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Analysis of adaptation and mitigation recommendations for Banjir rob disasters in the coastal area of Belawan, Medan

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Abstract
The Belawan Coastal Area in Medan is experiencing Banjir ROB/Tidal floods due to rising sea levels, resulting in the submergence of settlements, ponds and Warehouses. The increasing height of these floods each year amplifies the affected areas and leads to economic losses, particularly in vulnerable sectors. To address this, effective adaptation strategies are necessary based on the identified vulnerability factors content analysis is used to assess the relevance and application of adaptation measures, while qualitative descriptive analysis generates recommendations. These vulnerability factors are categorized into physical, social, economic, and environmental aspects. Mitigation efforts involve planning and organizing the coastal environment, while preparedness focuses in community readiness and capacity-building for disaster response. The response phase prioritizes accurate handling and meeting the needs of affected communities. Rehabilitation and reconstructions activities encompass physical, social, economic and environmental aspects, aiding in the recovery from tidal floods. By adopting a comprehensive disaster risk management approach, the Belawan Coastal Area can enhance its resilience and minimize the impact of ROB/tidal floods.

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Introduction

The continuous increase in the demand for groundwater, particularly in urban areas, raises concerns about the possibility of over-pumping, as noted by Chandra (2013) [1]. Over-pumping of groundwater can lead to the formation of cavities within the aquifer layers. If this issue is left unaddressed, it can result in land subsidence, water intrusion, and contamination with arsenic, as highlighted by Maghfira (2018) [2]. Failure to replenish aquifers with groundwater from conservation areas further exacerbates the problem. This phenomenon contributes to the sinking of the ground level, particularly in areas where the supply from upstream regions is inadequate.

The issue of tidal flood disasters, also known as "rob," is prevalent in Medan City. According to the Regional Disaster Management Agency (BPBD) of Medan City, six sub-districts in Medan Belawan, including Belawan 1, Belawan 2, Sicanang, Bahari, Bahagia, and Bagan Deli, have been affected. This situation arises from the high water level, reaching up to 70 centimeters, caused by tidal fluctuations. Approximately 15,000 houses have been submerged, and the lives of 70,685 individuals have been disrupted. The floods typically begin in the early afternoon and recede by evening. Residents have expressed difficulties in carrying out daily activities and practicing their religious rituals during the holy month of Ramadan due to the floods. They hope that the local government and the provincial administration will take prompt action along the coastline to mitigate the impact of future tidal floods.

The Medan City Government is planning to construct free raised houses for residents living in North Medan. The purpose of

building these raised houses is to address two issues: tidal floods and the need for suitable housing. The construction of raised houses will be specifically allocated for 600 households with a 36-square-meter floor plan. The raised houses will be provided to the residents free of charge. In addition to building raised houses, green open spaces (RTH) will be established by planting mangrove trees as an effort to anticipate tidal floods. The condition of the northern coastal area of Medan City demands attention to conduct research on mapping the areas prone to tidal floods as a disaster mitigation effort. This mapping is essential to help stakeholders understand the factors that influence the zones and vulnerability levels of ROB/tidal floods in the northern part of Medan City.

The objectives of this research are as follows: (1) Determine the distribution of vulnerability levels to ROB/tidal floods in the Belawan Coastal Area of Medan City; (2) Identify the factors causing the vulnerability levels of tidal floods in the Belawan Coastal Area of Medan City; and (3) Formulate guidelines for adapting to the areas prone to tidal floods in the Belawan Coastal Area of Medan City.

Literature

In the development of an area, the reality often faced is the limited availability of funds, while there are numerous proposals from each sector (Tarigan, 2006) [4]. On the other hand, sustainable development should exert pressure on the economic, social, political, and institutional mechanisms, both from the private sector and the government, in order to rapidly improve the standard of living of the community. According to the Republic of Indonesia Law No. 1 of 2011 concerning Housing and Settlement Areas, it is a unified system that consists of housing development, settlement area management, maintenance and improvement, prevention and quality enhancement of slums and settlements, land provision, funding and financing systems, as well as community involvement. The establishment of orderly settlement development, as stated by Doxiadis in Soetomo (2009) [3], is that human settlements are, by definition, settlements inhabited by humans. Settlements should consist of contents (the inhabitants) and containers (the physical settlement) that serve as the living environment for humans and their activities. According to Doxiadis' theory in Soetomo (2009) [3], one element of the container is shells, which refer to the built environment, including residential buildings and structures. This indicates that housing is one of the essential elements in the formation of settlements and cannot be separated from other elements.

