The Mapping of Temporary Evacuation Site (TES) and Tsunami Evacuation Route in North Pagai Island, Mentawai Islands Regency – Indonesia

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Abstract: Mentawai Islands Regency, especially north Pagai island, suffered two earthquakes on April 15 2016. The local government in cooperation with the relevant parties had tried to minimize casualties before the disaster or during the disaster by making an evacuation route to the TES. The purpose of this study was to the mapping of TES and tsunami evacuation route using the approach of Geographic Information Systems (GIS) for disaster mitigation of tsunami-potential earthquake in north Pagai island. The research was conducted at 3 locations in the coast of Sikakap village, 4 locations in the coast of Taikako village, 3 locations in the coast of Silabu village, 7 locations in the coast of Saumanganya village, and 3 locations in the coast of Matobe village. The effort taken was to evacuate people to the TES with an average distance of 372.62 m from the beach. The results showed that the feasibility of TES that could accommodate residents, among others, were in the hills behind Sikakap Port, Taikako Silaoinan hills, the hills near the Mapinang Silabu village chief’s office and Mapinang hills, Gulukguluk Saumanganya and Panatarat Matobe hills.

Keywords: TES, Evacuation route, Tsunami, SIG, North Pagai Mentawai.

1. Introduction
Indonesia is subscription area of natural disasters. Various regions in Indonesia is a disaster-prone, especially the earthquake disaster, tsunami, flood and volcanic eruptions. Indonesian territory surrounded by Eurasian plate, Indo-Australian plate and Pacific plate. Where at one time these plates will move and cause a earthquake potential tsunami [1], as happened in Aceh in 2004 and the Mentawai islands, in particular north Pagai island, in 2010.

Historically, the waters of western Sumatra have a very high level of seismicity which can be seen from the distribution of earthquake centers in the region with the depth of epicenter deeper eastward. The quakes are generally associated with Sunda subduction system that indicates the relative movement between the Indo-Australian plate and the Eurasian plate. Because the system has been Sunda subduction, earthquakes with magnitude above 7.0 Mw have partially produced a sizeable tsunami and damaging [2].

[3],[4],[5],[6],[7] add based on the data catalogs that major earthquakes which have occurred and caused a tsunami in the waters of western Sumatra among others (Fig. 1) were in 1797 (M~8,4); 1833...
(M~9.0); 1861 (M~8.5); 1935 (7.7 Mw); 2000 (7.9 Mw); 2002 (7.2 Mw) 2004 (Mw 9.15); 2005 (Mw 8.5); 2007 (8.4 Mw) (7.9 Mw); 2008 (7.3 Mw) dan 2010 (7.7 Mw) (7.8 Mw) (7.2 Mw).

The tsunami that hit North Pagai Island on October 25, 2010 with 7.7 Mw magnitudes occurred at coordinates 3.29 south latitude; 100.7 east longitudes with 20.6 km depth had caused more than 449 fatalities, 270 serious injuries and 142 minor injuries, while the refugees numbered 14,983 residents [8]. Furthermore, on April 15 2016, North Pagai Island suffered two earthquakes more i.e at 17:24 pm with the strength of 5.0 Mw located at coordinate 3.58 south latitude; 100.45 east longitude in 52 km depth, and the aftershocks occurred at 17:56 pm with the strength of 4.5 Mw at coordinates 3.74 south latitude; 100.51 east longitude in 10 km depth [9]. The earthquake which occurred was close to the location of the earthquake that triggered the tsunami on October 25, 2010.

Figure 1. Map of the History of earthquakes and tsunamis in the waters of western Sumatra from[3], Konca et al. (2008)[4], Shearer and Burgmann (2010)[5], Hill et al. (2012)[6], and Meltzner et al. (2015)[7].

The tsunami occurred in north Pagai Island, especially in the coastal villages such as the village of Saumanganya, Silabu, Matobe, Betumonga, and Taikako. According to the records of the Agency for Disaster Management (BPBD) of West Sumatra province, there were 282 people killed, 411 people missing and unaccounted, 77 people severely injured, 25 people slightly injured, and more than 100 houses damaged. Victims who evacuated were 150 residents of Sikakap and 150 residents of Silabu. All community activities in north Pagai island are concentrated in the coastal villages[10]. The villages of Saumanganya, Taikako and Sikakap are coastal villages which have the most residents in North Pagai Island having 9767 people in 2015[11].

