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Analysis of the Tsunami Disaster Risk Study in the Pelabuhanratu Bay Tourism Area

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ABSTRACT

The Palabuhanratu Bay area is a tourist-intensive area and the administrative center of Sukabumi Regency, so it has a very high threat of earthquake and tsunami disasters. This disaster risk assessment will form the basis of disaster management management. This research method uses a qualitative research approach with data analysis methods used are risk analysis in the form of hazard analysis, vulnerability and capacity analysis. In this study, it was found that there were 10 affected villages including Cibuntu, Cidadap, Cikakak, Citarik, Citepus, Jayanti, Palabuhanratu, Loji, Sangrawayang, and Tonjong. The tsunami risk in the affected area is classified as medium and high, meaning that the vulnerability in the 10 villages has not been efficiently balanced with regional capacity.

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1. INTRODUCTION

In 2006 in Pangandaran, West Java, there was an earthquake accompanied by a tsunami and it affected the Sukabumi coastal area. According to (Pramana, 2015), Sukabumi coastal area in the southern part of West Java is one of the coastal areas that has a relatively high level of geological hazard, because it is traversed by the active Cimandiri Fault which is the source of earthquakes with an ascending fault mechanism. On July 12, 2000, this fault reactivated and caused the Sukabumi Earthquake which caused considerable damage in several locations in the Sukabumi area. In addition, the southern coast of the island of Java is prone to tsunami disasters because it is located in an earthquake-prone zone due to the collision between the Indo-Australian oceanic plate and the Eurasian continental plate (Zakaria, 2008). The interaction of the two plates has occurred in the past and will still occur in the future. Earthquakes and tsunamis on the southern coast of Java Island can happen again at any time. The potential for disasters in Sukabumi Regency is also proven through historical records, where this region has a history of being hit by several earthquakes and tsunamis (Jokowinarno, 2011; Said, et al., 2011; Satake and Tanioka, 2003). On July 17, 2006 an earthquake occurred on the south coast of Pangandaran. The National Earthquake Center of the Meteorology and Geophysics Agency or PGN BMG stated that the earthquake that occurred in the Pangandaran coastal area occurred at 15.19 with a magnitude of 6.8 on the Richter Scale (SR), with a tectonic earthquake center at a depth of less than 30 km at 9.4 latitude. South, and 107.2 East Longitude. The earthquake also caused tsunami waves that hit the southern coast of West Java such as Cilauteureun, Kab. Garut, Cipatujah, Kab. Tasikmalaya, Pangandaran, Kab. Ciamis, the south coast of Cianjur and Sukabumi. These events should be used as lessons so that Pangandaran Regency is more alert to face disasters that can happen again at any time (Priyowidodo and Luik, 2013; Kennedy, et al., 2008; Saputro, et al., 2020).

Sukabumi Regency is located in West Java Province, which is located in the southern part of Java Island, directly adjacent to the Indian Ocean. The topography of the Sukabumi Regency includes mountains in the north and waves in the south and coastal areas in the south. This condition causes Sukabumi Regency to become a disaster-prone area. Sukabumi Regency is in the third rank of disaster-prone area in West Java Province. The disaster vulnerability experienced tends to be prone to landslides, earthquakes, and tsunamis. Part of the Sukabumi Regency area is in the south of Java Island, which is in an earthquake-prone zone due to the collision between the Indo-Australian Ocean plate and the Eurasian Continent plate (Kanamori, 1972; Pramana, 2015).

The Palabuhanratu Bay area is a tourist-intensive area so it has a very high threat of earthquake and tsunami disasters. Based on the Indonesian Tsunami catalogue, the Palabuhanratu bay area experienced small tsunamis in 2006 and 2009 with tsunami sources in Jogjakarta and Tasikmalaya. Although the source of the tsunami waves was relatively far away, the impact of the tsunami was felt by the Palabuhanratu bay area (Strunz, et al., 2011; Kimura, 2016; Paramesti, 2011). Based on these things, disaster management efforts are needed from the threat of a tsunami in the future given the potential for a tsunami to occur so quickly and its impact is very large, especially if the epicenter of the earthquake and tsunami occurred in an area close to Palabuhanratu Bay. Therefore, research on the study of tsunami risk in the Palabuhanratu Bay area was carried out as an anticipation of reducing the risk of disaster impacts and mitigation efforts in the Palabuhanratu Bay area (Pramana, 2015; Herawati, et al., 2017; Arisanti and Nugroho, 2018). So that this study can assist in the preparation of disaster management plans which can then be included in the Regional Long-Term Development Plan (RPJPD), Regional Medium-Term Development Plan (RPJMD) and