Analyzing coastal areas in housing development, the main problem is the rise in sea levels, which is an increase in the volume of seawater caused by complex factors (Pugh, 1987). The rise in sea levels is influenced not only by tidal processes but also by global climate change and human activities (Asmaul, 2008). The inundation resulting from the sea level rise is also known as tidal floods, and in Indonesia, it is commonly referred to as "banjir rob" (Setiyono, 1994). The increase in sea levels due to tidal effects can be predicted and measured in terms of magnitude and timing (Triadmojo, 1999, as cited in Martius, 2006).

The study conducted by Wunarlan (2019) on the flood disaster in Ipilo and Bugis Villages in Gorontalo City revealed that it was caused by natural factors, land-use change, and negative behavior of the population along the riverbanks who disposed of waste into the river. The adaptation measures taken by the residents included modifying the environment and their living spaces, as well as actively participating in preparedness and mutual assistance during natural disasters.

In another study by Silva Berlus Corni (2013) titled "Identification of Potential Sea Level Rise and Its Impacts on Spatial Structure and Pattern Planning in the Coastal Area of Balikpapan City, East Kalimantan Province," it was found that the spatial structure plan of Balikpapan City, particularly the central activity center and infrastructure network plans, influenced the sea level rise. The affected spatial pattern plans included plans for mangrove areas, protected forests, non-polluted industrial areas, residential areas, Pertamina areas, integrated fishery trading centers, and agropolitan areas.

Bayu Trisna Desmawan (2011) conducted a study on the adaptation of coastal communities to tidal floods in Sayung District, Demak Regency, Central Java. The study found that tidal floods caused damage to buildings, fishpond areas, tools and equipment, as well as vehicles used by the local community. The adaptation measures taken by the community included modifications to their residential buildings, ensuring the availability of clean water sources, and community-level adaptations.

A study by Anggara Dwi Putra (2013) titled "Study of Adaptation Forms to Flood and Tidal Flooding Based on Regional Characteristics and Activities in Tanjung Mas Village" showed that there were no differences in the adaptation measures taken by the community based on social strata or livelihood. The adaptation measures included raising the floor level of residential buildings and roads.

Overall, these studies highlight the importance of understanding the factors contributing to flood and tidal flooding disasters, as well as the need for community-level adaptations to minimize the impacts and enhance resilience in coastal areas.

Research Method

This study is a qualitative research with a rationalism approach. The rationalism approach holds the belief that reason is the source of all truth (Endro, 2010). The study utilizes both theoretical and empirical analytic methods, which involve the use of theories to analyze factors of vulnerability to tidal flooding and adaptation in flood-prone areas. The research was conducted in the Belawan District of Medan City.

The data collected for this study includes both primary and secondary data. The sampling technique employed is purposive sampling. The objects of purposive sampling in formulating the directions for adaptation in flood-prone areas in the Coastal Belawan Area of Medan City are stakeholders representing the government (governance), private sector, and civil society.

The theoretical and empirical analytic methods, along with the purposive sampling technique, allow for a comprehensive examination of the factors contributing to vulnerability to tidal flooding and the adaptation measures taken by various stakeholders in the study area. By involving different sectors and perspectives, the research aims to provide valuable insights for developing effective strategies and directions for adaptation in flood-prone areas.