Because of the tsunami disaster that would harm the society, the society then should be alert and vigilant to face any threat of disaster. However, this attitude must be accompanied by a correct understanding including the understanding of the procedures of how to save themselves because a false understanding would endanger them. One of the ways is with the mitigation of tsunami-potential earthquake disaster in the form of TES and evacuation route before or during the disaster. The community needs the TES and the evacuation route so that if the disaster happens people can go to the TES quickly through the correct route in accordance with the evacuation route to reduce the risk of casualties when tsunami occurs. The purpose of this study was to determine the mapping of TES and
tsunami evacuation route using GIS approach to mitigate tsunami-potential earthquake disaster in north Pagai Island, Mentawai islands.

2. Research Methodology

The research was conducted in the hamlet of Sibaibai, central Sikakap and eastern village of Sikakap; the hamlet of Pasibuat, Muara Taikako, Bulakmonga, and Kaute of Taikako village; West Silabu, Maguiruk and Tumalet of Silabu village; Mapinang, Pinairik, Mabulau Buggei, Patutukat Sibau, and Pasapuat of Saumanganya village; Matobe Tunang, Polaga, Mangaugau of Matobe village (Fig. 2). The research was held in March 2016 (before the April 15 2016 earthquake).

The research method used was mapping survey with GIS approach using network analysis. The step of determining the TES location was by identifying the distribution of residential settlements [12]. The elements of residential settlements distribution was used to determine residential areas which were vulnerable to tsunamis. The next step was verifying the results of map interpretation by conducting field surveys. The result of this verification was used to update the settlement data, while updating the road data was done based on field surveys using the Global Information System (GPS) in accordance with the road network map of north Pagai island. The road network data was needed in the analysis process to determine evacuation routes to the TES. The results of the analysis were in the form of a coverage polygon with location buffer as far as 270 m from the central location of TES.

The method used to determine the distance to TES referred to the Institute of Fire Safety and Disaster Preparedness Japan (IFSDPJ)[13] explains that the evacuation speed is 0.751 m / sec (the speed walk of the elderly). The time spent is <10 min. This study used a 6-minute time spent because it was assumed that was the time citizens needed to go to the nearest TES. The processing time of evacuation was 6 minutes = 6 x 60 seconds = 360 seconds, so the distance of TES was 360 seconds x 0.751 m / sec = 270.36 m = 270 m (Fig. 3). After determining the distance as far as 270 m in 6
minutes, then the network analysis process was carried out using the road network data and the distribution of residential settlements. From the process, the distance to the TES required at each study site could be determined. The result of the coverage analysis as far as 270 m was then overlaid with the distribution of residential settlement data. The results of the overlaid could determine the reachable and the unreachable TES from residential cluster.

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**Figure 3.** Time of the earthquake until the tsunami reached the shore [13].

3. Results and Discussion

3.1 The Altitude of TES

The TES altitudes in north Pagai island are very diverse with different percentages (Table 1). The map of location altitudes was used to determine the location of TES to be reached by residents before tsunami occurs located at the height of >15 metres above mean sea level (MAMSL) which was a safe evacuation site [14] states that the classification of tsunami hazard zone can be determined from the contour of the area. Based on the height of area, the risk zones which are prone to tsunamis are classified as very high risk at the height of 0–5 meters at, high risk at 5–10 meters, temporary secure at 10–15 meters, and secure at >15 meters (Fig. 4).

