Evacuation Route Mapping Based on Tsunami Hazard Area on Sawarna Tourist Village, Bayah, Lebak

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Abstract. Sawarna Village is a tourism village located on the southern coast of Lebak Regency, Banten and directly facing the Indonesian Ocean. The geographical location of Sawarna village might potentially affected by earthquake and tsunami disaster. Beside the local residents, tourists are also affected by the earthquake and tsunami. This research aims to determine the areas affected by the tsunami disaster and determining the evacuation route, especially the pathway from the location of attractions. Data obtained from the images of DEM IFSAR and Google Earth as well as field survey results. GIS analysis network was used as data analysis technique. The result showed the tsunami’s hazard area in Sawarna Village covers about 347.62 Ha, with a high risk level of 270.38 (77.78%). The tsunami hazard area covers all the sights and settlements along the coast, south of the village road and the border of the river. The evacuation direction of the tourist objects is straight away from the beach but away from the river. Meanwhile, the direction of evacuation in the settlement follows the road and away from the river to the nearby hill.

1. Introduction
Sawarna Village is a village on the southern coast of Lebak Regency, which was titled as a tourist village in 2009. Sawarna village got the title because of some various factors; one of them is having approximately 12 attractions that almost entirely exist along the beach. There is 40% in total, of village revenues come from tourism sectors, beside marine fisheries and handicraft industries. The craft industry is a sector that supports the tourism sector as well. Residents who work in the tourism sector are working as a guide, lodging, and so on (data of Bayah District, 2017). Tourists from outside the area are coming to Sawarna village almost every day. The number of tourism visits of Sawarna village has significantly fluctuated in the last 5 years. The number of tourists in 2016 was 80,034 persons and in 2017 were 65,256 persons (Sawarna Village’s monographic data, 2017). The number of visitors reached its highest peak especially on weekends and public holidays [1].

Astronomically Sawarna village is located at 6º 58'52,88" S and 106º18'26,21"E. This village is located on the South Coast of Java, directly facing Samudera Indonesia (Indian Ocean). This region is located in the subduction zone of the convergence plates Indo-Australia and Eurasian continental plates. This condition makes the village of Sawarna has a potentially dangerous earthquake accompanied by tsunami. However, for the village that contain about 4,358 persons has not yet had the information about how the earthquake and tsunami might occur and the impacts that will be received. Evacuation route for the residents is urgently needed. This guide of evacuation routes became highly needed considering that the population was evacuated not only to local residents but also the tourists as well [2][3].

2. Methods
This research aims to determine the areas affected by the tsunami disaster and determining the evacuation route. This research used a descriptive method in analysing the secondary data. The analytical technique that was used is by integrating the data based on GIS method. The first step of this research was using the Geographic Information System (GIS) software, ArcGIS 10.3 and Global Mapper 18.0.1. The data that was used is Digital Elevation Number (DEM) IFSAR with a high resolution. DEM
IFSAR data has a resolution of 5 meters with vertical accuracy of 3 meters in raster/grid format, in a form of DSM and DTM (Digital Terrain Model) [4][5]. Those data can be used to estimate inundations when tsunami occurs in Sawarna village [6]. Other data that were used in this research are topography map to determine the administrative area of Sawarna Village; data of the families and residents in Sawarna Village, data of land coverage from Google Earth’s satellite imagery. Field survey was done to determine the object distribution, tourism facility, and the condition of roads and buildings. Furthermore, basic data was made based on the data that has been collected before (tabular and digital). The digital data is satellite imagery data that has been transformed to shape file, and was added by some information from the tabular data thus made a thematic based map which represent every indicators.

The height of tsunami’s run up was determined by the potential height in tsunami’s repetitive period every 500 years based on the research by using a probabilistic tsunami hazard analysis (PTHA) modelling [7]. The result of PTHA showed that the maximum height of the run up in Sawarna Village in that period is 10 meters with 25 minutes of the estimated time from the upcoming tsunami. The submerged areas were obtained from the altitude map which was classified from the land’s contour by DEM IFSAR with the resolution of 5 meters. Furthermore, the altitude map that was produced being classified based on the hazard level of tsunami which was calculated from the maximum run up.