Table 1: Respondents of Purposive Sampling - First Target Group

No.	Party	Expertise
Pemerintah		
1.	BPBD Medan City	BPBD Medan City plays a role in coordinating the planning and implementation of flood and emergency disaster management activities in the Coastal Belawan Area of Medan City.
2.	Dinas PU Medan City	Dinas PU Medan City is involved in formulating technical policies in the field of Public Works, particularly in dealing with tidal flood disasters in the Coastal Belawan Area of Medan City.
Private Sector		
3.	Fisherman group Belawan I Belawan II Belawan Bahagia Belawan Bahari Belawan Sicanang Bagan Deli	Fishermen groups can provide an overview of the tidal flood conditions in the research area, contributing to a deeper understanding of the factors involved in solving the research problem.
Civil Society		
4.	Community Leaders	Community leaders can provide information about tidal flood disasters in the research area, offering insights into determining an ideal pattern of adaptation for the Coastal Belawan Area of Medan City.

***Source*:** Identified By Researcher, 2022

Table 2: Respondents of Purposive Sampling - Second Target Group

No	Government	Expertise
Sector		
1.	BPBD Medan City	Coordinates planning and implementation of flood and emergency disaster management activities in Medan City
2.	Dinas PU Medan City	Formulates technical policies in the field of Public Works for flood and tidal flood disaster management in Medan City
3	BPBD North Sumatera Province	Plans and implements disaster management in the province and districts/cities based on policies set by the National Disaster Management Agency
Private Sector		
4.	Fishermen Groups in Medan Belawan District	Provides an overview of the flood and tidal flood conditions in the research area, contributing to a more comprehensive understanding of the research problem
Society		
5.	Academics	Provides input on relevant adaptation patterns to be implemented in the research area, offering insights into flood and tidal flood disaster management in the Belawan Coastal Area, Medan City
6.	Community Leaders in Sub-districts	Provides information about flood and tidal flood events in the research area, aiding in determining the ideal adaptation patterns for the flood-prone Belawan Coastal Area, Medan City

***Source*:** Identified by Researcher, 2022

The analysis used to determine the factors influencing the vulnerability to tidal flood is content analysis. Content analysis is an analysis technique that relies on codes found in recorded data during interviews with subjects in the field (Bungin, 2007). It starts with coding the transcribed interview notes. These codes represent categories developed from the research questions, hypotheses, key concepts, or important themes (Miles & Huberman, 1992). Deductive content analysis is used to identify influential factors, testing categories, model concepts, or hypotheses. Deductive content analysis is employed when the analysis structure is based on prior knowledge and the research aim is theory testing (Kyngas & Vanhanen, 1999).

In this phase, the vulnerability factors to tidal flood are derived from the synthesis of literature reviews, including studies, research, and theories related to tidal flood disasters. The results of the literature review synthesis are then confirmed with the selected stakeholders through purposive sampling. Through in-depth interviews, the chosen stakeholders will validate the vulnerability factors related to tidal flood in the Belawan Coastal Area, Medan City.

Result and Discussion

By using the coastline map of Belawan, slope map, and land cover map in Medan Belawan, the vulnerability map of tidal flood in the area is obtained. Through overlay analysis and buffer functions, areas with low, moderate, and high vulnerability to tidal flood in Medan Belawan are identified. The distribution of affected sub-districts by tidal flood based on the analysis using Geographic Information System (GIS) is shown in the following Table 3.

Table 3: Sub-Districts Affected by Tidal Flood in Medan Belawan

The extent of vulnerability to tidal floods (ROB)							
No.	Subsdistrict	Low		Medium		High		Total
		Ha	Persentase	Ha	Persentase	Ha	Persentase	
1	Bagan Deli	4.01	1.13%	58.00	16.3%	294.38	82.60%	356.40
2	Belawan Bahagia	0.22	0.31%	3.65	5.3%	65.50	94.43%	69.36
3	Belawan Bahari	31.55	10.04%	159.67	50.8%	123.08	39.16%	314.29
4	Belawan I	5.37	2.01%	67.36	25.2%	194.41	72.78%	267.14
5	Belawan Ii	0.02	0.01%	50.28	30.0%	117.33	70.00%	167.62
6	Belawan Pulau Sicanang	64.27	3.65%	1340.20	76.1%	357.66	20.30%	1762.13
	Total	105.44	3.59%	1679.15	57.2%	1152.36	39.24%	2936.95