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Regional Government Work Plans (RKPD) or Regional Government Work Unit Work Plans (SKPD). Which is manifested in the preparation of programs or activities related to prevention, mitigation, and regional preparedness so that the program can run in an integrated manner in accordance with the duties and authorities of each agency for the realization of a tsunami-resilient region. This disaster risk assessment will form the basis of disaster management management. In addition, this research study tries to make a distribution of temporary evacuation sites to anticipate the impact of the tsunami which will one day occur so that people around Palabuanratu bay can save themselves to the nearest evacuation places. Thus, the implementation of disaster management programs can run in harmony and effectiveness in the context of realizing Sukabumi Regency as a disaster-resilient district (Dewi, 2019; Wahyuni, et al., 2018; Shaluf, 2007; Adiyoso and Kanegae, 2012; Desfandi, 2014; Baytiyeh and Naja, 2014; Zaqy, et al., 2018).

2. LITERATURE REVIEW

2.1 Disaster Risk Assessment

Disaster risk assessment is a tool to assess the possibility and magnitude of losses due to existing threats (Utami, et al., 2016). By knowing the possibility and magnitude of losses, the focus of planning and integrated disaster management will become more effective. It can be said that disaster risk studies are the basis for ensuring alignment of direction and effectiveness of disaster management in an area (Wahyuni, et al., 2018).

According to Law no. 24 of 2007 concerning Disaster Management, disaster risk is the potential loss caused by a disaster in an area and a certain period of time which can be in the form of death, injury, illness, threatened life, loss of sense of security, displacement, damage or loss of property. and disruption of community activities. In determining disaster risk in an area, there are three main components that are studied, namely the components of threat (hazard), vulnerability (vulnerability) and capacity (capacity) (Figure II.4). In this regard, threats indicate the possibility of occurrence of both natural and man-made events in a place. Vulnerability shows the vulnerability faced by the community in dealing with these threats. Disability is the scarcity of efforts or activities that can reduce the impact of a disaster. Thus, the higher the danger, vulnerability and disability, the greater the disaster risk faced (Kumalawati, 2015).

3. METHODS

This research method uses a qualitative research approach with the data analysis method used is risk analysis (R) in the form of hazard analysis (vulnerability) and capacity analysis (capacity). Calculation of disaster risk refers to the following concepts and formulas:

$$R \approx H \, x \, \frac{V}{C}$$

The formula can be interpreted that disaster risk has a direct relationship with threats and vulnerabilities, while risk has a non-unidirectional relationship with capacity. This relationship means that the higher the threat and vulnerability, the higher the risk of disaster, while the higher the capacity, the lower the risk. In Perka BNPB No. 2 of 2012 it is explained that in order to be able to use the formula in calculating risk, it is necessary to modify it so that the formula can be used. Multiply by inverse capacity (1-C) to avoid high values in extreme cases

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of low C values or errors such as empty C values. The result of the multiplication index must be corrected by showing the power of 1/n, to get back the original dimensions (0.25 x 0.25 x 0.25 = 0.015625, corrected 3√0.016526 = 0.25). Based on these corrections, the formula used to calculate tsunami risk is shown in the following equation.

4. RESULTS AND DISCUSSION

This chapter will explain the process and results of the risk assessment carried out in this research which includes hazard analysis, vulnerability analysis (social, physical, economic and environmental), capacity analysis and disaster risk analysis in the Palabuhanratu bay area, Sukabumi Regency.

