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RESEARCH ARTICLE

Challenges of Tsunami Risk Reduction on the Serang West Coast

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Abstract. The 2018 Sunda Strait tsunami that was not sourced from tectonics earthquakes hit the west coast of Serang Regency as one of the affected areas. On this account, addressing the tsunami risk in this region shall be done wisely through the Disaster Risk Reduction (DRR) effort. This research aims to firstly examine the DRR that has been implemented after the 2018 tsunami, and secondly identify the internal and external environmental factors, as valuable input in developing the strategies on enhancing the tsunami resilience. This research has a qualitative descriptive study, using primary and secondary data sources. The data collection techniques employ the literature studies, interviews, FGDs, and field observations. Furthermore, this study applies SWOT analysis to identify the internal and external environmental factors. The results indicate the progresses made in tsunami DRR on the west coast of Serang Regency. However, although policies for coastal area planning and management have been established, there is still a need for community socialization, proper implementation, and enforcement of the law. Moreover, both of robust tsunami early warning system and public education on vandalism prevention is also needed. Finally, the results of identifying the internal and external environmental factors show that there are 3 strengths, 3 weaknesses, 3 opportunities and 3 challenges. Accordingly, the results of this identification can be used to formulate advance strategies in increasing the tsunami resilience on the west coast of Serang Regency.

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1. Introduction

The Sunda Strait tsunami on December 22, 2018, was sourced from neither tectonics nor earthquakes. The tsunami was triggered by the eruption of Mount Anak Krakatau, and the local community did not receive previous tsunami warnings (Syamsidik et al., 2020). Anak Krakatau Mountain in the Sunda Strait released volcaniclastic material, which caused a tsunami with a height of up to 13 meters on adjacent beaches in Java and Sumatra (Grilli et al., 2019). The tsunami occurred at night and there was no significant earthquake. Thus, people were unaware which caused high number in fatalities, injuries, losses, and damages in the area around the Sunda Strait (Banten and Lampung) (Sabara et al., 2021). The affected areas in Banten Province include Pandeglang and Serang Regencies, while in Lampung Province include South Lampung, Tanggamus and Pesawaran Regencies (Widiyanto et al., 2020). This tsunami caused a total of 437 fatalities, 10 losses, 31,943 injuries, and 16,198 displaced people (BNPB, 2019).

A young volcano called Anak Krakatoa appeared above the sea in 1929 (Widiyanto et al., 2020), and almost every year, it erupts so that it grows rapidly (Ningtyas et al., 2022). Before the beginning of the 20th century, at the same location, there was an enormous volcano named Krakatau (or Krakatoa) (Takabatake et al., 2019). Mount Krakatau is one of the most active volcanoes in Indonesia. In 1883, its eruption triggered a tsunami which caused 36,000 deaths and 297 damaged villages (BMKG, 2019; Mahelda et al., 2020). Sea water raised as high as 30 m on the edge of the Sunda Strait, 4 m on the south coast of Sumatra Island, 2-2.5 m on the north and south coasts of Java Island, and 0.5-1 m in the Pacific Ocean to South America (Soloviev & Go, 1964). Moreover, according to Ponangsera et al (2021), apart from the volcanic activity of Mount Anak Krakatau, the hazard of tsunamis in the Sunda Strait also comes from seismic activity at the Megathrust subduction zone in the Sunda Strait segment.

Tsunamis generated by material avalanches are still rarely known by the public, even though they occur and cause negative impacts (Paris et al., 2020). The hazard of a tsunami in the Sunda Strait needs attention, considering that the Sunda Strait has an important role locally and globally. The Sunda Strait has a major role in connecting the islands of Java and Sumatra, which have 77.7 % of Indonesia's population (BPS-Statistics Indonesia, 2023). Besides, Serang Regency is one of the autonomous regions within the Banten Province area, which has a western coastal area directly bordering the Sunda Strait. According to Zahro (2017) the west coast area of Serang Regency has a high risk for tsunamis, up to 100 m inland from

the coastline. Related to this, Serang Regency is dominated by a high class of tsunami hazard, covering an area of 377.64 ha (Paramita et al., 2021).

The conditions of the absence of early tsunami warnings, the short travel time of tsunami waves, and various other problems during the 2018 tsunami event created major challenges in mitigation and preparedness efforts in coastal areas around the Sunda Strait. Correspondingly, this research aims to examine tsunami Disaster Risk Reduction (DRR) efforts that have been carried out after the 2018 tsunami, as well as to identify internal and external environmental factors that can be used as valuable input in developing strategies to increase resilience to tsunami hazard on the west coast area of Serang Regency. This research is important, as it delivers some implications. Firstly, by contributing to new knowledge regarding mitigation efforts and preparedness for tsunami. And secondly, by providing specific information and input that can help policy makers in developing strategies to increase resilience to the tsunami. And thirdly, by becoming a benchmarking for future research related to tsunami DRR.

2. Methods

Research was conducted on the west coast area of Serang Regency, by taking samples in 11 villages selected purposively. According to Sugiyono (2010) purposive sampling is a technique for determining research samples with justification which aims to make the data obtained more representative. The justification for determining the research location sample is the villages on the west coast of Serang Regency, facing directly to the Sunda Strait. A total of 11 villages were selected, of which 4 villages in Anyar Subdistrict (Anyar, Tambangayam, Cikoneng, and Bandulu Villages), and 7 villages in Cinangka Subdistrict (Cinagka, Kamasan, Sindanglaya, Karangsuraga, Bulakan, Pasauran, and Umbultanjung Villages). The distribution of research locations can be seen in Figure 1.