***Source*:** Data Proceed, 2023

In Table 3 above, it can be seen that the estimated sub-districts affected by ROB/ tidal floods vary. Almost all sub-districts in Medan Belawan fall into the categories of Low, Moderate, and High Vulnerability. The tabulation results in the table indicate that overall, the Medan Belawan sub-district is classified as follows: 105.44 hectares (4%) in the Low Vulnerability category, 1,679.15 hectares (57%) in the Moderate Vulnerability category, and 1,152.36 hectares (39%) in the High Vulnerability category. The visualization of tidal flood vulnerability in Medan Belawan can be seen in the following image.

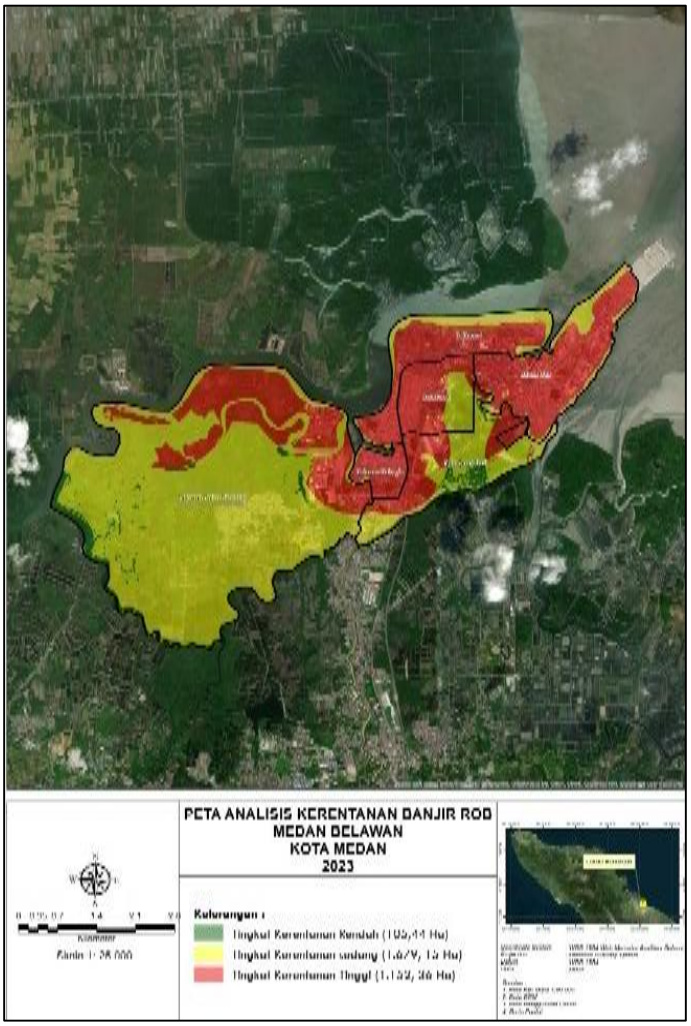

Fig 1: Map of Tidal Flood Vulnerability in Medan Belawan

Based on the qualitative descriptive analysis, adaptation directions that can be applied in the research area have been obtained. These adaptation directions encompass several phases: mitigation, preparedness, response, and recovery. In

addressing vulnerability factors, there are several vulnerability factors that can be addressed through multiple phases of adaptation, as tackling these factors may require more than one phase alone. Some of the vulnerability factors in the Coastal Area of Belawan, Medan City, include high building density, flooded road networks, suboptimal drainage systems, settlements located in low-lying areas, inundated public facilities, high population density, declining income in vulnerable sectors, reduced water absorption areas, decreased mangrove forest areas, settlements located near rivers, and built-up areas on former marshlands.

Here are the adaptation directions for the mitigation phase in the Coastal Area of Belawan, Medan City:

1. Construction of Embankments

Construct embankments in low-lying areas of the research area, specifically along the coastline and river estuaries. Focus on areas with residential settlements below sea level. Embankments can be constructed using materials such as concrete or river stones, tailored to the characteristics of each area. In shrimp farming areas, embankments should be accompanied by the installation of nets and screens to protect the fish habitat from being swept away by tidal floods.