4.1 Hazard Analysis

The modeling of the tsunami hazard zone in the study area was carried out using the ComMIT software. The data needed in the modeling process is data integration between DEMNAS and BATNAS from the Geospatial Information Agency. The data processing uses the worst case scenario, which is modeling a tsunami with a magnitude of 9.3 SR, with an ETA (estimated time arrival) of 24 minutes. The results from the ComMIT software modeling, obtained information on areas inundated by tsunamis (inundations) with varying depths of up to 25.6 meters. The modeling is a model obtained from earthquakes originating from the sea. The results of the modeling are raster data with a resolution of 100 m which shows the depth of inundation. These results are not necessarily used as an inundation area. The inundation area of the model is added to anticipate the worst possibility, the addition is made by taking into account the topography obtained from DEMNAS data. The comparison of the modeling results area with its adjustments can be seen in the image below:

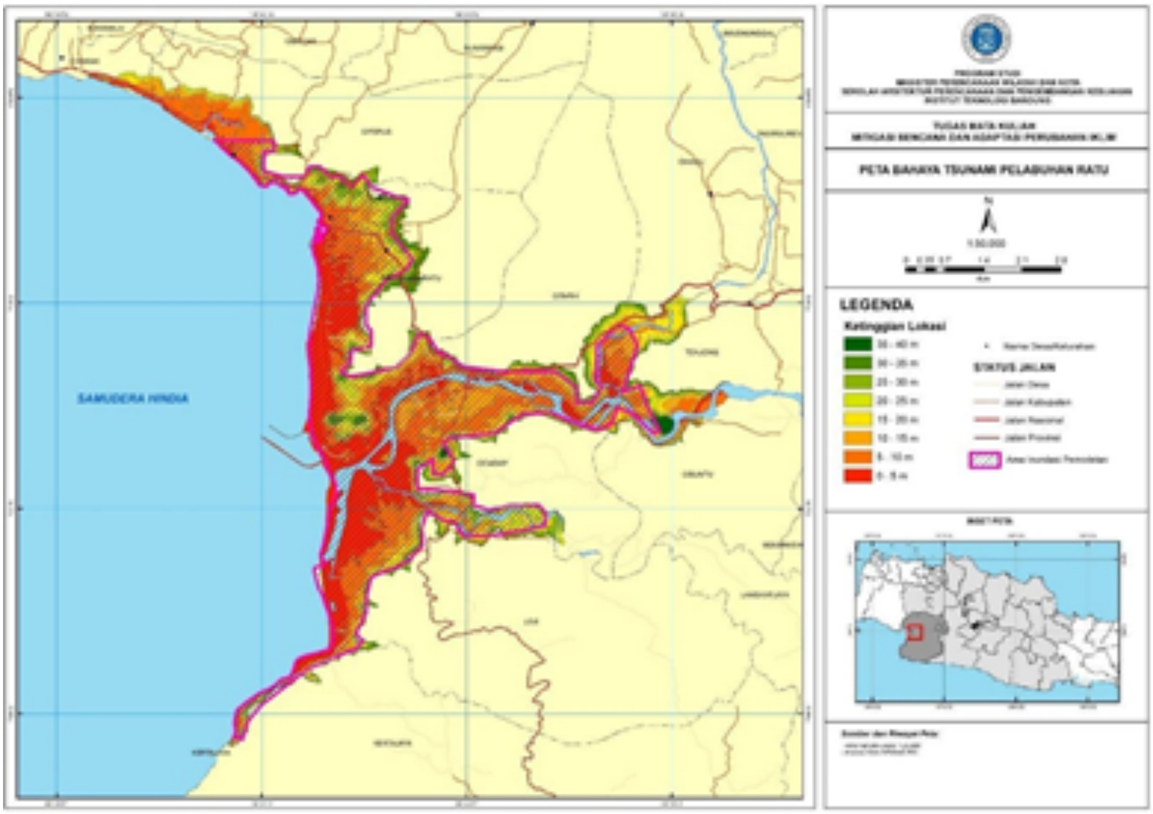

Figure 1. Tsunami Inundation Map and ComMIT Modeling Results

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The results of the adjustment of the inundation area from the model are known for the steep inundation area, the maximum height reaches 35 m, compared to the maximum height of the model, which is 25 m. In addition, for sloping areas, especially in river flows, the inundation area follows the flow of the river. The furthest distance from the inundation is 7.5 km, while the closest distance is 35 m. The inundation area is then overlaid with village administrative boundary data to find out the number and area of affected villages.