To determine the index of tsunami, the data was obtained based on the dominant exposed hazard area resulted from GIS. The hazard index scale is divided into three categories i.e. low with index 0.0 – 0.333, medium with index > 0.333 – 0.666, and high with index > 0.666 – 1. The parameter can be adjusted to the standard parameters specified by BNPB (Perka No. 2 of 2012), namely using national guidelines of the Indonesian Tsunami Risk assessment by Indonesian National Board for Disaster Management (BNPB) [8], as follows:
Table 1. Classification of Potentially Exposed Areas to Tsunami

| Level | The height of inundation | Index values | Hazard level |
|-------|--------------------------|--------------|--------------|
| 1     | <1 meter                 | 0.0 – 0.333  | Low          |
| 2     | 1 – 3 meters             | >0.333 – 0.666 | Medium     |
| 3     | > 3 meters               | >0.666 – 1   | High         |

Source: Guidelines of the Indonesian Tsunami Risk Assessment, BNPB 2011

To determine the number of residents and tourism facilities that was affected, the map of tsunami’s hazard level was being layered with settlement and tourism facilities distribution map, furthermore the picture of settlements and tourism facilities in every hazard areas could be obtained. The number of affected residents in every hazard area could be obtained by this approach as follow:

\[ JPT = JBNG \times RJK \]

in which:
- JPT = number of residents who were affected in every classification
- JBNG = number of buildings in every classification
- RJK = average number of families in the village

Furthermore, after the hazard area in Sawarna village was obtained, tsunami evacuation route both from the settlement and tourism objects were created. However, before determining the appropriate evacuation route, first the location of the temporary evacuation site/shelter and evacuation zones should be determined. The location of shelter should be based on:

1) The determined location should be in where the people would have an approximate spare time to reach the area before the tsunami happen (based on the estimated evacuation time that has been calculated)
2) Should be at a considerable height above the estimated maximum inundation height (> 10 m),
3) must be away from the source of hazardous and toxic materials (B3) and radioactive materials, such as industrial areas, gas stations, oil tanks, tanks gases, chemical plants, etc.,
4) Should be in an approximate distance from the potential for harmful sources of large debris, such as the containment of lumber near the container of the port or the timber from the power plant.
5) Should be reachable by everyone, whether healthy, or have physical limitations such as elderly, expectant mothers, children and persons with special needs. Thus, a by passed evacuation route must be able to pass with wheelchairs for elderly and people with other physical disabilities.
The evacuation zone was determined based on shelter location as a meeting point on each of affected areas by determining the number and population’s density, road network (accessibility) as well as the estimated time arrival of tsunami and time response of the residents. Evacuation zones were analysed using the network analyst/service area in ArcGIS by using the service distance function, which is the distance to the safe point. Distance to safe point was calculated by the equation:

\[ JTA = RKB \times T \]

Which,

\[ T = WTT - WR \]

\[ JTA = \text{Distance to temporary safe point (shelter)} \]

\[ RKB = \text{Average velocity of person (0.71m/second) (Japan Institute For Fire Safety and Disaster Preparedness)} \]

\[ T = \text{Time needed to go to safe point} \]

\[ WTT = \text{Tsunami arrival time} \]

\[ WR = \text{Time response (7 minute)} \]

Schematically the mechanism for determining the evacuation zone is as follows:

![Figure 4. The Method of Determining Tsunami Evacuation Zones](image)

After obtaining the shelter and evacuation zone, the next step is to determine the evacuation route. Every evacuation zone has 1 safe point which is used for gathering point, until the entire evacuation route going to that point. Evacuation zone designed with consideration based on arrangement of evacuation route in SNI 776-2012 [9]: 1) Tsunami evacuation route designed through the existing road that will be away from the coastline, river estuary and the body of river flows, as well as aqueducts that end on a shore, 2) Evacuation route isn’t crossing the river or bridge, especially those which close to the coastal areas.

For accuracy, ArcGIS process evacuation results are confirmed with field survey result. The field survey result is a ground check and observation of existing road network, it is likely that the destination to be used as an evacuation site such as escape hill or vertical building, the road existing of each tourist attraction, road condition, road width, roadblocks, and the presence of rivers and bridges as objects to avoid.
3. Results and discussion