This research was conducted using a qualitative descriptive approach. The data used is both primary and secondary data, obtained from various sources. The primary data collections were carried out by expert interviews, Focus Group Discussions (FGD), and field observations. The direct interviews were conducted on 8–10 November 2022 with experts from stakeholders in Serang Regency (Regional Disaster Management Agency/BPBD of Banten Province and Serang Regency). The FGD was held at the BPBD Banten Province Office on November 9, 2022 (see Figure 2), aimed to verify the preparedness efforts against the tsunami, as well as to explore the roles and responsibilities of stakeholders. Stakeholders involved in the FGD include the BPBD, Government Social Office, Government Public Works and Public Housing Office, Government Tourism Office, and representatives from the subdistricts and villages of research locations. Moreover, field observations were carried out to complete the required primary data, as well as to verify the data and information acquired from FGDs and interviews.

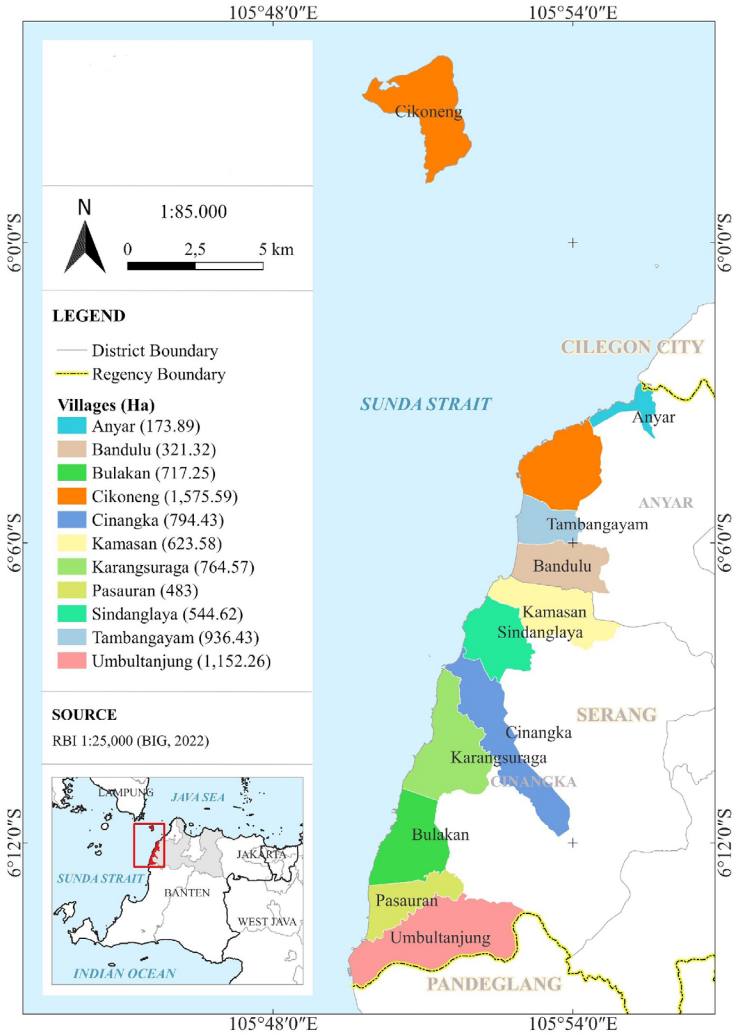


Figure 1. Research location (Source: Research Result, 2022)



Figure 2. FGD with Serang Regency stakeholders (Source: Reseach Result, 2022)