Based on the results of inundation data processing, the area affected by the tsunami was 320.26 ha out of a total village area of 1,175.51 ha spread over 10 villages, 3 sub-districts. Villages with the largest inundation area are Jayanti Village (78.37%) and Palabuhan Ratu Village (56.77%) in Pelabuhan Ratu District, while the smallest inundation area are Simpenan Village (1.93%) and Cikakak (3.74%). The distribution of villages and the area of inundation can be seen in the following table.

Table 1. The Inundation Area of the Research Area

No	Desa/Kelurahan	Luas Inundasi (Ha)	Luas Desa	Inundasi (%)
1	Cibuntu	27,84	1.438,90	**1,93**
2	Cidadap	468,45	1.195,62	**39,18**
3	Cikakak	18,71	500,81	**3,74**
4	Citarik	181,61	1.105,31	**16,43**
5	Citepus	241,55	1.175,51	**20,55**
6	Jayanti	320,26	408,63	**78,37**
7	Palabuhanratu	462,77	815,13	**56,77**
8	Loji	472,53	3.146,77	**15,02**
9	Sangrawayang	57,61	1.419,89	**4,06**
10	Tonjong	197,56	864,78	**22,85**
		2.448,89	**12.071,36**	**20,29**

4.2 Vulnerability Analysis

In identifying vulnerabilities, analysis is carried out on 4 aspects of vulnerability, namely social, economic, physical, and environmental. Vulnerability can be defined as Exposure multiplied by Sensitivity. The assets exposed include human life (social vulnerability), economic areas, physical structures and ecological/environmental areas. Each asset has its own sensitivity which varies for different disaster phenomena depending on the intensity of each disaster. The indicator used in the vulnerability analysis is exposure information. In two cases information was included on the composition of exposures such as population density, sex ratio, poverty ratio, disability ratio and age group ratio. Sensitivity is only covered indirectly through the division of weighting factors.

After each analysis of social, physical, economic and environmental vulnerability has been carried out, the vulnerability scores are combined to identify the total vulnerability of Sukabumi Regency. Calculation of the combined vulnerability or Total Vulnerability Index (IKT) is carried out referring to the formula contained in Perka BPNB No. 2 of 2012 below.

IKT = (40% x Social) + (25% x GPhysical) + (25% x Economic) + (10% x Environment)

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By referring to the formula, the following is the result of the calculation of the combined vulnerability or the Total Vulnerability Index by village.

Table 2. Calculation Results of Total Vulnerability Index

Desa/Kelurahan	**Indeks Kerentanan**				**Perhitungan Indeks Kerentanan Total**				**Kerentanan Gabungan**	
	IKS	IKF	IKE	IKL	40% IKS	25% IKF	25% IKE	10% IKL	Skor	**Indeks**
Cibuntu	1.4	1.8	2	1	0.55	0.45	0.5	0.1	1.6	**Sedang**
Cidadap	1.8	1.6	2	1	0.72	0.4	0.5	0.1	1.72	**Sedang**
Cikakak	0.6	1	1.4	1	0.24	0.25	0.35	0.1	0.94	**Rendah**
Citarik	1.2	2	2	1	0.48	0.5	0.5	0.1	1.58	**Sedang**
Citepus	0	2.1	2	1	0	0.53	0.5	0.1	1.13	**Sedang**
Jayanti	0.6	2.8	1.2	1	0.24	0.7	0.3	0.1	1.34	**Sedang**
Palabuhanratu	3	2.6	2	1	1.2	0.65	0.5	0.1	2.45	**Tinggi**
Loji	0.8	2.6	2.6	1	0.31	0.65	0.65	0.1	1.71	**Sedang**
Sangrawayang	2.3	2	2	1	0.91	0.5	0.5	0.1	2.01	**Tinggi**
Tonjong	**1.1**	**1.6**	**1.4**	**1**	**0.43**	**0.4**	**0.35**	**0.1**	**1.28**	**Sedang**

Based on the results of the combined vulnerability calculation above, it was found that the area with high vulnerability was Palabuhanratu Village with a score of 2.45. Palabuhanratu Village has a high vulnerability because it is an urban center and minapolitan activities based on capture fisheries. As a center of activity, Palabuhanratu Village has the highest population density compared to other villages/kelurahan in the western coastal area of Sukabumi Regency. The high number of population makes social vulnerability in Palabuhanratu Village classified as high, and the number of residential areas and public facilities makes the level of physical vulnerability relatively high as well.