**Figure 4.** Map of tsunami-prone zones in North Pagai Island based on the height of TES.
### Table 1. The average height of TES in north Pagai Island.

| Village       | Hamlet       | Evacuation Site | Average (MAMLS) | Morphology of area |
|---------------|--------------|-----------------|-----------------|--------------------|
| Sikakap       | East Sikakap | 3               | 21.5            | Hillsides          |
|               | Central Sikakap | 3               | 23.6            | Hillsides          |
|               | Sibaibai     | 3               | 48.8            | Highland           |
| Taikako       | Pasibuat     | 2               | 15.7            | Hillsides          |
|               | Muaro Taikako | 4               | 10.3            | Hillsides          |
|               | Kaute        | 1               | 17.5            | Highland           |
|               | Bulakmonga   | 1               | 33.1            | Highland           |
| Silabu        | West Silabu  | 2               | 25.7            | Hillsides          |
|               | Tumalei      | 2               | 45.2            | Hillsides          |
|               | Maguiruk     | 2               | 47.2            | Hillsides          |
| Saumanganya   | Mapinang     | 3               | 24.2            | Highland           |
|               | Mabulau Buggei | 2               | 47.7            | Hillsides          |
|               | Patutukat Sibau | 2               | 32.1            | Hillsides          |
|               | Pasapuat     | 3               | 19.1            | Hillsides          |
|               | East Saumanganya | 1           | 29.5            | Hillsides          |
|               | Manganjo     | 1               | 22.5            | Hillsides          |
| Matobe        | Matobe Tunang | 1               | 23.3            | Hillsides          |
|               | Mangau –ngau | 1               | 25.5            | Hillsides          |
|               | Polaga       | 1               | 28.4            | Hillsides          |

### Table 2. The population of the coastal area of north Pagai Island.

| Hamlet      | Village       | Sub-district | Population |
|-------------|---------------|--------------|------------|
| Central Sikakap | Sikakap     | Sikakap      | 673        |
| East Sikakap  | Sikakap     | Sikakap      | 1039       |
| Sibaibai     | Sikakap     | Sikakap      | 660        |
| Pasibuat     | Taikako     | Sikakap      | 191        |
| Muaro Taikako | Taikako   | Taikako      | 418        |
| Kaute        | Taikako     | Taikako      | 258        |
| Bulakmonga   | Taikako     | Taikako      | 271        |
| West Silabu  | Silabu      | North Pagai  | 181        |
| Maguiruk     | Silabu      | North Pagai  | 283        |
| Tumalei      | Silabu      | North Pagai  | 172        |
| Mapinang     | Saumanganya | North Pagai  | 201        |
| Pinairik     | Saumanganya | North Pagai  | 119        |
| Mabulau Buggei | Saumanganya | North Pagai  | 252        |
| Patutukat Sibau | Saumanganya | North Pagai  | 105        |
| Pasapuat     | Saumanganya | North Pagai  | 530        |
| Manganjo     | Saumanganya | North Pagai  | 460        |
| East Saumanganya | Saumanganya | North Pagai  | 348        |
| Matobe Tunang | Matobe      | Sikakap      | 411        |
| Mangau –ngau | Matobe      | Sikakap      | 85         |
| Polaga       | Matobe      | Sikakap      | 135        |

| Jumlah       | 6792         |

Source: BPS of Mentawai Islands Regency, 2016

3.2 The hamlet’s monographs, road network and evacuation route selection

The hamlet’s monographs data were used as a parameter to determine the number of people who would be evacuated to the predetermined TES (Table 2). In this study, not all the population of north Pagai Island was evacuated, because a small proportion of the population had been in a place at the height of > 15 MAMSL so that the evacuation was not necessarily done. The assumption was that the
point that became the starting point of the evacuation of the entire population identified as the tsunami victims was determined by analyzing areas which height were less than 15 MAMSL.

Whilst, the road network became the main parameter because in the road network data attributes were the road class, road width and road length (Table 3) in which the making of the evacuation route map would consider the length of the route to be taken by the people in the coastal village of North Pagai. The following is the parameter of evacuation routes to be taken by residents to get to the TES which had been selected.

**Table 3. Parameter of north Pagai island road network.**

| Evacuation route | Road Class* | Average width (m) | Average length (m) |
|------------------|-------------|------------------|-------------------|
| I                | Main road (PT Minas Pagai Lumber road) | 18 | 619 |
| II               | Village/hamlet road | 3.32 | 376.46 |
| III              | Footpath/ground | 1.5 | 389.745 |

According to (Table 2 and Table 3) above, the number of people estimated to be the victims of the tsunami disaster was 6792 residents. The tsunami disaster mitigation was based on the parameters used for the determination of TES and evacuation routes namely: altitude, road networks and the hamlet monographs. The road network data were then analyzed with GIS approach using network analysis in which could be known the information of the travel time to the TES through the 38 predetermined evacuation routes (Fig. 5 and Table 4) in north Pagai island coastal areas which were vulnerably affected by the tsunami.