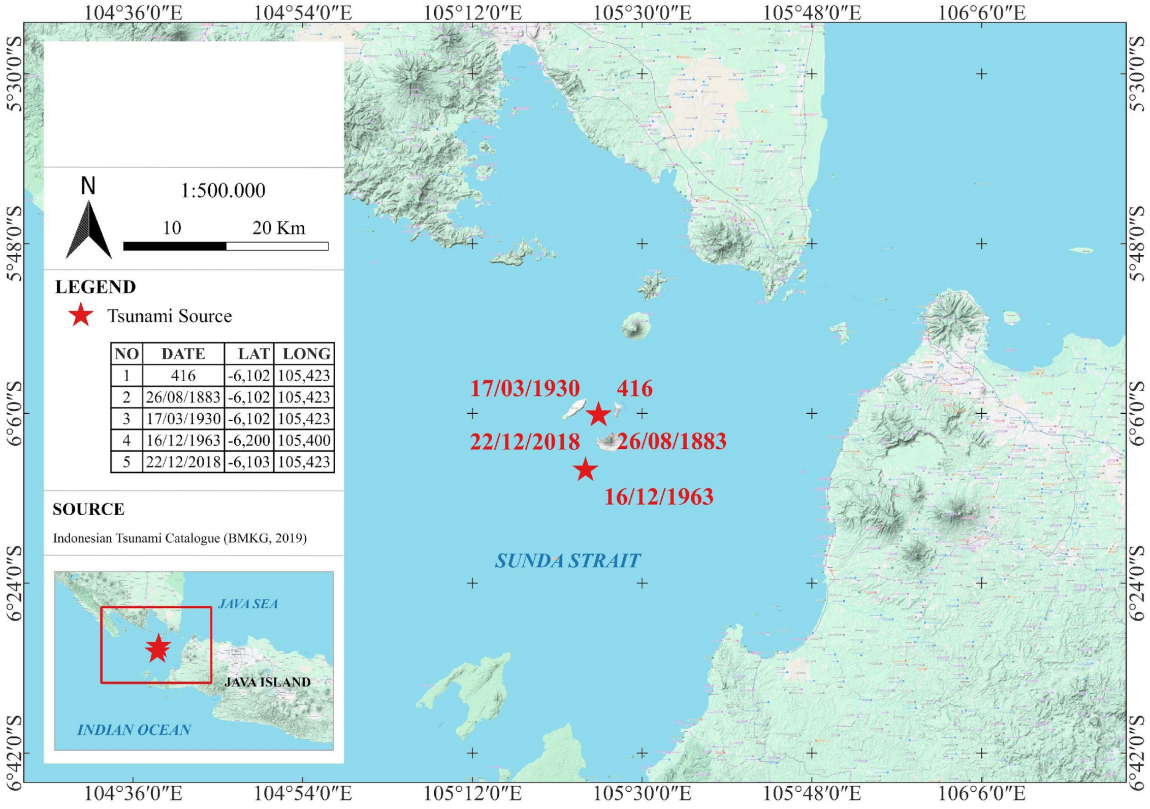


Figure 3. Tsunami sources in the Banten Region and DKI Jakarta (Source: BMKG, 2019)

Secondary data was obtained from literature studies of various documents and the results of previous scientific studies. SWOT analysis was employed to identify the resilience of the west coast of Serang Regency to tsunami hazard. According to (Rangkuti, 2013) SWOT analysis is defined as a logical analysis that can maximize strengths and opportunities, but simultaneously minimize the weaknesses and threats.

3. Result and Discussion

Potential of Tsunami Hazard on the West Coast of Serang Regency

The Serang Regency has an altitude of 0–1,778 m above sea level (m asl). Areas with a height of 0 m asl are located on the west coast of the Sunda Strait, starting from Tirtayasa Subdistrict to Cinangka Subdistrict (Serang Regency, 2015). The western coastal area of Serang Regency is situated in the Sunda Strait, facing directly to the Anak Krakatau Volcano. Topographically, the subdistrict of Anyar and Cinangka are lowlands with a gentle slope (BPS-Statistics of Serang Regency, 2023a, 2023b). The subdistrict of Cinangka has 7 coastline-bordered villages (Kamasan, Sindanglaya, Cinangka, Karang Suraga, Bulakan, Pasauran, and Umbul Tanjung). Hydrologically, there are 6 rivers in Serang Regency, namely the Ciujung, Cidurian, Cibanten, Cipaseuran, Cipasang and Anyar Rivers. Moreover, there also many rivers flowing inland, which can increase the speed of tsunami waves, thus increasing the risk of tsunamis.

According to BPBD Serang Regency (2021) earthquakes that occurred in the Banten area and its surroundings were

influenced by the activities of Megathrust subduction, and local faults (such as the Ujung Kulon Fault, Cimandiri Fault, Palabuhan Ratu Fault, and the Semangko Fault). The existence of a seismic gap in the south of the Sunda Strait indicates a process of stress accumulation in the earth's crust, which can later cause strong earthquakes and trigger tsunamis. According to Ponangsera et al (2021) the Sunda Strait Segment Megathrust Subduction Zone has a potential source to tsunami with high impact. The estimated tsunami run-up in Banten from seismic activity in the Sunda Strait Segment Megathrust Subduction Zone is 5.99 m, with a golden time of 40 minutes and 19 seconds. According to Soloviev & Go (1964) there had been two earthquakes that caused tsunamis around the Sunda Strait, i.e. on August 24, 1757 (Magnitude 7.5) and December 16, 1963 (Magnitude 6.6). Moreover, BMKG has mapped tsunami sources in the Banten area based on historical tsunami events, as seen in Figure 3.

Based on the data in Figure 3, there are 6 tsunami source points around the Sunda Strait, from tectonic and non-tectonic (volcano) sources. Tsunamis around the Sunda Strait have occurred 7 times (BMKG, 2019). Complete historical data on tsunami events around the Sunda Strait can be seen in Table 1.

Table 1 shows that the volcanic-triggered tsunami around the Sunda Strait caused high fatalities, both in 1883 and 2018. According to Soloviev & Go (1964) the height of the 1883 tsunami wave on the edge of the Sunda Strait was as high as 30 m. Meanwhile, the non-tectonic Sunda Strait tsunami in 2018 was considered a silent tsunami. And due to the lack of early warning dissemination and minimal signs before the tsunami arrived, many people became victims (Tiwi et al., 2023).

According to BNPB (2021) based on the tsunami hazard classification, Serang Regency is one of the regions in Banten Province that has a high tsunami hazard. The area of potential tsunami hazard in Serang Regency is 3,329 ha or 16.5% of the total area of potential tsunami hazard in Banten Province. Serang Regency, in terms of its level of vulnerability to tsunami, is also high. This is due to the potential exposure of 17,404 people and potential losses of 72,592 million rupiah (BNPB, 2021). Based on the tsunami risk analysis carried out by BNPB in 2021, Serang Regency is included in the high risk class, that is influenced by the classes of high hazard, high vulnerability, and medium capacity. Therefore, mitigation and preparedness efforts are highly necessary to reduce the risk of tsunami in Serang Regency.