3.1. Tsunami Hazard Area

The tsunami modelling using DEM IFSAR and high-resolution base map image results tsunami hazard area in Sawarna village included the area along the coast and around the river. With topography around 800 ha from the plain, 700 ha from the hills/mountains and the elevation around 2 – 90 masl, the submerged area in Sawarna Village affected about 347,62 ha from the surface/plain.
Based on ArcGIS modelling, almost 50% of the land area in Sawarna Village which directly facing the sea is in high risk zone. Based on table 2, 77.78% of Sawarna’s land areas are in the high classification hazard zone. The remaining 18.02% are in a moderate zone and 4.2% are in the low classification hazard zone. The existence of river gives an influence in measuring tsunami’s hazard level in Sawarna Village, as river was known as a variable that would affect the altitude of the tsunami. Here is the table of tsunami hazard areas and the width of the areas resulted from using ArcGIS modelling.

| No | Hazard area (in width) | Index value | Hazard classification | Affected area (RW) |
|----|------------------------|-------------|-----------------------|--------------------|
| 1  | 14,6025 | 4,2 | 0 – 0,333 | Low | RW 4, RW 10 |
| 2  | 62,6402 | 18,02 | 0,333 – 0,666 | Moderate | RW 1, RW 2, RW 4, RW 8, RW 10 |
| 3  | 270,3759 | 77,78 | 0,666 – 1 | High | RW 5, RW 6, RW 7, RW 8, RW 9 |
| Total | 347,6186 | 100 | | High | |

Source: Fieldwork, 2019

The monographic data of Sawarna Village in 2017 states that the total population of Sawarna are 4,358 persons with 2,263 persons of male population and 2,095 persons of female population while the number of head of family in Sawarna village is 1,324 persons. Based on the simulation of the settlement areas (the location of RWs), the number of estimated affected residents in the area are 1,979 persons of male population and 1,848 persons of female population.
Based on the figure above, the affected residents are identified by the distribution of RWs that could be classified as follow:

### Table 3. Affected Residents in Number (person)

| No. | RW   | Hazard Classification          | Number of Residents (person) |
|-----|------|-------------------------------|------------------------------|
| 1   | RW 1 | High, moderate                | 513                          |
| 2   | RW 2 | High, moderate                | 488                          |
| 3   | RW 4 | Low, moderate, high           | 310                          |
| 4   | RW 5 | High                          | 260                          |
| 5   | RW 6 | High                          | 503                          |
| 6   | RW 7 | High                          | 519                          |
| 7   | RW 8 | High, moderate                | 425                          |
| 8   | RW 9 | High                          | 387                          |
| 9   | RW 10| Low, moderate                 | 422                          |
|     | Total|                               | 3,827                        |

Source: Fieldwork, 2019

Besides the residents, there are also tourists who visit the tourist attractions along the beach of Sawarna village. Based on the monographic data of Sawarna Village, the number of tourists visiting Sawarna equals to 65,256 persons in 2017. The average number of visitors is 1,255 persons per week. The estimated number of visitors per tourism object is 100 to 105 persons, with the assumption if every tourism objects were visited by the visitors. Based on the survey of the number of visitors in every tourism objects on weekdays is 10% of the number of visitors on holiday or weekend. Thus the potentially affected tourists to tsunami can reach as much as 100 to 1000 people.

The threat of tsunami will also affect the buildings in Sawarna village. The result of digitized data of buildings in each settlement results the potential number of buildings affected by the tsunami as follow:

### Table 4. Potentially Affected Buildings to Tsunami in Sawarna Village

| No | Hazard Classification | Number of Buildings Unit | % |
|----|------------------------|--------------------------|---|
| 1  | Low                    | 32                       | 2.30|
| 2  | Moderate               | 161                      | 11.55|
| 3  | High                   | 1201                     | 86.15|
|    | **Total**              | **1394**                 | **100**|

Source: Fieldwork, 2019

There are 1,394 buildings will be affected by tsunami in total. As many as 1,201 buildings or 86.15% of the total buildings are in high hazard zone areas. Subsequently as many as 161 buildings (11.55%) are in moderate hazard area. The remaining 32 buildings (2.3%) are in low hazard zone.

From the whole building affected by the tsunami, it also includes a building that serves as a hotel or lodging in Sawarna village. The houses in Sawarna village, especially in RW 4, have been functioning as lodging. Along the shores of Sawarna village, from west to east, there is a semi-permanent building that serves as a stall and lodging. The building was built to facilitate the needs of tourists visiting every tourist attraction. Quite a lot of residents who inhabit the building, that serves as a stall or lodging as a place to stay daily. If long holidays such as holiday, New Year or national leave, inns and stalls by the beach cannot accommodate tourists.

