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EVALUATION OF TSUNAMI EVACUATION PLANS IN PADANG, INDONESIA

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ABSTRACT

This paper presents an evaluation of the of Padang's tsunami evacuation plans. The plans consist of horizontal evacuation to tsunami free zones and vertical evacuation to the nearest shelter. Three possible epicenters are simulated to estimate the most dangerous earthquake with tsunami scenario. Base on the speed of tsunami wave and the time required to prepare evacuation, an effective evacuation time was estimated. The average walking speed of people in evacuation plan was used to estimate the coverage area of shelters and to draw a line describing the farthest point where people could reach the safety zone within the effective evacuation time. By drawing the areas where people in the areas are possible to reach the safety zone on a map, blank area where people in the area could not be safe without adding more shelters or change evacuation plan was identified.

Keywords: Tsunami, Shelter, Padang, Evacuation, Coverage Area

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1. INTRODUCTION

People in Padang are threatened by the most anticipating earthquake and tsunami which was predicted by many scholars (Rino, et al., 2012). Many world largest earthquake have been hit the city. For example, the M 9.1 earthquake near Aceh on December 26, 2004; the M 8.6 earthquake near Nias Island on March 28, 2005; and the M 8.5 and M 7.9 earthquake near Mentawai Island on September 12, 2007 (Rino, et al., 2012; Yosritzal, et al., 2016).

Learning from the 2004 Aceh's earthquake which followed by a tsunami shortly after the initial shock, some preparations have been made by authorities such as setting evacuation scenarios either horizontally or vertically. Some temporary evacuation sites or shelters have been assigned which includes new shelter buildings and some structurally reinforced of existing buildings. Nevertheless, less attention has been made in evaluating the capacity and adequacy of the shelters (Yosritzal et al., 2016).

Yosritzal et al. (2016) attempted to draw the coverage area of each shelters as circles and estimate the adequacy of the shelter servicing population within the area. However, it is arguable that the estimate contains bias as it assumes that the coverage area is a circle. In fact, it is unreasonable to ask people who were already far away from the coast to evacuate to a shelter which located more nearer to the coast. Therefore, this paper is based on Yosritzal et al. (2016) with some updates on the estimation of the coverage area of shelters by changing the area from circle to a more realistic form.

This paper aims to investigate the coverage areas of tsunami evacuation plans based on the effective available evacuation time (EAET) and spot uncovered area to allow the authorities to make further plan to safe them.

2. LITERATURE REVIEW

Tsunami is a series of ocean waves occur after an impulsive disturbance of the under water ground vertically (Pond and Pickard, 1983) or horizontally (Tanioka and Satake, 1995). The tsunami sends surges of water onto land as a result of a tectonic earthquake, volcanic eruption, and underwater landslide (Ward, 1982). However, in Indonesia, earthquake is the most often causal (Puspito and Triyoso, 1994). Characteristics of tsunami are: length of wave is about 100-200 km or more, within 10-60 minutes' periods, and the speed of the wave is depending on the depth of water.

In December 26, 2004, one of the deadliest natural disasters in history occurs in Indonesia. Preceded by a magnitude 9.1 earthquake, the tsunami killed 227,898 people in 14 countries around the Indian Ocean with about 78% of them in Indonesia (Folger, 2014). Folger (2014) noted that it is not the worst of it. The worst ones is that scientists believe within the next few decades, a large tsunami will strike the Indian Ocean again. The question is will Indonesia be ready?

As part of the preparation, Indonesian government establish National Board for Disaster Management (Badan Nasional Penanggulangan Bencana - BNPB) with many province and district branches. BNPB (2012) outlined strategies in mitigation and resilience of tsunami with some programmes such as: to build tsunami early warning system, to build shelters in residential areas, sea wall, planting mangrove along the beach to reduce tsunami forces, to improve community knowledge especially those who live at the coastal region on tsunami and how to survive tsunami and to report as soon as possible the sign of tsunami to authorised officers.

Government has also enacted a regulation about disaster mitigation namely PP No. 64 Tahun 2010, where mitigation is defined as all effort attempted to reduce the risk of disaster, either physically or non-physically. Physical preparations include activities in reinforced older structures or build a new structure that can be used as a shelter whilst non-physical preparations are an improvement in capacity of the buildings to deal with disasters in the coastal areas and small islands.

