Identification of Paths and Places of Tsunami Evacuation Based on P646 Fema for Tourism Beaches in the Regency of Gunungkidul, Yogyakarta

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Abstract. The maximum number of monthly visitors to the tourism coasts in Gunungkidul Regency between 2012 and 2015 is 25,160 people. Those Indian Ocean beaches that are in the southern sides of the Island of Java are prone to tsunami disaster. However, there were no systematic and scientific study to make analysis of the tsunami disaster mitigation to those tourism beaches. Therefore, a series of policies with comprehensive rescue strategies and efforts to minimize the risk of the tsunami disaster is required. The purpose of this study is to identify the paths and places of tsunami evacuation for the tourism beaches in Gunungkidul Regency based on P646 of FEMA (Federal Emergency Management Agency) and compare them with the result of the identification of paths and places of tsunami evacuation conducted by BPBD (Local Disaster Management Authority) of Gunungkidul Regency, Yogyakarta. This purpose also includes the want of the authors to implement the method of this study to be the policy of tsunami mitigation for similar tourism beaches in the Special Territory of Yogyakarta as well as similar beaches in Indonesia. This study uses quantitative method with descriptive analysis technique that is analyzing the paths and places of tsunami evacuation based on P646 of FEMA. Given location elevation is the basic ingredient of the analysis, and therefore, elevation data, tsunami arrival time, projected number of visitors to support the analysis need to be gathered. The analysis of the evacuation areas is required to determine the evacuation places that are safe points in the evacuation process. An elevation of a safe point elevation can be a point that is beyond the reach of tsunami waves or safe areas within the tsunami pool areas. The results of this study are the height of the gathering point / safe point 25 meters above sea level to be the basis for saving themselves, if connected with the speed of walking (weak condition), then the arrival time / arrival time of the tsunami is not more than 0.5 hours. This is still within limits in accordance with the Federal Emergency Management Agency (FEMA P-646, 2008), the location of the gathering point / tsunami evacuation safe point can be used as the first rescue of tsunami victims by considering the arrival time of the tsunami. On the other hand, BPBD accommodate tsunami victims using public facilities even though they are far away and heed the arrival time of the tsunami.
1. Introduction
Gunungkidul Regency has a coastal area with a length of ± 72 km, which covers 6 sub-districts (Purwosari, Panggang, Saptosari, Tanjungsari, Tepus and Girisubo) and consists of 19 villages bordering the sea. There are 5 beaches which are areas of human activity that are quite high both from the tourism sector, fisheries and trade. The coastal areas include Baron, Kukup, Krakal, Sundak, and Indrayanti [5]. The location of all coastal tourism objects in this study can be seen in Figure 1.

Figure 1. Map of the location of coastal tourism objects in this study (http://Google Earth)

The number of visitors to each beach in Gunung kidul Regency at the peak holiday conditions in this study [5], can be seen in Table 1.

Table 1. Number of Visitors on peak holidays

| No | Beach Name | Number of Peak Vacation Visitors (per day) (people) |
|----|------------|---------------------------------------------------|
| 1  | Baron      | 167.112/8 = 20.889                                |
| 2  | Kukup      |                                                   |
| 3  | Krakal     | 34.173/8 = 4.271                                  |
| 4  | Sundak     |                                                   |
| 5  | Indrayanti | 201.285/8 = 25.160                               |

Approximately 28% (150 of 530) of cities / districts [4] in Indonesia have a high risk of tsunamis, including the Region of Yogyakarta Special Region. Gunungkidul District has a high risk of tsunami; the policy of the disaster risk reduction with a comprehensive rescue strategy is needed in order to minimize the risk of casualties during a tsunami. In addition to the need for Tsunami Early Warning Systems, tsunami disaster risk reduction efforts are also needed, namely in the form of identification of tsunami evacuation routes and paths in tsunami prone areas. Beach tourism objects in Gunungkidul require evacuation sites and shelter when the tsunami disaster occurs. Identification of lanes and evacuation sites that is used as a refuge can be in the form of fields, hills, both natural hills and artificial hills that are designated as lanes and evacuation sites, existing buildings, and new buildings specifically made for the purpose of lanes and evacuation sites.

The parameters in determining the tsunami paths and evacuation locations base on relevant codes and standards, namely FEMA P646. This FEMA P646 guideline provides an explanation of the analysis of time, speed and maximum distance that must be determined by considering the number and place of evacuation, as well as the visitor population as an important parameter so that the existence of
the evacuation site is optimum in accommodating the surrounding population to the maximum
distance.

The purpose of the study was to identify tsunami evacuation pathways and places on coastal
 tourism objects in Gunungkidul Regency based on FEMA P646, and compare the results of
identification of tsunami evacuation routes and places conducted by Gunungkidul District BPBD in
accordance with FEMA P646 guidelines.