The development of the Minapolitan sector which is accompanied by the development of the tourism sector also makes Palabuhanratu Village increasingly attractive for tourists to visit both from within and outside the country. Although the area with the highest economic vulnerability is Loji Village (triggered by the development of the tourism sector), but judging by the economic vulnerability score, Palabuhanratu Village has a score close to high vulnerability, namely 2. residential areas and public facilities as well as high economic income triggered by the development of the minapolitan sector which leads to high vulnerability.

4.3 Capacity Analysis

The capacity assessment refers to the Regulation of the Head of the National Disaster Management Agency Number 03 of 2012 concerning Guidelines for Assessing Regional

$$R \approx H \, x \, \frac{V}{C}$$

Capacity in Disaster Management. According to this regulation, capacity assessment is carried out through the Hyogo Framework for Actions (HFA) indicator assessment. HFA

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analysis data collection is ideally done with a focus group discussion (Focus Group Discussion) using a questionnaire tool. However, in this paper, the capacity assessment was only carried out through a literature review with sources available online due to limited access, time and cost. The Hyogo Framework for Action is composed of 5 priorities which are translated into 22 indicators as follows. However, to add detail to the capacity assessment in terms of evacuation sites, a sixth indicator is added, namely evacuation sites.

The results of the above capacity score analysis are then reprocessed to produce the following capacity index. This capacity index will then be used as input for disaster risk analysis.

Table 3. Results of capacity index assessment

Desa	Skor	Indeks
Desa Citarik	0.37	1.11
Desa Citepus	0.46	1.38
Desa Jayanti	0.46	1.38
Keluarahan Palabuhanratu	0.45	1.35
Desa Tonjong	0.40	1.2
Desa Cidadap	0.38	1.14
Desa Loji	0.39	1.17
Desa Sangrawayang	0.39	1.17
Desa Cibuntu	0.39	1.17
Desa Cikakak	0.47	1.41

4.4 Disaster Risk Analysis

After conducting the vulnerability and capacity analysis, a risk analysis is carried out using the results of the two analyzes. Calculation of disaster risk refers to the following concepts and formulas:

$$Risk = \sqrt[3]{Hazard \ x \ Vulnerability \ x \ (1 - Capacity)}$$

The formula can be interpreted that disaster risk has a direct relationship with threats and vulnerabilities, while risk has a non-unidirectional relationship with capacity. This relationship means that the higher the threat and vulnerability, the higher the risk of disaster, while the higher the capacity, the lower the risk. In Perka BNPB No. 2 of 2012 it is explained that in order to be able to use the formula in calculating risk, it is necessary to modify it so that the formula can be used. Multiply by inverse capacity (1-C) to avoid high values in extreme cases of low C values or errors such as empty C values. The result of the multiplication index must be corrected by showing the power of 1/n, to get back the original dimensions (0.25 x 0.25 x 0.25 = 0.015625, corrected 3√0.016526 = 0.25). Based on these corrections, the formula used to calculate tsunami risk is shown in the following equation.

Table 4. Results of Calculation of Tsunami Risk in Sukabumi District

Desa/ Kelurahan	Kerentanan	Kapasitas	Skor Risiko	Indeks Risiko
Cibuntu	1.6	1.17	1.43	**Sedang**
Cidadap	1.72	1.14	1.86	**Sedang**

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Cikakak	0.94	1.41	1.65	**Sedang**
Citarik	1.58	1.11	2.08	**Tinggi**
Citepus	1.13	1.38	1.76	**Sedang**
Jayanti	1.34	1.38	1.29	**Sedang**
Palabuhanratu	2.45	1.35	2.3	**Tinggi**
Loji	1.71	1.17	2.11	**Tinggi**
Sangrawayang	2.01	1.17	2.23	**Tinggi**
Tonjong	**1.28**	**1.2**	**1.32**	**Sedang**