Table 1. History of tsunami events in the Sunda Strait

No.	Date	Tectonic/ Volcanic	Tsunami source	Location		High (m)	Explanation
				Lat	Lon		
1.	416	Volcanic	Sunda Strait	-6.102	105.423	-	No information
2.	24/08/1757	Tectonic (Mag 7.5)	Jawa Sea	-6	107	0.5	No information
3.	18/03/1863	Tectonic	Jawa Sea	-	-	-	No information
4.	26/08/1883	Volcanic	Sunda Strait	-6.102	105.423	-	Mount Kratau erupted, 36,000 people died, 297 villages suffered damage
5.	17/03/1930	Tectonic	Sunda Strait	-6.102	105.423	500	No information
6.	16/12/1963	Tectonic (Mag 6.5)	Banten	-6.2	105.4	0.7	A small tsunami occurred in Labuan
7.	22/12/2018	Volcanic	Anak Krakatau Mountain	-	-	1.4–5	431 people died, 7,200 people injured, 15 people lost, 46,646 people displaced

Source: BMKG (2019)

Table 2. Tsunami evacuation routes in Serang Regency

No.	Street name	Subdistrict
1.	Umbul Tanjung Street	Cinangka
2.	Pasauran–Sadatani Street	Cinangka
3.	Bulakan Street	Cinangka
4.	Karangsuraga–Bantarwaru Street	Cinangka
5.	Karangsuraga–Cinangka Street	Cinangka
6.	Cinangka Street	Cinangka
7.	Sindanglaya Street	Cinangka
8.	Kamasan–Sindanglaya Street	Cinangka
9.	Kamasan Street	Cinangka
10.	Bandulu Street	Anyar
11.	Cikoneng–Tanjung Manis Street	Anyar
12.	Tambangayam Street	Anyar
13.	Anyar–Tanjung Manis Street	Anyar
14.	Mekarsari–Tanjung Manis Street	Anyar
15.	Grogol Indah–Banjarsari Street	Anyar

Source: Serang Regency Regional Regulation No. 5/2020

Tsunami DRR Policy in Serang Regency Post-tsunami 2018

After the 2018 tsunami, the Serang Regency Government developed a regional spatial planning strategy that had concerns about disaster-related spatial planning policies. Based on Regional Regulation No. 5/2020 concerning amendments to Regional Regulation No. 10/2011 regarding Serang Regency Regional Spatial Planning (RTRW) for 2011-2031 there are changes related to the tsunami disaster. Especially on the additional designated tsunami evacuation routes, from only 5 routes to 15 routes. Complete tsunami disaster evacuation route data can be seen in Table 2.

Based on the data in Table 2, the designated tsunami evacuation routes still have not covered all tsunami-prone areas in the 7 subdistrics of Serang Regency (Pulo Ampel, Bojonegara, Pontang, Tirtayasa, Tanara, Anyar, and Cinangka), as specified on its RTRW document. However, the tsunami evacuation routes that have been determined by BPBD Serang Regency in Cinangka and Anyar Subdistricts can be seen spatially in Figure 4. According to Fisaini et al (2022) evacuation routes have an important role in tsunami-prone areas, especially those where there are no vertical evacuation buildings. This role is supported by the opinion of (Trindade et al., 2018) that establishing evacuation routes can reduce population vulnerability, make communities more resilient, and reduce the risk of disasters.