2. Method

A tourism object is a place or state of nature that has tourism resources that are built and developed so
that it has an attraction and is sought as a place visited by tourists [5]. The object of research for
planning tsunami pathways and evacuation sites based on FEMA P646 is coastal tourism objects in
Gunungkidul, namely Baron, Kukup, Krakal, Sundak, and Indrayanti [4].

In analysing the paths and evacuation sites (TE) for identification of tsunami evacuation routes and
paths, the road network is the basic material of the analysis carried out. Since the evacuation site (TE)
is needed in the evacuation process, an analysis of the evacuation area needs to be carried out. The
analysis process is carried out by first determining the safe area. Safe areas can be areas that are
outside the reach of the tsunami wave or areas that are inside the tsunami inundation area [7]. For
evacuations carried out by directing refugees to areas that are beyond the reach of the tsunami,
horizontal evacuation is called. While evacuation carried out by directing refugees to a safe area
within the tsunami coverage area is called vertical evacuation.

In this study, the data that has been collected, both through field research and library research is
analyzed quantitatively combined with qualitative as a supplement to the explanation of the
conclusions obtained. Quantitatively Google Earth is used, while qualitatively using the FEMA P646
Guidelines. The stages of data analysis in the study through the following 5 steps.

1) Analysis of population distribution

Estimates of the number and distribution of populations in tourist areas are very important to know
for evacuation planning, meaning that tsunami evacuation sites can be placed correctly. Service
areas related to evacuation capacity can also be known, so that it can be known the needs of the
number and capacity of evacuation sites needed, population distribution data, among others, are as
follows.

a. The population in each tourism object includes men, women, persons with disabilities, and
others.

b. The maximum number of visitors to each tourist attraction.

c. Number and type of buildings such as houses, schools, offices, places of worship, etc. in each
tourist attraction.

d. Height (elevation) of the land surface, distance from the coastline using the Altimeter and
Google Earth Applications

2) Analysis of time, speed and distance of evacuation

Within the estimated time of arrival of the tsunami or ETA (estimated time of arrival), not all can
be used as an evacuation time, but there is time to detect a tsunami, preparation time and time to
climb to a safe position.

Empirical calculations for analysis of time, speed and distance of evacuation can be seen at the
maximum distance of evacuation sites based on warning times [6].

3) Analysis of direction and behavior of evacuation

The potential of the road lane in the tourism object is used for tsunami evacuation routes by
looking at the map of the road network in the area of the tourism object. In tsunami evacuation,
residents walk from population distribution points to the nearest evacuation route, then to the
tsunami vertical evacuation site [7].

4) Analysis of the capacity of tsunami vertical evacuation sites and existing tsunami vertical
evacuation sites

If a safe tsunami evacuation site is identified, an analysis of the capacity of the tsunami vertical
evacuation site is carried out, which includes the need for evacuation space and the effectiveness of
evacuation spaces. If a tsunami evacuation site is identified, the criteria for tsunami vertical evacuation are determined based on FEMA P646 [7].

5) Digitize the map

This process is carried out to get a thematic map that will be derived data using Google Earth, then the results are used as a reference in making evacuation routes.

3. Results and Discussion

The Regional Disaster Management Agency (BPBD) of Gunungkidul Regency in 2012 created a tsunami evacuation map for the Beaches of Baron, Kukup, Krakal, Sundak, and Indrayanti, then with the Google Earth map application the length of the evacuation route from the coast to the point of gathering and the capacity of the place Tsunami evacuation of each tourism object can be searched, more details can be seen in Table 2.

Table 2. Details of Gunungkidul District BPBD Evacuation Map

| No | Beach Name     | Maximum number of visitors | l (m) | H (m) | L (m²) | V₁ (weak) (km/hr) | ETA (minute) | Space Need (1 m² = 2 orang) |
|----|----------------|---------------------------|-------|-------|-------|------------------|--------------|-----------------------------|
| 1  | Baron dan Kukup| 20.889                    | 2.773 | 75    | 1.729 | 3.22             | 51.67        | 3.458                       |
| 2  | Kukup          | 2.507                     | 3.22  |       |       | 46.71            |              |                             |
| 3  | Krakal         | 3.276                     | 3.22  |       |       | 61.04            |              |                             |
| 4  | Sundak         | 4.271                     | 2.605 | ± 500 | 3.22  | 48.54            | ± 1000       |                             |
| 5  | Indrayanti     | 3.277                     | 3.22  | ± 500 |       | 61.06            | ± 1000       |                             |

1) Determination of Location of Evacuation / Safe Points with Altimeter

Altimeter is a tool to measure the height of a point from the surface of the sea. In this study to determine the height of the evacuation gathering point as the first safe point due to the tsunami using an altimeter application. Collecting points are determined at a minimum of 25 meters above sea level [4] as the first safe point for tsunami evacuation by considering the potential of the area for evacuation and distance not too far from the coast location. Details of height and location of evacuation points can be seen in Table 3 and Figure 2.