*Figure 5. The map of TES and tsunami evacuation routes in north Pagai island.*
Figure 6. The location of evacuation route in central Sikakap.

Figure 7. The location of evacuation route in SMP N 1 Sikakap.

Figure 8. The location of evacuation route in the gate of Pasibuat.

Figure 9. The plan of evacuation shelter in the port of PT. Minas Pagai.

Figure 10. The location of TES and evacuation routes in west Silabu.

Figure 11. The condition during tide.

Figure 12. The location of evacuation route in east Saumanganya.

Figure 13. The condition of bridge as an evacuation route in the Pasapuat Port.

Figure 14. The gate of Matobe village in Matobe Tunang which was a tsunami evacuation route.

Figure 15. The condition Tsunami evacuation route in Polaga.
According to [15], a bunch of people running together can cover a distance of 3225.81 m within 20 minutes. Considering the strength differences (based on age and sex), the length of the evacuation route should be less than 3225.81 m. The length of the evacuation route E-01 to E38 had met the criteria of the tsunami evacuation route length with an average length of 382.44 m which was less than the maximum distance of a bunch of people running together with maximum distance of 3225.81 m. It can be concluded that the evacuation routes that had already existed in North Pagai Island were very appropriate for evacuation when a tsunami potential-earthquake hit.

| Location          | Length (m) | Width (m) | Roadtype | Lane   | Condition | time (minute) |
|-------------------|------------|-----------|----------|--------|-----------|---------------|
| E_01 Central Sikakap | 250        | 3.5       | concrete | village| well      | ± 3           |
| E_02 Central Sikakap | 96         | 3.5       | concrete | village| well      | ± 1           |
| E_03 East Sikakap   | 140        | 3.5       | concrete | village| well      | ± 3           |
| E_04 East Sikakap   | 415        | 3.5       | concrete | village| well      | ± 3           |
| E_05 East Sikakap   | 140        | 3.5       | concrete | village| well      | ± 2           |
| E_06 Sibaibai       | 607        | 3.5       | concrete | village| damaged   | ± 7           |
| E_07 Sibaibai       | 188        | 3.5       | concrete | village| well      | ± 2           |
| E_08 Sibaibai       | 937        | 3.5       | concrete | village| damaged   | ± 13          |
| E_09 Pasibbuat      | 365        | 3         | concrete | village| damaged   | ± 3           |
| E_10 Pasibbuat      | 313        | 3.5       | concrete | village| well      | ± 2           |
| E_11 Muara Taikako  | 145        | 3.5       | concrete | village| well      | ± 2           |
| E_13 Muara Taikako  | 305        | 3.5       | concrete | village| well      | ± 3           |
| E_14 Muara Taikako  | 500        | 3.5       | concrete | village| well      | ± 5           |
| E_15 Kaute          | 577        | 18        | ground   | company| well      | ± 5           |
| E_16 Bulakmonga     | 619        | 1.5       | ground   | village| basic     | ± 7           |
| E_17 West Silabu    | 530        | 3         | concrete | village| damaged   | ± 5           |
| E_18 West Silabu    | 428        | 3         | concrete | village| damaged   | ± 4           |
| E_19 Tumalei        | 502        | 1.5       | ground   | village| basic     | ± 5           |
| E_20 Tumalei        | 778        | 1.5       | ground   | footpath| basic     | ± 8           |
| E_21 Maguiruk       | 150        | 1.5       | concrete | village| damaged   | ± 2           |
| E_22 Maguiruk       | 215        | 1.5       | concrete | village| damaged   | ± 2           |
| E_23 Mapinang       | 1.49       | 1.5       | soil     | footpath| basic     | ± 13          |
| E_24 Mapinang       | 720        | 3.5       | concrete | village| well      | ± 8           |
| E_25 Pinairik       | 879        | 3.5       | concrete | village| damaged   | ± 9           |
| E_26 Mabulau Buggei | 825        | 3.5       | concrete | village| damaged   | ± 9           |
| E_27 Patutukat Sibau| 611        | 3.5       | concrete | village| damaged   | ± 7           |
| E_28 Patutukat Sibau| 1.21       | 3.5       | concrete | village| damaged   | ± 7           |
| E_29 Pasapuat       | 579        | 3.5       | concrete | village| damaged   | ± 7           |
| E_30 Pasapuat       | 650        | 3.5       | concrete | village| damaged   | ± 7           |
| E_31 Pasapuat       | 676        | 3.5       | concrete | village| damaged   | ± 7           |
| E_32 Mabulau Buggei | 1.854      | 5         | concrete | village| damaged   | ± 14          |
| E_33 Manganjo       | 1.825      | 3.5       | concrete | Village| damaged   | ± 14          |
| E_34 East Saumanganya | 1.79     | 3.5       | concrete | Village| damaged   | ± 14          |
| E_35 Matobe Tunang  | 1.429      | 3.5       | concrete | Village| damaged   | ± 13          |
| E_36 Matobe Tunang  | 581        | 3.5       | concrete | Village| well      | ± 7           |
| E_37 Mangau -ngau   | 2.195      | 3.5       | concrete | Village| damaged   | ± 15          |
| E_38 Central Sikakap| 136        | 3.5       | concrete | Village| well      | ± 2           |
3.3 Determining TES