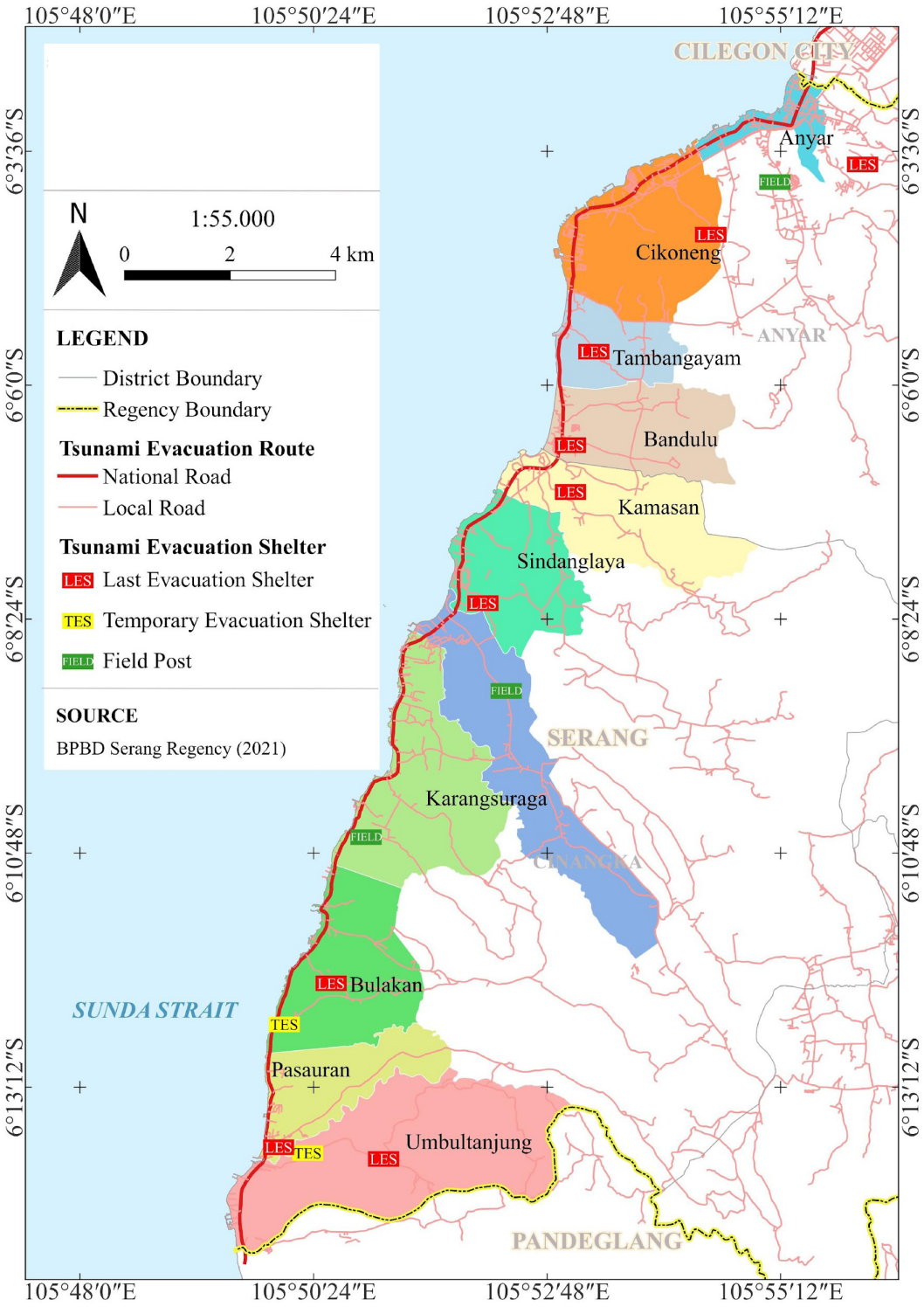


Figure 4. Tsunami evacuation routes on the west coast of Serang Regency (Source: Research Result, 2022)

In order to integrate the spatial planning based DRR, the Serang Regency government also conducts out activities in the Sunda Strait coastal area with priority locations in Anyar Subdistrict. The Head Section of the Utilization and Supervision for the Spatial Planning Sector of the Public Works and Public Housing Department of Serang Regency in his explanation on the FGD said that, to support the 2020-2024 RPJMN Major Project related to post-disaster recovery, a Detailed Spatial Planning (RDTR) for Anyar Subdistrict was prepared starting from the 2020 fiscal year. Here, there are four disaster-prone zones in the RDTR of Anyar Subdistrict, namely: 1) Development zone (new development priorities following applicable standards); 2) Conditional zone (priority function for rural settlements with earthquake-resistant buildings); 3) Limited zone (to certain functions, for example, disaster adaptive tourism); and 4) Prohibited zone (priority function as protected area, tsunami green belt and green open space).

In the RDTR of Anyar Subdistrict, the main programs related to tsunami DRR are determined, such as the development of structural and non-structural mitigation infrastructure. The development of a tsunami early warning system and tsunami retaining walls is the main structural mitigation program, while the main non-structural mitigation program consists of community development and counseling, mangrove planting, reforestation of coastal borders, as well as socialization and workshops on managing coastal border areas. According to Daulat et al (2021) built-up areas from the tourism sector dominate the coastal buffer areas of Serang Regency, in the form of buildings, facilities and infrastructure for 22.3 ha in Anyar Subdistrict and 7.2 ha in Cinangka Subdistrict. Thus, it is necessary to evaluate the implementation of coastal buffer zones in areas where there is a potential tsunami hazard to minimize impacts in the future. According to Nuryanti (2020) RDTR plays a key role in licensing space utilization because it takes into account the carrying capacity of the environment, as the substance of RDTR has a depth of analysis with a scale of 1:5,000.

Moreover, BPBD Serang Regency has established a policy, determining the tsunami evacuation places/shelters in Cinangka and Anyar Subdistricts. The shelters are integrated with buildings of worship, schools and government offices. The following Table 3 is a list of shelters designated by BPBD Serang Regency in Cinangka and Anyar Subdistricts.

Based on the data in Table 3, on the west coast of Serang Regency (Cinangka and Anyer Subdistricts) there are no buildings specifically made for shelter. All evacuation places designated by the BPBD Serang Regency are existing buildings that are given additional functions. According to (BNPB, 2013) efforts to provide shelters are very strategic to anticipate tsunami disasters, especially if the time for self-rescue (golden time) is very short and the coastal area is densely populated

Table 3. Tsunami evacuation place (shelter) in Serang Regency

No.	Village	Subdistrict	Shelter name	Mileage (m)	Height (m asl)
1.	Umbul Tanjung	Cinangka	SDN Cikokol	2,670	60
2.	Umbul Tanjung	Cinangka	Masjid Kp. Bojong Kidul	1,160	46
3.	Pasauran	Cinangka	Mess Pemda Kabupaten Serang	354	23
4.	Pasauran	Cinangka	Masjid Nur Abdillah	225	15
5.	Bulakan	Cinangka	MTs Al Khairiyah Bulakan	679	44
6.	Karang Suraga	Cinangka	Lapangan Kp. Cipacung	435	22
7.	Sindang Laya	Cinangka	Kp. Pametung Ciparay	753	28
8.	Kamasan	Cinangka	Pesantren Tahfidz An Nadzir	901	10
9.	Bandulu	Anyar	Kp. Ranca Lembang	932	26
10.	Tambang Ayam	Anyar	Kantor Desa Tambang Ayam	648	28
11.	Cikoneng	Anyar	Masjid Nurul Falah Kp. Karang Jetak	1,640	21
12.	Anyar	Anyar	SMKN 1 Anyar	2,120	21

Source: BPBD Serang Regency (2021)