Table 3. Elevation of Evacuation / Gathering Points

| No | Beach Name   | Elevation of Gathering Point AMSL (m) |
|----|--------------|-------------------------------------|
| 1  | Baron dan Kukup | 37                                  |
| 2  | Kukup        | 37                                  |
| 3  | Krakal       | 34                                  |
| 4  | Sundak       | 34                                  |
| 5  | Indrayanti   | 34                                  |
2) Data and Analysis of Projected Number of Visitors in 2025
The number of tourists visiting coastal tourism objects in Gunungkidul Regency makes the potential for tsunami victims very large. The current tsunami evacuation site provided by the local government, if we calculate the comparison with the number of visitors to the coastal tourism object in 2015, the capacity / need for an evacuation room is still insufficient. As shown in Table 2. Based on data obtained from Statistic Gunungkidul Regency, it is known that the growth rate of the number of visitors to coastal tourism reaches 30% [5]. The growth rate is used as a reference to calculate the projected number of visitors in the next 10 years, assuming the growth rate is the same every year. Then it can be calculated the projection of the number of visitors to the beach tourism object in the next 10 years from 2015. As shown in Table 4.

| No | Retribution Post                  | Year 2015 | Year 2025 |
|----|-----------------------------------|-----------|-----------|
| 1  | Baron, Kukup                      | 167.112   | 2.303.781 |
| 2  | Tepus (Krakal, Sundak, Indrayanti) | 34.173    | 471.104   |
|    |                                   | 201.285   | 2.774.885 |

3) Determination of Path, Distance and extent of tsunami evacuation gathering points
In determining the evacuation route, distance and extent of gathering points using Google Earth, it will get direct path, distance and extent of the gathering points of tsunami evacuation. As shown in Table 5.

Table 5. Height and distance of tsunami evacuation gathering points

| No | Beach Name | Elevation of Gathering Point AMSL (m) | Distance (m) |
|----|------------|--------------------------------------|--------------|
| 1  | Baron      | 37                                   | 1,044        |
| 2  | Kukup      | 37                                   | 778          |
| 3  | Krakal     | 34                                   | 1,429        |
| 4  | Sundak     | 34                                   | 758          |
| 5  | Indrayanti | 34                                   | 1,430        |

Figure 4. Map of the location of evacuation points of Baron Beach and Kukup Beach

Figure 5. Map of the Baron Beach evacuation route
Figure 6. Map of Kukup Beach evacuation routes

Figure 7. Wide map of evacuation locations for Baron Beach and Kukup Beach

Figure 8. Map of Krakal Beach evacuation points and Sundak Beach
Figure 9. Map of Krakal Beach evacuation routes

Figure 10. Broad map of Krakal Beach evacuation points

Figure 11. Map of Sundak Beach evacuation routes
Figure 12. Wide map of Sundak Beach evacuation points

Figure 13. Wide map of Sundak Beach evacuation points

Figure 14. Map of Indrayanti Beach evacuation routes
4) Determination of the arrival time / arrival time of the tsunami

According to the Federal Emergency Management Agency [4], the average capacity of healthy people can run at a speed of 6.44 km per hour and the speed of people walking with physical limitations is 3.22 km per hour, so the arrival time / arrival time tsunami (ETA) can be determined, as shown in Table 6.

Table 6. Warning time based on safe point distance

| No | Beach Name | Distance (m) | Speed of people walking (weak) (km/hour) | Tsunami arrival time (minutes) |
|----|------------|--------------|-----------------------------------------|-------------------------------|
| 1  | Baron      | 1044         | 3.22                                    | 19.45                         |
| 2  | Kukup      | 778          | 3.22                                    | 14.50                         |
| 3  | Krakal     | 1429         | 3.22                                    | 26.63                         |
| 4  | Sundak     | 758          | 3.22                                    | 14.12                         |
| 5  | Indrayanti | 1430         | 3.22                                    | 26.64                         |

Gunungkidul BPBD tsunami evacuation map shows that the evacuation distance taken takes a long time and the need for evacuation is still insufficient for the number of victims in the event of a tsunami. For this reason, this research base on [4] that the height of a tsunami reaches a height of 25 meters, which is then used as a reference to determine the first safe point in the rescue process in the event of a tsunami as shown in Table 7.