Besides the buildings near the beach, the residential buildings also took place along the coast of Sawarna. This settlement is an area with a dense number of buildings. The buildings consist of residential houses and lodgings/inns. Nevertheless, there are quite a lot of resident’s houses that becomes lodges as well. The houses in Sawarna were connected by a narrow road that could be passed by motorcycle only. The main road in Sawarna Village is a provincial road that divides Sawarna village into two parts, the southern part and the northern part of the road. These are the result of the identified lodges/inns that could potentially affected by the tsunami:
### Table 5. Potentially affected Inns/Lodges to Tsunami

| No | Inns/Lodges                        | Hazard Classification |
|----|-----------------------------------|-----------------------|
| 1  | Malibu Resort Sawarna             | High                  |
| 2  | Sinar Legon Pari                  | High                  |
| 3  | Penginapan Srikandi               | High                  |
| 4  | Sawarna Resort                    | High                  |
| 5  | Srikandi Sawarna Homestay         | High                  |
| 6  | Andrew Homestay                   | High                  |
| 7  | Mutiara Resort                    | High                  |
| 8  | Sawarna Paradiso                  | Medium                |
| 9  | Hotel Sawarna                     | High                  |
| 10 | Bukit Indah Sawarna               | High                  |
| 11 | Puri Homestay                     | Safe                  |

Source: Data analysis, 2019

Besides lodges and inns, tsunami also affects tourist attraction sites. Below is the distribution of tourist attraction sites:

### Table 6. Potentially Affected Tourist Attractions to Tsunami

| No | Name of Tourist Attractions | Kelas Bahaya |
|----|-----------------------------|--------------|
| 1  | Pantai Pulo Manuk           | High         |
| 2  | Tanjung Beruk               | High         |
| 3  | Karang Bokor                | High         |
| 4  | Goa Sarah                   | High         |
| 5  | Bukit Cariang               | High         |
| 6  | Pantai Muara                | High         |
| 7  | Pantai Pasir Putih          | High         |
| 8  | Surfing Sport               | High         |
| 9  | Pantai Tanjung Layar        | High         |
| 10 | Karang Bodas                | High         |
| 11 | Pantai Legon Pari           | High         |
| 12 | Karang Taraje               | High         |

Source: Data Analysis, 2019

[Figure 9. The Distribution of Tourist Attractions]
3.2. Evacuation Routes

As a village that is vulnerable to tsunami, the existence of settlements and supporting facilities has not been accompanied by the evacuation route. The making of evacuation route could not instantly follow the existing road. The evacuation routes and evacuated residents will be more accurate and precise to be determined based on the location of tsunami hazard area. Residents from the hazard areas will be evacuated to a safe evacuation site from danger. The safe evacuation site is an area that is not included in the submerged area. When the water covers about 10 meters in height in a submerged area, the safe area from would be a region with the height above 10 meters, which can be a hill or a building that has a height of more than 10 meters.

The estimated time to evacuate is set at the human walking pace. The speed used is the minimum speed of the running person is 0.751 m/sec or equivalent to the speed of the elderly (source: Japan Institute for Fire Safety and Disaster Preparedness). The time required is calculated based on the arrival/departure of the tsunami at the beach minus the response time of the Government/community (about 7 minutes). The tsunami arrival time for the vulnerable beaches in Indonesia can be seen in the TRA document. The estimated arrival of tsunami in Sawarna village (Lebak Regency) is estimated to be 25 minutes from the earthquake incident.

The using of network analyst to make tsunami evacuation route in Sawarna Village has also been done by other researchers [10][11][12][13]. In this research, the simulation resulted by network analyst in ArcGIS shows that there are several safe locations that could be considered as an evacuation site with height above 10 meters. Based on the topography of Sawarna some places are suitable as a temporary evacuation site which is a hill as shown in the image below:

![Image](image_url)