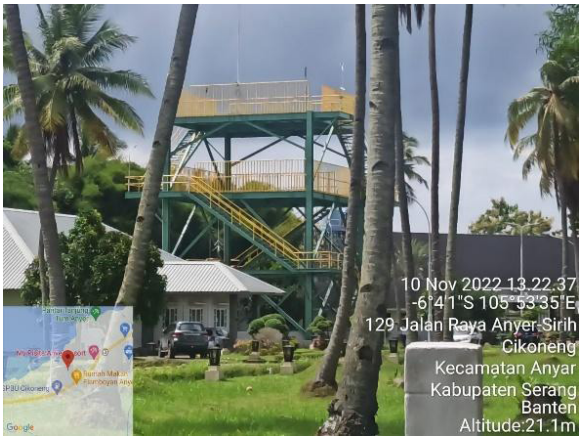


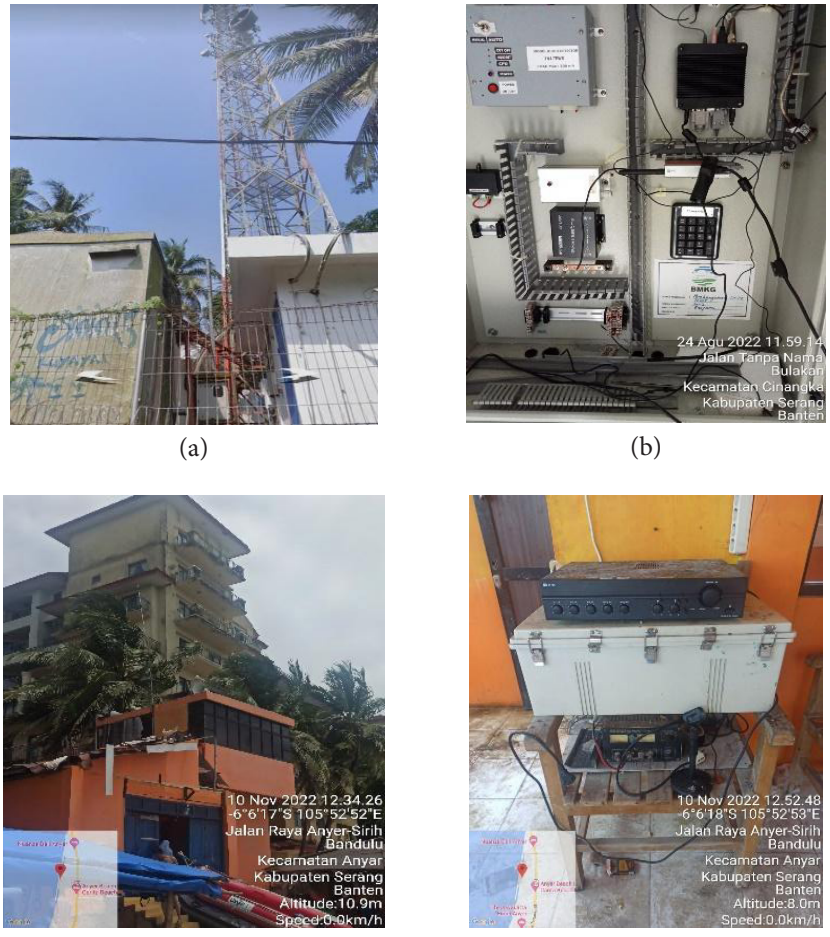
Figure 5. One of the shelters on Anyar Subdistrict (Source: Research Result, 2022)

with people and buildings. The existence of evacuation places on the west coast of Serang Regency needs to be evaluated from the aspects of capacity, evacuation routes and the community ability to reach evacuation places. Besides, population size is also an important parameter in determining evacuation places. Figure 5 shows one of the shelters on Jalan Raya Anyar, Anyar Subdistrict.

As part of the DRR tsunami, BPBD of Serang Regency has established a policy by preparing a contingency plan document for the tsunami disaster in 2021, that aimed to respond tsunami disasters quickly, precisely, and effectively. Besides, it can also arrange the roles and functions of each institution involved in handling the tsunami disaster (BPBD Serang Regency, 2021). According to Mowafy et al (2022) contingency planning is the most flexible approach and can be applied in various community conditions in order to mitigate the impact of disasters. Responses to emergency conditions may be in effective without well-defined and implemented procedures, managerial and operational systems. According to Alhadi et al (2018) with a contingency plan, stakeholders can predict the actions that will be taken when a disaster occurs, therefore they must work together to develop a comprehensive contingency plan involving all aspects. The existence of a tsunami disaster contingency plan for Serang Regency still needs to be completed with a Disaster Risk Assessment document as part of disaster risk information services, as well as a Disaster Management Plan document as a disaster prevention and preparedness service. This is in accordance with the mandate in Minister of Home Affairs Regulation No. 101/2018 concerning "Basic Service Technical Standards on Minimum Service Standards for Disaster Sub-Affairs in Regency/City".