3.3.1 Sikakap

Residential settlements located in the coast of Sikakap village included in the tsunami-prone zones were western and central Sikakap, and Sibaibai. Based on field surveys, it was found out that, in general, residential settlements in the eastern and central Sikakap and Sibaibai were within ±10 m from the shoreline with a population of 2372 inhabitants[11]. The coast of Sikakap village was not severely affected by the tsunami although based on the facts in the field as well as the interviews of local people there were some buildings severely damaged by the earthquake before the tsunami. Geographically, Sikakap village is close to hills as an alternative of TES when tsunami hits. The position of Sikakap village as the center of economy and administration, as well as the main gate of north Pagai island has resulted in a lot of buildings that have more than 2 floors as evacuation shelters.

To determine the location of TES in the village of Sikakap (Fig.16), it was necessary to know the location altitude of TES region (Table 1). In the study site could be seen 8 evacuation routes to TES. There were 3 routes in eastern Sikakap with the height of 21.5 MAMSL, 2 routes in central Sikakap with the height of 23.6 MAMSL, and 3 routes in Sibaibai with a height of 48.8 MAMSL to TES. The average time needed to TES was ±4 minutes with the furthest route of 415 m from central Sikakap.

![Figure 16. The map of TES in Sikakap village scale 1:30.000.](image)

3.3.2 Taikako

Residential settlements in the coast of Taikako village included in tsunami-prone zones were the hamlets of Pasibuat, Muaro Taikako, Kaute dan Bulakmonga. According to field surveys, the residential settlements in Pasibuat which were ±68 m from the shoreline with a population of 191 inhabitants, in Muaro Taikako which were ±40 m from the shoreline with total population of 418 inhabitants, in Kaute which were ±310 m from the shoreline with total population of 258 inhabitants, and in Bulakmonga which were ±1.6 km from the shoreline with total population of ±271 inhabitants.
had not yet received permanent housing assistance planned to be built of 80 units[16]. According to BPS data (2016), the number of residents in Taikako village was 1138. The people in Taikako village proposed permanent housing on the land of PT. Minas Pagai at an altitude of 120 MAMSL and on Silaoinan hills with the height of 46 MAMSL. The coastal area of Taikako village was not so badly affected by the tsunami on October 25, 2010. The suggested evacuation shelter in the village was located in Kaute within ±90 m towards the south of the port of PT. Minas Pagai consisting of a 3-storey building.

To determine the location of TES in the village of Taikako (Fig. 17), it was necessary to know the location altitude of TES region (Table 1). In the study site could be seen 6 evacuation routes to TES. There were 2 routes in Pasibuat with the height of 15.7 MAMSL, 2 routes in Muaro Taikako with the height of 10.3 MAMSL, and 1 route in Kaute with a height of 17.5 MAMSL, and 1 route in Bulakmonga with a height of 33.1 MAMSL to TES. The average time needed to TES was ±4.87 minutes with the furthest route of 664 m from Muaro Taikako.