2. Construction of Water Gates

Constructing water gates is considered effective in addressing tidal floods that enter through rivers in the research area. The water gate system should be designed to open during low tide and close during high tide, effectively mitigating tidal flood events. Focus on constructing water gates at river estuaries directly facing the sea.

3. Coastal, River, and Marshland Development Restrictions

Based on the existing conditions, many buildings have been constructed inappropriately, leading to the conversion of water absorption areas into built-up areas. This exacerbates the impacts of tidal floods. Therefore, restrictions on building construction in water absorption areas are necessary to minimize flood inundation. Limiting efforts can be implemented through incentive and disincentive mechanisms, as well as tightening building permits (IMB) in water absorption areas. Additionally, local regulations are needed to control land use allocation in the research area for building development.

Relocation of settlements and infrastructure, including facilities and amenities, is an adaptation measure aimed at avoiding inundation or hazards. In the case of tidal floods, residential settlements and other critical infrastructure should be relocated to higher ground to avoid flood disasters. Long-term adaptation to tidal floods in the research area requires development and spatial planning. This involves the implementation of control instruments that regulate zoning and land use allocation in flood-prone areas. Additionally, in the context of disaster-resilient spatial planning, a master plan is needed to regulate protective facilities, including evacuation routes and locations of community shelters from disasters in the research area.

The formation of disaster-prepared communities is based on a paradigm shift in disaster management. In disaster management, involving the community as a subject rather than an object is essential. The community should be actively involved in disaster management activities, particularly because they have a good understanding of the research area. In this regard, the formation of community-based disaster-preparedness groups aims to create communities that are prepared for tidal floods from an early stage. These community groups play a role in planning emergency response actions for tidal flood disasters, with guidance from the government, especially the Regional Disaster Management Agency (BPBD).

The formation of this working group is an effort to coordinate between departments or relevant agencies in the mitigation of flood and tidal flood disasters. Agencies involved in flood and tidal flood disaster management, such as the Department of Public Works, Department of Social Affairs, Department of Marine Affairs, Department of Health, and the Regional Disaster Management Agency (BPBD) as the coordinating body, participate in the establishment of this working group. The formation of this working group aims to formulate integrated disaster management efforts, where the actions taken are not isolated between agencies but are unified.

Mapping of flood and tidal flood-prone areas is a mitigation effort carried out to identify areas at risk of flood and tidal flood disasters. This effort is considered relevant because there has been no previous mapping conducted in the research area regarding flood and tidal flood disasters. Mapping efforts are carried out by identifying flood-affected areas, including the extent of inundated areas, affected communities, and the resulting losses.

1. Provision of Flood and Tidal Flood-Prone Area Maps

The provision of flood and tidal flood-prone area maps aims to provide information to the communities in the research area. The existence of these maps can serve as a reference for the community to formulate preventive measures against flood and tidal flood disasters. The maps should also include evacuation routes, temporary evacuation locations, and the locations of observation posts and sea level monitoring stations. These maps can be placed in strategic locations such as community offices and other accessible areas.

2. Conservation of Mangrove Forests in Flood and Tidal Flood-Prone Areas

The development of mangrove forests indirectly helps minimize the impact of flood and tidal flood disasters on mainland areas. Mangrove forests generate sedimentation and mud deposition, which act as natural barriers in preventing flood and tidal flood events. Moreover, the presence of mangroves as habitats for marine organisms indirectly benefits coastal fishermen in the research area. After describing the guidelines for adapting to flood and tidal flood-prone areas in the Belawan Coastal Area in Medan City, the following table presents the categorization of adaptation guidelines to reduce vulnerability factors in the research area.