Tsunami Preparedness in Serang Regency Post-Tsunami 2018

Based on Presidential Regulation No. 93/2019 concerning "Strengthening and Development of Earthquake and Tsunami Early Warning Information Systems", the Meteorology, Climatology and Geophysics Agency (BMKG) has the authority to provide and disseminate earthquake and tsunami early warning information. However, in the case of the tsunami in the Sunda Strait in 2018, the BMKG tsunami early warning system did not provide a warning (BMKG Earthquake and Tsunami Center, 2022). The BMKG tsunami early warning system at that time was only able to provide tsunami warnings caused by tectonic earthquakes, and was not able to process the volcanic activity of Mount Anak Krakatau, which triggered a tsunami in the Sunda Strait (Rini, 2018). In the 2018 Sunda Strait tsunami, the BMKG was only able to confirm the tsunami occurred 1.5 hours after the actual time of the event, by checking tide gauge data in the Sunda Strait (BMKG Earthquake and Tsunami Center, 2022). Here, improving and innovating the tsunami early warning system is necessary, considering that the Sunda Strait is not the only one that has the



(a) (b)

(c) (d)

Figure 6. Siren for tsunami early warning system (a) Siren building in Bulakan Village, (b) Siren device in Bulakan Village, (c) Siren building in Bandulu Village, (d) Siren device in Bandulu Village (Source: Research Result, 2022)

non-tectonic tsunami potential in Indonesia. Various volcanic activities that triggered non-tectonic tsunamis in Indonesia and caused many casualties, include the activities of Mount Gamkonora (1673), Mount Gamalama (1763 and 1840), Mount Awu (1856), Mount Ruang (1871), Mount Krakatau (1883), and Mount Rokatenda (1928) (Ibrahim, 2021). In order to solve this problem, BMKG began developing a non-tectonic tsunami early warning system or InaTNT, where the pilot project development and testing is in the Sunda Strait (BMKG Earthquake and Tsunami Center, 2022).

Another problem related to tsunami early warning on the west coast of Serang Regency is vandalism. This information was obtained from the Chief Executive of the BPBD Banten Province during the FGD, where vandalism occurred to the tsunami early warning siren device in Pasauran Village, Cinangka Subdistrict. The tsunami early warning siren in Bandulu Village, Anyar Subdistrict, was also damaged, so it did not function. It is necessary to increase the local community's knowledge of the importance of tsunami early warning sirens. The condition of the tsunami early warning siren, which was vandalized, can be seen in Figure 6.

Moreover, road access conditions are an important factor in supporting the evacuation process. However, on the west coast of Serang Regency, some roads used as evacuation routes were in a damaged condition. Some evacuation routes infrastructure also needed improvement, such as the damaged bridge in Umbul Tanjung Village and dead street lights. This condition can be dangerous, especially for the evacuation process at night. According to Refiyanni & Silvia (2020) if the evacuation route is damaged it will impact the safety of the people who use it because the travel time to the evacuation site will increase. The condition of damaged roads and bridges on the evacuation route in Umbul Tanjung Village can be seen in Figure 7.

In order to increase the community preparedness for disasters, there are intervention programs carried out by stakeholders in Serang Regency. Disaster Resilient Village (Destana) is one of the programs in Serang Regency which was initiated by BNPB. Based on the Head of BNPB Regulation No. 1/2012 concerning "General Guidelines for Disaster Resilient Villages", Destana is a village that has the independent ability to adapt and face potential disaster hazards, as well as recover immediately from the adverse impacts of disasters. As of 2021, there are already 24 Destana established in Serang Regency. According to (Akhirianto et al., 2023) lack of budget and sustainability of development program implementation are the two main problems of the Destana program. Besides, the Ministry of Social Affairs also has a Disaster Preparedness Village (KSB) program, according to Minister of Social Affairs Regulation No. 128/2011. KSB is a community-based disaster management forum that is used as an area/place for disaster management programs. Cinangka and Anyar Subdistricts have been designated as KSBs in Serang Regency. One of the facilities that must be available in the KSB is a social barn as a place for storing and providing logistics and disaster needs for disaster management preparedness. Figure 8 shows the condition of the social barns.

Tsunami DRR Challenges on the West Coast Serang Regency

The resilience of the west coast area of Serang Regency to the tsunami hazard can be identified from existing internal and external environmental factors. The internal environmental



(a) (b)

Figure 7. Damage conditions on tsunami evacuation routes (a) Road damage in Umbul Tanjung Village, (b) Damage to bridge in Umbul Tanjung Village (Source: Research Result, 2022)



(a) (b)

Figure 8. Social barn conditions (a) Sosial barn in Cinangka Subdistrict, (b) Sosial barn in Anyar Subdistrict (Source: Research Result, 2022)

factors can be seen from existing strengths and weaknesses, and the external environmental factors can be seen from opportunities and threats. The tsunami DRR carried out after the 2018 tsunami can be a strength factor, as follows:

a. There is an intervention program to increase community capacity

   Various intervention programs to increase community disaster literacy need to be done sustainably, to foster preparedness. The Destana and KSB programs are examples of intervention programs that exist to increase community capacity in facing the tsunami hazard. According to (Chen et al., 2020) the capacity of a region in reducing coastal disaster risk is characterized by the resources that can be mobilized during pre-disaster, emergency response and post-disaster.

b. There is a revision of the Serang Regency RTRW

   Changes on the Serang Regency RTRW based on Serang Regency Regional Regulation No. 5/2020 are expected to accommodate efforts to reduce tsunami risk, especially on the west coastal area of Serang Regency. According to (Sagala et al., 2021) mainstreaming the DRR in spatial planning is important from preparation to implementation, considering that disasters will occur when there is a knowledge gap in the planning process.

c. The existence of the Anyar Subdistrict RDTR

   Spatial planning in coastal buffer areas is mandated by central and regional legislation. The preparation of the RDTR for Anyar Subdistrict was facilitated by the Ministry of Agrarian Affairs and Spatial Planning/ National Land Agency, as a part of efforts in developing tourist areas based on disaster mitigation.