Figure 17. The map of TES in Taikako village scale 1:30,000.

3.3.3 Silabu
Residential settlements located in the coast of Silabu village included in tsunami-prone zones were the western Silabu, Maguiruk, and Tumalei. According to field surveys, the residential settlements in west Silabu which were ±1.2 km from the shoreline with a population of 181 inhabitants, in Maguiruk which were ±532 m from the shoreline with total population of 238 inhabitants, and in Tumalei which were 851 m from the shoreline with total population of ±172 inhabitants had not yet received permanent housing assistance planned to be built of 87 units[16]. Based on the facts in the field supported by interview with the local community, western Silabu was also prone to flood (rob). According to[11] data, the population of the coast of Silabu village was 636 inhabitants. Local people asked for permanent housing on the high land near the office of Silabu village chief to anticipate tsunami dan rob in Western Silabu. The coastal areas of Silabu village were badly hit by the
tsunami, one of them was Macaronis resort located on the island of Sinaia. In 2010 (Fig. 18), the resort was hit by 3 m high tsunami waves that damaged buildings and mangroves which protect the coastal area [17].

Figure 18. Macaronis before and after tsunami 2010.

To determine the location of TES in the village of Silabu (Figure 19), it was necessary to know the location altitude of TES region (Table 1). In the study site could be seen 6 evacuation routes to TES. There were 2 routes in western Silabu with the height of 25.7 MAMSL, 2 routes in Maguiruk with the height of 47.2 MAMSL (the suggested TES in the north area), and 2 routes in Tumailei with a height of 45.2 MAMSL to TES which did not yet have evacuation shelter. The average time needed to TES was ± 4.66 minutes with the furthest route of 778 m from Tumalei.

Figure 19. The map of TES in Silabu village scale 1:70,000.
3.3.4 Saumanganya

Residential settlements located in the coast of Saumanganya village included in tsunami-prone zones were Mapinang, Pinairik, Mabulau Buggei, Patutukat Sibau, Pasapuat, Manganjo and east Saumanganya. According to field surveys, the residential settlements in Pasapuat which were ± 110 m from the shoreline with a total population of 460 inhabitants, in Manganjo which were ± 745 m from the shoreline with a total population of 119 inhabitants, in Pinairik which were ± 656 m from the shoreline with a total population of 460 inhabitants, in east Saumanganya which were ± 550,8 m from the shoreline with total population of 348 inhabitants, in Mabulau Buggei which were ± 230 m from the shoreline with total population of 242 inhabitants, and in Patutukat Sibau which were ± 105 inhabitants had not yet had permanent housing planned to be built of 88 units[16]. Based on the facts in the field supported by interview with the local community, western Silabu was also prone to flood (rob). According to BPS (2016) data, the number of population of the coast of Saumanganya village was 2025 inhabitants. Similar to Taikako village, the people living in the coastal areas asked for permanent housing on the land of PT. Minas Pagai Lumber at the height of 100 MAMSL, and in Gulukguluk hills at the height of130 MAMSL. Whilst the evacuation shelter proposed in Pasapuat was ± 200 m towards the west at the construction site of the pier port which planned to be the 2nd port after Sikakap port consisting of 3-storey building. Pasapuat was the area in the eastern part of North Pagai Island which was the worst affected by the tsunami, beside the western area of Batumonga village such as Muntei Barubar with 98 fatalities and Sabeugugung with 75 fatalities. Those areas had been given an assistance of permanent housing by related parties [18].

To determine the location of TES in the village of Saumanganya (Fig.20), it was necessary to know the location altitude of TES region (Table 1). In the study site could be seen 12 evacuation routes to TES. There were 3 locations in Mapinang, one of them was the suggested TES in western Mapinang with average height of 24.2 MAMSL, 1 location in Pinairik with the height of 20.5MAMSL 3 locations in Pasapuat with the height of 19.1 MAMSL, 1 locations in Manganjo with the height of 22.5 MAMSL, 1 location in Mabulau Buggei with the height of 47.7 MAMSL, 2 locations in Patutukat Sibau with the height of 32.1 MAMSL and 1 location in east Saumanganya with a height of 29.5 MAMSL which did not yet have evacuation shelter. The average time needed to TES was ± 9.07 minutes with the furthest route of 1.823 km from Mabulau Buggei, Manganjo and east Saumanganya.
3.3.5 Matobe