**Figure 10.** The process of determining shelter or meeting point location using ArcGIS

Based on the topography of Sawarna village and the high tsunami threat, there are 13 temporary evacuation sites or meeting points for residents and tourists as shown in the table below:
| No. | Evacuation areas | Outreach areas | Meeting point location (represented by green triangle) | Outreach Areas (in figure) |
|-----|------------------|----------------|--------------------------------------------------------|---------------------------|
| 1   | Shelter 1 and 2  | Karang Bereum, Bateum, Pantai Legon, Pan, Karang Tanjung, Pantai Tanjung Layar |  | ![Map 1](image1) ![Map 2](image2) ![Map 3](image3) |
| 2   | Shelter 3        |                | Surfing sport                                          | ![Map 4](image4)          |
| 3   | Shelter 4        |                |                                                        | ![Map 5](image5)          |
No | Evacuation areas | Outreach areas | Meeting point location (represented by green triangle)
---|----------------|---------------|--------------------------------------
4  | Shelter 5      | Pantai Pasti Path dan RW 4 | Shelter 6
5  | Shelter 6      | RW 4          | Shelter 6
| No. | Evacuation areas | Outreach areas | Meeting point location (represented by green triangle) |
|-----|------------------|----------------|-------------------------------------------------------|
| 6   | Shelter 7        | Outreach 6     | SMAN 2 BAYAH                                          |
| 7   | Shelter 8        | Outreach 7     | RW 6                                                  |
| 8   | Shelter 9        | Outreach 8     | SMPN 2 Bayah                                          |
| No | Shelter | Area |
|----|---------|------|
| 9  | 10 and 11 | Pantai Muara |
| 10 | 12 and 13 | Bukit Cariang |
However, to get to the evacuation site, the evacuation routes should be adjusted to the normal speed of people running, condition and capacity of the road, and should avoid rivers and bridges. Below is the process of determining the evacuation zone and evacuation route in ArcGIS:

![Network analysis process in determining evacuation route in ArcGIS](image1.png)

**Figure 11.** Network analysis process in determining evacuation route in ArcGIS

The result of evacuation route that has been resulted by network analysis in ArcGIS, which based on the tsunami hazard map, existing road condition and other variables, was resulted as below:

![Tsunami Evacuation route map](image2.png)

**Figure 12.** Tsunami Evacuation route map

The result of survey on existing road conditions are still required to obtain the attention of Sawarna Village government to maximize the road capacity as an evacuation route. Some roads are still soil-based or gravelled roads. This road is recommended as an evacuation route because it has been commonly passed by residents, as well as the road is easy to travel by residents or tourists to reach the height more than the height of the bath. Below is the table of the decent roads that could be used as an evacuation route based on ArcGIS simulation and field survey:
Table 8. The condition of existing roads for tsunami’s evacuation route in Sawarna Village 2018

| No  | Coordinate X  | Coordinate Y  | Location          | Road condition | Shelter | Distance from beaches to Shelter |
|-----|---------------|---------------|-------------------|----------------|---------|---------------------------------|
| 1   | -696936       | 106.26548     | Pantai Pulo Manuk | Stairs         | 13      | 519 m                           |
| 2   | 106.30178     | -6.97674      | Goa Langir        | 100 cm Concrete| 12 and 13 | 105 m and 519 m             |
| 3   | 106.30414     | -6.97820      | SMP 2 Bayah       | 350 cm Gravel  | 9       | 507 m                           |
| 4   | 106.30383     | -6.97795      | Pantai Muara      | 170 cm Concrete| 10 and 11| 387 m                           |
| 5   | 106.30878     | -6.97906      | SMA 2 Bayah       | 210 cm Concrete| 10 and 11| 387 m                           |
| 6   | 106.30233     | -6.97740      |                   | 290 cm Concrete| 7       | 1,395 m                         |
| 7   | 106.30998     | -6.98123      |                   | 150 cm Concrete| 5       | 363 m                           |
| 8   | 106.31023     | -6.98211      |                   | 200 cm Soil    | 5       | 363 m                           |
| 9   | 106.31023     | -6.98221      | RW 4              | 150 cm Soil    | 5       | 363 m                           |
| 10  | 106.30960     | -6.98328      |                   | 170 cm Paving  | 5       | 363 m                           |
| 11  | 106.30956     | -6.98374      |                   | 120 cm Concrete| 5       | 363 m                           |
| 12  | 106.30944     | -6.98361      |                   |                |         |                                 |
| 13  | 106.30973     | -6.98565      | Pantai Pasir Putih| 120 cm Soil   | 5       | 363 m                           |
| 14  | 106.31000     | -6.98811      |                   |                |         |                                 |
| 15  | 106.30938     | -6.98980      |                   |                |         |                                 |
| 16  | 106.31002     | -6.98887      | Surfing Sport     | 120 cm Concrete| 4       | 282 m                           |
| 17  | 106.30798     | -6.99400      | Tanjung Layar     | 190 cm Soil    | 4       | 282 m                           |
| 18  | 106.31169     | -6.99039      | Bukit Senyum      | 70 cm Soil     | 3       | 137 m                           |
| 19  | 106.31555     | -6.97833      |                   | 50 cm Soil     | 4       | 282 m                           |
| 20  | 106.32146     | -6.98808      | Legon Pari        | 50 cm Concrete | 1       | 222 m                           |
| 21  | 106.32434     | -6.98709      | Karang Taraje     | 60 cm Soil     | 1       | 222 m                           |
| 22  | 106.32617     | -6.98879      |                   | 60 cm Soil     | 2       | 145 m                           |