3. METHODOLOGY

Data for this study is taken from Yosritzal et al. (2016) such as the scenarios of earthquake, walking speed and EAET which will be explained further in next section. Similar to Yosritzal et al. (2016) this study used Google Earth application in estimating and drawing the coverage areas of each evacuation strategy. Different from

Yosritzal et al. (2016), the coverage area of the shelters in this paper was estimated by considering the natural hazard such as building, street, valley and river. Furthermore, in this paper, it is assumed that people will not be evacuated to a shelter if the position of the shelter is nearer to the coast, but one third of the farthest distance that can be follow within the EAET.

4. RESULTS AND DISCUSSION

4.1 Estimation of the Available Evacuation Time

The available evacuation time used in this study is based on the finding of Yosritzal et al. (2016). Yosritzal et al. (2016) simulated three scenarios of the epicenter of the earthquake and then estimated the propagation time of the tsunami wave to the land as shown in Figure 1. The location of each epicenter was chosen because big earthquake occurred at the location years ago. The selected epicenters are located at megathrust area, i.e. an area where some reverse or thrust faults exist. In this area, there are some locations with high potential of very shallow earthquake centers to happen, which could lead to further impacts of tsunamis. The west area of the Mentawai islands is the highest probability to trigger a major earthquake followed by tsunami (Putra, 2011). This has been proven by the report that the major earthquakes in 1797, 1833, and the last one in 25th October 2010 (Gunawan BMKG, 2011) were occurred in this area.

The propagation time was estimated based on the ocean depth shown in the Google Earth Application and acceleration due to gravity. It was found that the shortest propagation time has been the epicenter 3 which was located under the sea between Siberut and Sipora Island. The distance from the epicenter to the land was 213 km and the average speed of the wave is 344,5 km/hour and the wave propagation time was 37 minutes. With assumption that authorities spent 5 minutes for deciding whether tsunami most likely to happen (BKMG, 2015), 3 minutes for spreading the information and 10-12 minutes for the people to prepare everything before starting to evacuate, the effective evacuation time would be 17.1 minutes.

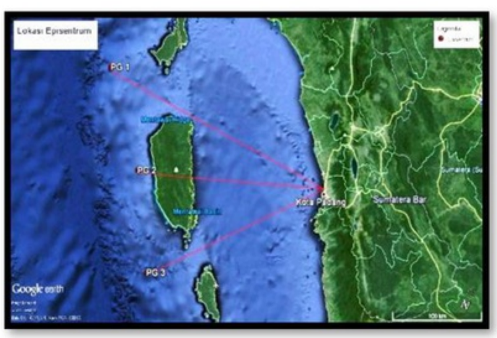

Figure 1. Epicenter Scenarios (Yosritzal, et al., 2016)

4.2 Evacuation Scenarios

There are two types of evacuation scenarios available for Padang namely horizontally and vertically evacuation. Horizontal evacuation is to evacuate people from the lower land to a hilly land higher than the highest land predicted to be reached by the wave. Vertical evacuation is to evacuate people from the lower land to nearest strong with at least 3-storey building or higher than the highest predicted tsunami wave. Scholars predict the highest wave would be 5 m above sea level.

As the effective evacuation time was 17.1 minutes as estimated by Yosritzal et al. (2016), the distance of horizontal evacuation would be the most importance thing to evaluate. The distance is influenced by the walking speed during evacuation. Yosritzal et al. (2016) found that the walking speed is 1.33 m/s whilst Rienne et al. (2010) found 1.3 m/s for adult and 1.5 m/s for children. Therefore, the distance would be in 1.37 km in average.

4.2.1 Horizontal Evacuation

Perhaps horizontal evacuation is cheaper than vertical because the infrastructures have already exist. Therefore, the first scenario is to evacuate all vulnerable people horizontally. First the safety zone border line was drawn and then a line of 1.37 km the effective evacuation distance was plotted from the safety zone border to the beach. The area between the lines is the area where people possible to reach the safety zone within 17.1 minutes' effective evacuation time. Figure 2 shows the area.

As shown in Figure 2, the green shading is the area where people possible to reach the safety zone.