Residential settlements located in the coast of Matobe village included in tsunami-prone zones were Matobe Tunang, Polaga and Mangaungau. According to field surveys, the residential settlements in Matobe Tunang were ± 643 m from the shoreline with a population of 411 inhabitants, in Polaga were ± 182 m from the shoreline with total population of 135 inhabitants, and in Mangaungau were 325 m from the shoreline with total population of 85 inhabitants. According to BPS (2016) data, the number of population of the coast of Matobe village was 631 inhabitants. Local residents asked for permanent housing which located on Panatarat hills at the height of 85 above sea level within ± 2 km from Matobe Tunang, and ± 2.5 km from Mangaungau, while the suggested permanent housing was located in Polaga at a church near the Posyandu/Polmades of Polaga. Based on the information from the interview conducted to local residents, in the locations was also planned to be built a 3-floor building which was the allocation of aid for trans-area settlement. The coast of Matobe village was not badly affected by the tsunami, though according to information from local people there were several buildings severely damaged because of it. However, there were not any fatalities when the tsunami hit north Pagai Island on October 25 2010.

To determine the location of TES in the village of Matobe (Fig.21), it was necessary to know the location altitude of TES region (Table 1). In the study site could be seen 2 evacuation routes to TES. The TES in Mangaungau with the height of 25.5 MAMLS, in Matobe Tunang with the height of 23.3 MAMLS and in Polaga did not have evacuation route signs yet, and were the suggested location of TES. Based on the field observation, one of the routes to the TES location with the height of 28.4 MAMLS was the area of Panatarat hills plantation, while the evacuation shelter in Matobe village was not yet available. The average time needed to the TES was ± 9.25 minutes with the furthest route of ± 2.195 km from Mangaungau.
4. Conclusions and Recommendations

4.1 Conclusions
In general, the residential settlements in the village of Sikakap were within ± 10 m from the coastline with a population of 2372 inhabitants. The average time needed to get to TES was ± 4 minutes with the furthest route of 415 m from Central Sikakap. The residential settlements in Taikako village were in average within ± 504 m from the coastline with a population of 1138 inhabitants. The people of the coast of Taikako village asked for permanent housing on Silaoinan hillsat the height of 46 MAMLS. The average time needed to get to TES was ± 4.87minutes with the furthest route of 664 m from Muaro Taikako. The residential settlements in Silabu village were in average within ± 218.17 m from the coastline with a population of 707 inhabitants. Local residents asked for permanent housing on the hill near the office of Silabu village chief at the height of 25.7 MAMLS. The average time needed to get to TES was ± 4.66minutes with the furthest route of 778 m from Tumalei. The residential settlements in Saumanganya village were in average within ± 435.33 m from the coastline with a population of 1804 inhabitants. The residents of the coast of Saumanganya village asked for permanent housing on the hill of Gulukguluk at the height of 130 MAMLS. The average time needed to get to TES was ± 9.07minutes with the furthest route of ± 1.823 km from Mabulau Buggei, Manganjo and east Saumanganya. The residential settlements in Matobe were in average ± 383.33 m from the shoreline with a population of 631 inhabitants. Local residents insisted on permanent housing which located on Panatarat hill sat the height of 85m above sea level within ± 2 km from Matobe Tunang, and ± 2.5 km from Manguagau, while the suggested permanent housing was located in Polaga at a church near the Posyandu/Polmades of PolagaThe average time needed to the TES was ± 9.25 minutes with the furthest route of ± 2.195 km from Manguagau.
4.2 Recommendations
Intensive socialization needs to be done for each coastal village in North Pagai Island because historically these villages had been hit by tsunami. The socialization is in the form of an introduction to the evacuation route map so that if the calamity occurs, residents are more directed in the action to save themselves. The evacuation routes need to be provided with signs to show the evacuation direction so that residents can easily identify the evacuation routes. Maintenances of the road and the access of the evacuation routes of north Pagai Island coast needs to be done.

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