Source: Fieldwork, 2019

Overall the direction of the tsunami evacuation route in Sawarna village is to avoid approaching the nearby hill or higher than the bath area. Some locations besides avoiding the beach, also avoid the right river facing the beach.

4. Conclusions

4.1 The result of modelling the tsunami hazard area with DEM IFSAR and using ArcGIS software, the area of the tsunami potentially the village of Sawarna 347.62 Ha with 77, 78% in the high category is higher than 3 meter.

4.2 From an estimate of 1,394 affected buildings units are estimated as many as 3,827 residents of Sawarna village to be evacuated from 9 RW, and tourists in 12 tourist attractions.

4.3 Results of modelling with Network Analyst/Service area function in ArcGIS and accuracy with a field survey obtained 13 shelter and evacuation zones tsunami Hazard in Sawarna village.

4.4 By leading to the shelter/meeting point, the overall direction of the tsunami evacuation route of Sawarna village is away from the beach and also away from the river.

References

[1] Akbar, Abrar, dkk 2015 Efektivitas Penggunaan Jalan Gambong Sebagai Jalur Evakuasi Bencana Tsunami Kota Banda Aceh (Studi Kasus Jeulingke, Tibang, Deah Raya) Jurnal Teknik Sipil 4 Pascasarjana Universitas Syiah Kuala

[2] Badan Standarisasi Nasional 2012 SNI: Jalur Evakuasi Tsunami Jakarta

[3] BNPB 2011 Panduan Nasional Pengkajian Risiko Bencana Tsunami Badan Nasional Penanggulangan Bencana
[4] Dewi R S 2012 A-Gis Based Approach of an Evacuation Model for Tsunami Risk Reduction. *Journal of Integrated Disaster Risk Management* **2** 108–139 https://doi.org/10.5595/jdrim.2012.0023

[5] Horspool N, Pranantyo I, Griffin J, Latief H, Natawidjaja D H, Kongko W, …Thio H K 2014 A Probabilistic Tsunami Hazard Assessment for Indonesia *Natural Hazards and Earth System Science* **14** 3105–3122. https://doi.org/10.5194/nhess-14-3105-2014

[6] Juniansah A, Tyas B I, Tama G C 2017 Spatial Modelling sor Tsunami Evacuation Route in Parangtritis Village. *IOP Conf. Series: Earth and Environmental Science* **118** 012034 doi:10.1088/1755-1315/118/1/012034

[7] Latief Hamzah 2013 *Pedoman Teknik Pembuatan Peta Bahaya Rendaman Tsunamic* Bandung: Pusat Penelitian Mitigasi Bencana ITB dan BNPB

[8] Latief Hamzah 2012 *Kajian Bahaya Gempabumi dan Tsunami Terhadap Infrastruktur Pertamina di Teluk Kabung Padang* Laporan LAPI ITB bekerjasama dengan Pertamina

[9] Latief, H and H. Sunendar 2006 *Database of Precalculated Tsunami Model with Area Study of West Sumatera* Technical Report BPPT-JICA ITB

[10] Sinaga T P T, Nugroho A, Lee Y W, Suh Y 2011 GIS mapping of tsunami vulnerability: Case study of the Jembrana regency in Bali, Indonesia *KSCE Journal of Civil Engineering* **15** 537–543 https://doi.org/10.1007/s12205-011-0741-8

[11] Sun Y, Yamori K, Kondo S 2014 Single-person Drill for Tsunami Evacuation and Disaster Education. *Journal of Integrated Disaster Risk Management* **4** 30–47 https://doi.org/10.5595/jdrim.2014.0080

[12] Yosritzal, Kemal B M, Purnawan 2017 An Observation of the Walking Speed of Evacuees During a Simulated Tsunami Evacuation in Padang, Indonesia *IOP Conf. Series: Earth and Environmental Science* **140** 012090 doi:10.1088/1755-1315/140/1/012090