the historical facts of the earthquake that hit Palu and the possible forecast of the worst earthquake scenario in this paper, efforts to increase community capacity from a cultural point of view and the role of active non-discriminatory participation by the Palu government from a structural perspective must be built from now on, accompanied by adaptation and mitigation lifestyles. society as a whole in accordance with existing local wisdom. The term "Earthquakes don't kill people, buildings do it" has a fundamental meaning, that going forward, the people of Palu must construct buildings according to building codes that are safe and earthquake-friendly. The costs incurred may be greater, but the family remains safe. On the other hand, the construction of new productive land clearing must refer to the maximum ground acceleration value in bedrock and the spectrum design at 0.2 and 1 second and be aware of areas affected by damage in 2018 such as along the Palu Koro fault field, which was affected by massive liquefaction. and tsunamis.

Another strategy is the existence of clear and firm and non-discriminatory rules regarding zones that cannot be built, establishing evacuation routes, temporary/final gathering points and signs throughout the city of Palu. Equally important is the independent development of Tsunami sirens and a comprehensive early warning system in accordance with the local wisdom of the people of Palu accompanied by an unsaturated and tiring process of outreach education and field simulations of earthquakes and tsunamis to the entire community in an open manner. It needs to be realized, all people have the same rights and obligations in terms of earthquake mitigation and the best learning is the 2018 earthquake case and the handling of COVID-19. Tell the next generation so they are ready to face the chance of a strong Palu Koro earthquake.

6. CONCLUSION

The conclusions obtained from earthquake source modeling based on history and the scenarios that have been carried out are as follows:

a) In general, Palu City is an area that has a high risk of earthquakes. The earthquake was caused by the activity of the Palu Koro Fault which consists of 4 segments with a left fault pattern that obliquely descends on its north side in the Makassar Strait segment.

b) Based on depth, the earthquake in the Palu Koro fault area is a shallow earthquake which generally occurs between 4 and 25 km with the largest history of earthquakes being Mw7.4 on September 28 2018. This Mw7.4 earthquake pattern is included in the Mogi 2 category which has earthquakes introduction/startup, mainshock and aftershock with active duration towards normal reaching about 32 days after the mainshock occurred.

c) The impact of the earthquake shaking, the case study of the Mw7.4 Central Sulawesi Damaging Earthquake (2018) reached VII-IX MMI in Palu. In addition to damage to physical infrastructures such as roads, bridges, buildings with floors above 3 floors and housing, it will also have an impact on environmental conditions such as cracks on the surface along the fault plane as surface rupture which has a certain offset value as well as the occurrence of a ground-failure process (power failure). soil support maintains its initial condition so that it experiences deformation).

d) Another primary impact is the probability of a tsunami occurring along Palu Bay with different heights and creep induction of the tsunami on each coast. This tsunami opportunity comes from the seeds of potential landslides on the coastal cliffs with an estimated arrival time of the tsunami between 4-8 minutes from the triggering source. In addition, liquefaction events can occur, especially in the Palu valley area due to the thickness of the sediment layer and the large volume of subsurface water which is very shallow at depths of 4-20 m from the surface.

e) The probability of shaking in Palu City based on the worst scenario is the Mw6.8 earthquake scenario of VII MMI for Wang's equation (2016). Based on shakemap maps ranging from VI-VIII MMI and VIII MMI for the Cornel equation (1968).

f) The risk of earthquakes, tsunamis and liquefaction can be reduced by efforts to increase community capacity from a cultural point of view and the role of active non-discriminatory participation by the local government from a structural perspective, accompanied by a lifestyle of adaptation and mitigation of society as a whole in accordance with existing local wisdom.

7. RECOMMENDATION

The suggestions that can be submitted are as follows:
a) It is recommended that the construction of buildings and infrastructure in Palu use safe/earthquake resistant building codes.
b) There is a need for outreach and field simulations of earthquakes and tsunamis to the people in Palu, as an effort to mitigate earthquakes that is carried out comprehensively and repeatedly.

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