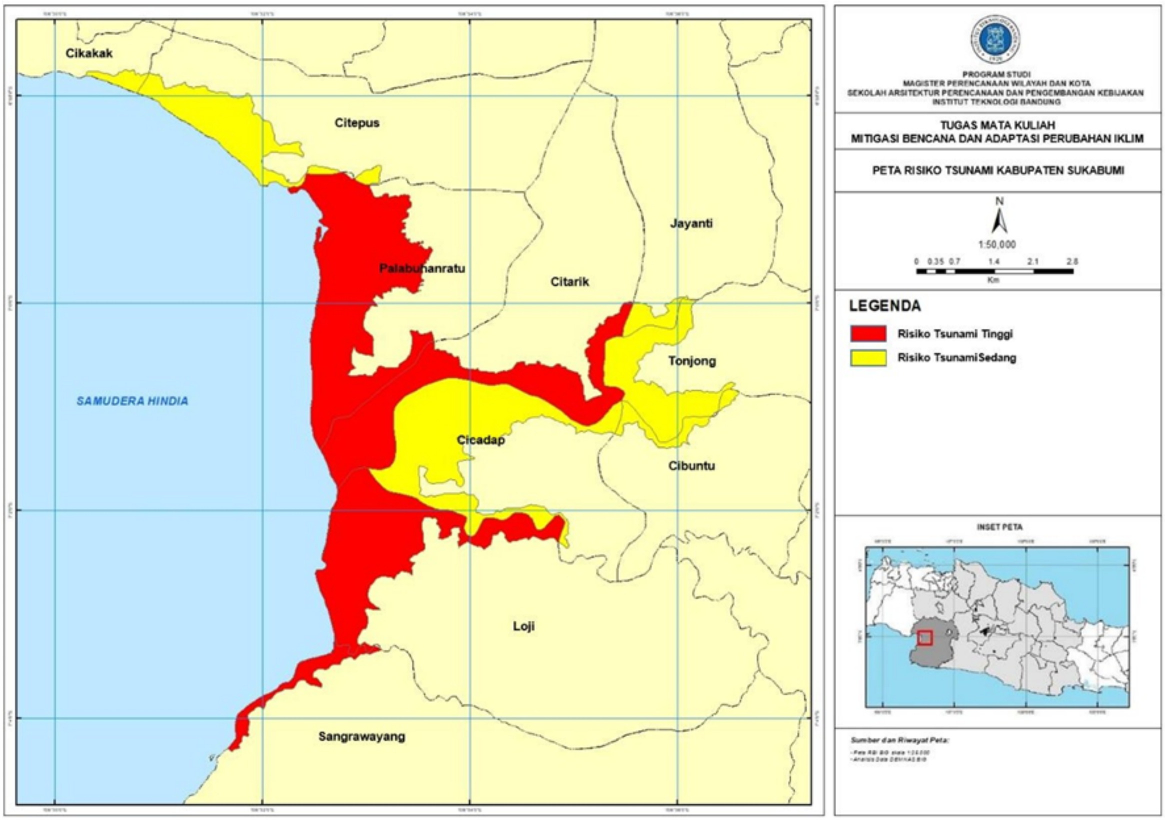

Figure 2. Tsunami Risk Map of Sukabumi Regency

Based on the risk calculation, Palabuhanratu and Loji Villages were found to be the villages with the highest tsunami risk. Meanwhile, other villages have moderate risk. The risk in Palabuhanratu and Loji villages is due to the high level of economic activity that focuses on minopolitan and tourism. The high risk in both villages is also due to the high vulnerability not being matched by the regional capacity.

5. CONCLUSION

In this study, it was found that there were 10 affected villages including Cibuntu, Cidadap, Cikakak, Citarik, Citepus, Jayanti, Palabuhanratu, Loji, Sangrawayang, and Tonjong. The tsunami risk in the affected areas is classified as medium and high, meaning that the vulnerability in the 10 villages has not been efficiently balanced with regional capacity. The analysis shows that there are 3 villages with high risk, namely Citarik, Palabuhanratu, Loji, and Sangrawayang. The four villages have a high risk due to the high level of economic activity in the form of minapolitans in the area. The development of the minapolitan sector in these

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coastal villages invites people to live near the coast which makes the population high exposed and the area of settlement is large in the four villages.

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