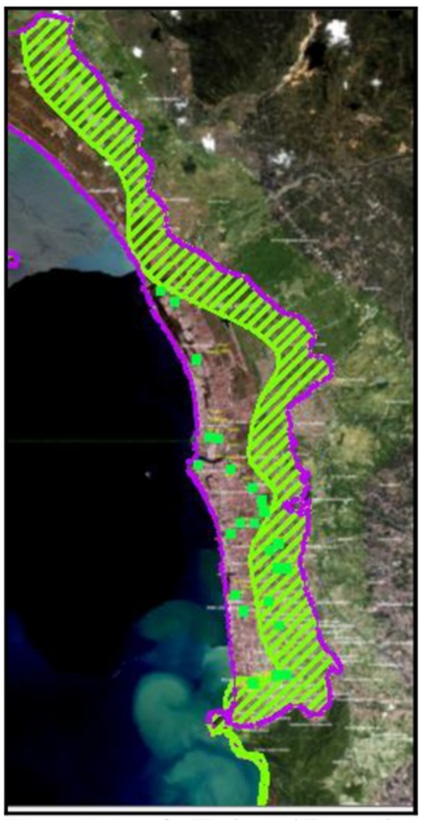

Figure 2. Area for Horizontal Evacuation

Green spots are the location of existing shelters. As shown in the Figure 2, a large part of Padang specifically the nearest place to the seashore is not shaded. Those people would not possible to reach the safety zone within 17.1 minutes and therefore horizontal evacuation alone would not be enough.

4.2.2 Vertical Evacuation

In this scenario, all of the vulnerable people will be evacuate vertically to the nearest shelter. There are 24 shelters set by authorities in Padang as shown in Table 1.

Table 1 Shelters in Padang in 2015 (source: BPBD Prov. Sumbar, 2016)

No.	Name	Capacity
1	Masjid Raya Sumatera Barat	4000
2	Masjid NurulIman	2500
3	Masjid Al Muhajirin	4000
4	Masjid Darussalam	5000
5	Masjid NurulHaq	4000
6	Hotel Grand Zuri	3000
7	Hotel Ina Muara	4000
8	Hotel Mercure	3000
9	Hotel Ibis	3000
10	BPK PerwakilanSumbar	2000
11	KanwilDitjenPerbendaharaan Negara	2000
12	Kantor Gubernur	5000
13	Kantor DinasPrasjaltarkimSumbar	5000
14	Kantor BappedaSumbar	2000
15	Gedung DPRD Sumbar	2000
16	Gedung Bank Indonesia	1000
17	GedungFak. Olah Raga UNP	2000
18	Gedungpascasarjana Univ. Bung Hatta	2000
19	GedungKesenian UNP	2000
20	SMK Negeri 5 Padang	3000
21	TK AL Azhar	3000
22	SMP Negeri 25 Padang	3000
23	SMA Negeri 1 Padang	3000
24	SD Negeri 24 Purus	3000

Based on the 17.1 minutes' effective evacuation time, a shaded area was made around the shelters.

Yosritzal et al. (2016) designed the coverage area as a circle with radius of 1.37 km and the shelter as the center without taking street/natural hazard into account. This approach is reasonable because people should be evacuated within 17.1 minutes time to the nearest possible safety zone (shelter) even though the shelter is closer to the beach than the location of the people at that time. People should not be evacuated to a safety zone away from the beach if the location cannot be reach within 17.1 minutes. However, Yosritzal et al. (2016) yet to take into account natural hazard such as river and valley or man made hazard such as fence and building. Therefore, in this presented study, those hazards are taking into account so that the coverage area would not be a circle but make a shape in response to the the hazard. Furthermore, when the area coincident with each other, the area will be divided between the shelters. The shaded area is the coverage area of the shelter which shows that people in this area should be evacuate to the shelter.

Figure 3 shows the coverage area of the shelter with hazard is taking into account. Similar to the horizontal evacuation, a large part of the seashore area has been covered by the shelters however, yet a lot more areas have not been covered. So, vertical evacuation alone would also not enough to safe people.