Table 4: Adaptation Guidelines for Flood and Tidal Flood-Prone Areas

Guidelines for Adaptation in Flood and Tidal Flood Prone Areas	Construction of elevated houses on stilts
	Construction of embankments
	Installation of flood gates
	Construction of pumping stations
	Implementation of a polder system consisting of embankments, reservoirs, flood gates, and pumping stations
	Restriction on development along coastal areas, rivers, and swamps
	Relocation of settlements affected by flood and tidal floods to higher areas
	Planning and development of coastal spatial zoning based on climate change adaptation

***Source*:** Data Processed, 2023

The Coastal Area of Belawan, Medan City is predominantly used for residential, warehousing, and aquaculture purposes. Therefore, in this adaptation guideline, it will be categorized based on land use in the study area. The adaptation guidelines will be tailored to each land use, with reference to the Spatial Planning of Medan City. The following is the categorization of adaptation measures for each land use to facilitate visualization of the adaptation guidelines in the study area. The implementation of these adaptation measures will focus solely on the mitigation phase, while preparedness, response, and recovery phases are considered beyond the scope of spatial adaptation.

Table 5: Adaptation Guidelines for Each Land Use

No.	Land Use	Adaption Guidelines
1	Residential	1. Restrict development in coastal areas, riversides, and marshlands. a. Implement incentive and disincentive mechanisms, where incentives are provided for buildings that meet recommended requirements, and disincentives are imposed for buildings that violate designated rules. b. Tighten building permits in water infiltration areas. c. Control building development through zoning regulations related to land use in those areas.
		2. Construction of Embankments a. Construct flood barriers along the coastal areas, focusing on residential areas located below sea level. b. Build embankments using concrete or cobblestone materials. c. Enhance embankments with sidewalks to serve dual purposes.
		3. Contruction Of Water Gates a. Construct water gates at every river estuary that directly faces the sea.
		4. Construction of Pump Houses a. Construct pump houses at every river estuary that directly faces the sea. b. Construct pump houses accompanied by the construction of reservoirs that function as temporary storage when river volume is high.
		5. Construction of Stilt Houses a. Adjusting building structures to the concept of stilt houses, where communities are encouraged to renovate their houses with a stilt house concept. b. Construction of stilt houses should be focused in areas that are frequently affected by flood and tidal flood, such as those near the coast, rivers, and marshes. c. Relocation of Flood and Tidal Flood-Affected Settlements to Higher Grounds
2	Aquaculture	1. Construction of embankments along with periodic embankment raising 2. Installation of nets and screens around the fish ponds 3. Construction of inter-pond water channels 4. Conservation of mangrove forests in flood and tidal flood-prone areas: a. Preserve existing mangroves in the research area b. Construction of offshore breakwaters in front of mangrove forests c. Improve mangrove planting patterns in accordance with the resilience of coastal habitat types
3	Warehousing	1. Restrict construction in coastal areas, riversides, and marshes a. Incentive and disincentive mechanisms: Incentives are provided when buildings meet the recommended requirements, while disincentives are given when buildings violate the specified rules. b. Tightening building permits in water absorption areas. c. Controlling building development through zoning regulations related to land use in the area.

***Source*:** Data Processed, 2023

Result and Recommendation

Factors influencing the vulnerability to tidal flood disasters include slope steepness, coastal proximity, and land use. The adaptation and mitigation guidelines for flood-prone and tidal flood-prone areas in the coastal region of Belawan, Medan, consist of the following measures: construction of raised houses, embankments, floodgates, pumping stations, polder systems comprising embankments, reservoirs, floodgates, and pumping stations; restrictions on development along the coastal areas, rivers, and swamps; relocation of settlements affected by tidal floods to higher areas; planning and development of coastal spatial zoning based on climate change adaptation and Integrated Coastal Zone Management (ICZM).

Based on research findings regarding the analysis of recommendations for adapting and mitigating tidal flood disasters in the coastal region of Belawan, Medan, the community needs to enhance skills and optimize coastal

resources. Additionally, the community should increase the role and capacity of local communities in managing tidal flood disasters and maintaining the quality of settlement environments. Furthermore, it is essential to delineate or zone each area within the research area to establish tailored guidelines based on the specific characteristics of each area.

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