Table 7. Perbandingan Rincian Peta BPBD dan Titik Kumpul Penelitian

| No | Beach Name | Peta BPBD | Penelitian |
|----|------------|----------|------------|
|    |            | Panjang (m) | Ketinggian (m) | ETA (minute) | Panjang (m) | Ketinggian (m) | ETA (minute) |
| 1  | Baron      | 2.773    | 75          | 51.67        | 1044       | 37             | 19.45         |
| 2  | Kukup      | 2.507    | 75          | 46.71        | 778        | 34             | 14.50         |
| 3  | Krakal     | 3.276    | 75          | 61.04        | 1429       | 34             | 26.63         |
| 4  | Sundak     | 2.605    | 75          | 48.54        | 758        | 34             | 14.12         |
| 5  | Indrayanti | 3.277    | 75          | 61.06        | 1430       | 34             | 26.64         |
Determination of the maximum distance based on the warning time, illustration of the calculation, if the speed of the person walking with physical limitations is 3.22 km per hour and if the golden time after the tsunami warning is 30 minutes, the Evacuation Place (TE) can be placed at a distance maximum 1.61 km from the departure point. This will result in an average maximum distance of 3.22 km between two Evacuation Places (TE). Likewise, the 15 minutes warning time assumption, Evacuation Place (TE) will be located at a maximum distance of 0.8045 km from the departure point, and 1.61 km distance between the two Evacuation Points (TE). Longer warning times will require a longer distance.

Determination of vertical evacuation locations considering evacuation behavior and natural high places, when determining the structure of natural vertical evacuation, refugee behavior must be considered. Most of their population in coastal communities has been educated to go to high places. The natural tendency for refugees to migrate away from the coast. Therefore, vertical evacuation structures must be located on the inland side of the evacuation zone and must take advantage of natural topography that will tend to attract refugees towards them. In this study, the results of height and distance obtained have taken into account these provisions. Height, distance and extent of tsunami evacuation gathering points. Side effects of hazards around each building are considered in determining the location of vertical evacuation structures. Potential hazards of buildings including waves, debris carried through waves. If possible, the vertical evacuation structure must be far from potential hazards that could result in additional damage to structures and safety for occupants. Perhaps due to the limited availability of buildings, and restrictions on travel and population mobility in the community, some vertical evacuation structures need to be in places that would be considered less than ideal.

Evacuation routes in this study use existing road lines, considering that the accesses are easily seen and passed. These routes aim to stay away from the wave direction and must be clearly shown through signs, such as away from the coastline, avoid crossing bridges, utilizing existing lines, towards roads with greater widths so as not to occur bottle necks, and avoid obstacles or obstacles. In addition, the mass movement of each block is directed so that it is not mixed with other blocks to avoid congestion. In the consideration of accessibility, vehicles are prohibited from parking on the road, so that congestion or congestion does not occur on the main road. Thus, this study has considered both its accessibility and away from the coastline to determine the tsunami evacuation site.

For horizontal evacuation, the evacuation point is the intersection between the road and the tsunami immersion limit. But in the study there is no tsunami wave inundation map, so what is done is to determine the point with the altimeter randomly, but consider the distance, the height that is safe from the tsunami wave, then from these points a service area of how many minutes is made, meaning the location whichever can reach the evacuation point within 60 minutes. 60 minutes is the time available to evacuate.

An outline comparison is that in this study the safe location / point is not the same as the location for determining the safe point on the tsunami evacuation map contained in BPBD, because it is based on [4]. If in this study the tsunami evacuation location / safe point was used as the first rescue site for tsunami victims by considering the arrival time of the tsunami, and could be used as a temporary tsunami victim shelter. In BPBD for tsunami victims' shelter, they use public facilities even though they are far away and heed the arrival time of the tsunami.

4. Conclusion
The height value of the 25-meter gathering point from the sea level becomes the basis for saving yourself. If connected with the speed of walking (weak condition), then the arrival time / arrival time of the tsunami is obtained not more than 0.5 hours. This is still within limits in accordance with the Federal Emergency Management Agency guidelines [6]. If the extent of the tsunami evacuation gathering point is associated with the maximum number of visitors between 2012-2015, the evacuation point as a whole cannot accommodate the number of visitors / refugees if a tsunami occurs.

In addition, the location / safety point of the evacuation in the study is not the same as the location for determining the safe point on the tsunami evacuation map contained in BPBD. In this study the tsunami evacuation safe location / point was used as the first rescue place for tsunami victims by
considering the arrival time of the tsunami, and could be used as a temporary tsunami victim shelter. In BPBD for tsunami victims' shelter, they use public facilities even though they are far away and heed the arrival time of the tsunami.

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