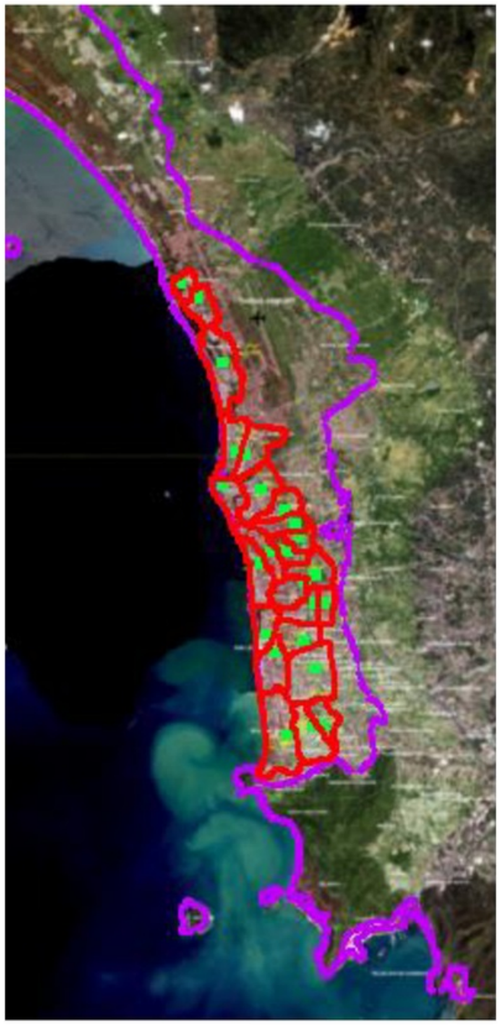

Figure 3. Coverage area of the shelters

4.2.3 Combo Evacuation

Combo evacuation is a combination of horizontal and vertical evacuation. People who are possible to reach the safety zone within 17.1 minutes are recommended to do horizontal evacuation whilst those who are not, are recommended to conduct vertical evacuation to the nearest shelters. With the effective evacuation time in mind, there will be some people who can neither reach the safety zone nor shelters. Authorities should provide more shelters for them. This will be discussed later in another paper.

Figure 4 shows the area coverage by the combo evacuation where people in those area are possible to reach the shelters or safety zone within the effective evacuation time.

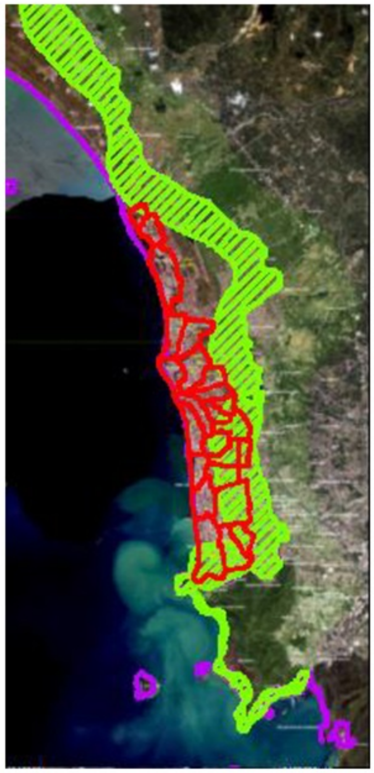

Figure 4. Combo Evacuation

The green shaded area is the area of those who possible to reach the safety zone by horizontal evacuation whilst the area with red boundary is the coverage area of the shelters. There are some shelters coverage area coincides with the horizontal evacuation which means those who are in this area have a choice whether to evacuate horizontally or vertically. However, some areas are not covered by both horizontal and vertical evacuation area. It is recommended for the authorities to prepare an evacuation plan for them.

4. CONCLUSION

Horizontal and vertical evacuation has been simulated in this study. It is found that the horizontal evacuation plan alone would not be enough to evacuate people in the vulnerable areas. Similarly, vertical evacuation to the existing shelters would not be enough as well. There are a lot of areas not covered by the evacuation plan. Therefore, combo evacuation is recommended for Padang. Using combo evacuation, the coverage area much larger than the single evacuation plan.

Even though combo evacuation covers larger areas, some vulnerable areas are still leaving helpless. Therefore, the authorities are recommended to make an evacuation plan for them such as build new shelters or reinforced the existing building and use them as temporary evacuation sites.

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