Moreover, the internal environmental factors included in the weaknesses based on research results are as follows:

a. Limitations of tsunami early warning device

   The western coastal area of Serang Regency still needs to improve the installed tsunami early warning sirens. The availability of tsunami early warning device is limited, and their condition is also damaged and subjected to vandalism. The existence of a tsunami early warning system is highly needed by the community, local government and related parties as a warning sign for quick evacuation, considering that not all tsunami phenomena have the same natural signs.

b. Limited tsunami evacuation facilities

   Tsunami evacuation facilities such as evacuation routes, temporary evacuation places, and evacuation route signs have been carried out by the Serang Regency BPBD. However, there is still a need to repair the roads and bridges, evaluate the capacity and strength of shelter structures, as well as socialize the tsunami evacuation routes to the community. Apart from that, shelters which function as evacuation places for the community are currently not available on the west coast area of Serang Regency.

c. There is no continuous tsunami evacuation simulation

   Tsunami evacuation simulation activities can increase the community's capacity to face the tsunami, as well as may test and evaluate the evacuation procedures that have been established in the contingency plan document, as was done by the Serang Regency BPBD on June 22, 2022 in Anyar Subdistrict. However, tsunami evacuation simulation activities need to be carried out periodically. According to BNPB, (2014) the functions of command, control and communication between stakeholders involved in the evacuation simulation are carried out, and all available resources are synergized to overcome the emergency situations.

Besides, the external environmental factors that can affect the resilience to tsunamis on the west coast of Serang Regency are divided into opportunities and threats. The following external environmental factors included in opportunities are as follows:

a. The role of universities in disaster

   Through the Tri Dharma of University, educational institutions have a role in tsunami DRR. Various activities have been carried out, including analysis of the disaster curriculum for basic education to higher education, Kuliah Kerja Mahasiswa (KKM) on disaster thematics, disaster education for the community, and disaster research.

b. Availability of village funds for disaster mitigation and preparedness programs

   Based on Government Regulation No. 60/2014 jo. Government Regulation No 8/2016, village funds are used to fund the government administration, implementation of community development, and community empowerment. In accordance with the Regulation of the Minister of Villages, Development of Disadvantaged Regions and Transmigration No. 7/2021, there are three main points regarding the priority use of village funds in 2022, one of which is to mitigate and handle natural and non-natural disasters according to village authority.

c. There is a pentahelix collaboration in tsunami PRB

   Pentahelix elements in Serang Regency played a role in the tsunami DRR, such as government elements through various Regional Apparatus Organizations (OPD), academics from universities, elements of the business (represented by hotel and restaurant owners), mass media, and elements of society. According to Arfani (2022) through pentahelix collaboration, the community gains knowledge of disasters and efforts to reduce disaster risks, so that the community has preventive knowledge on the potential disasters.

Finally, the external environmental factors included in the threats based on the research results are:

a. Potential hazard of tectonic and non-tectonic tsunamis

   Based on various previous research, there are a tsunami hazards on the west coast area of Serang Regency, sourced from the tectonic plate of Sunda Megathrust for tectonic, as well as from the non-tectonic activity of the Anak Krakatau Volcano.

b. Potential for increasing population density in coastal areas

   Population density in Cinangka District 546 per km^2 in 2020 to 562 per km^2 in 2022. And the population density of Anyar District increased from 1,034 per km^2 in 2020 to 1,067 per km^2 in 2022 (BPS-Statistics of Serang Regency, 2021, 2023c). Population density is an important variable that can provide an overview of the population at risk and population concentration in disaster-prone areas.

The higher the level of population density, the higher the vulnerability to the risk of tsunami.

c. Potential to increase the number of tourist visits

After the 2018 tsunami disaster, beach tourism visitors in Serang Regency tended to increase, from 347,807 visitors in 2019 to 350,821 visitors in 2022. According to Prihartanto et al (2023) the more tourist visitors, the greater the potential for people to be affected by a tsunami.

4. Conclusion

Some progress in tsunami DRR has been achieved on the west coast of Serang Regency after the 2018 tsunami. However, there are still challenges and gaps that need to be addressed to increase resilience to tsunamis. Firstly, the existence of a robust tsunami early warning system, which can detect seismic and non-seismic tsunamis, is urgently needed. Considering that the tsunami hazard does not only come from tectonic earthquakes, but also from non-tectonic ones (the activity of the Anak Krakatau Volcano). Secondly, the existing tsunami early warning device and evacuation infrastructures needed to be improved and protected from vandalism. So that the hazard of tsunamis on the west coast of Serang Regency can be anticipated with mitigation and increased preparedness.

Moreover, spatial planning in Serang Regency is gradually being adapted to be more sensitive to disasters in order to reduce disaster risks. The policy for structuring and managing coastal areas based on disaster mitigation has been implemented since 2020, through the revision of the RTRW and the preparation of the RDTR for Anyar Subdistrict. It requires good socialization to the community, followed by appropriate programs and budget allocation. Apart from that, implementation needs to be monitored and accompanied by law enforcement to minimize the impact of tsunamis that could occur in the future.

Furthermore, ther is an urgent need for innovative approaches that can reduce tsunami risks, one of which is by educating the public about the risks and signs of tsunamis as well as how to respond and act early. And formulating a strategy to increase resilience to tsunamis can be done by utilizing 3 strengths and 3 opportunities, as well as minimizing 3 weaknesses and 3 existing threats. Apart from that, synergy between stakeholders and the sustainability of existing tsunami DRR programs are needed, because this will also determine the success of collaborative work to create a tsunami-resilient west coast of Serang Regency.

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