

Identification of Settlements in Disaster-Prone Areas and Disaster Mitigation Strategies in Denpasar City

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ABSTRACT

Denpasar City, as the economic and administrative center of Bali Province, faces significant disaster risks due to its geographical location and rapid urbanization. This study aims to identify and map residential areas located in disaster-prone zones in Denpasar and to formulate appropriate disaster mitigation strategies. A spatial analysis approach was employed, utilizing Geographic Information System (GIS) technology to overlay settlement distribution maps with multi-hazard disaster-prone maps (tsunami, earthquake, liquefaction, and flood) obtained from the Denpasar City Rencana Tata Ruang Wilayah (RTRW) and related agency data. The analysis was complemented by field surveys to verify the conditions of affected settlements. The results reveal that a substantial portion of residential areas in Denpasar is situated within high-risk zones. Specifically, settlements in South Denpasar District are highly exposed to tsunami, earthquake, and liquefaction threats, while flood risks are more widespread across West, South, East, and North Denpasar. The findings underscore a critical gap between rapid spatial development and disaster risk considerations. Consequently, this study recommends the integration of disaster risk zoning into spatial planning, the development of disaster-resistant infrastructure, the strengthening of building codes, and the establishment of clear relocation protocols for settlements in the highest-risk areas. The study implies an urgent need for coordinated efforts between the government and communities to enhance urban resilience and minimize potential future losses.

INTRODUCTION

According to Law Number 24 of 2007, a disaster is an event or series of events that threaten and disrupt people's lives and livelihoods, caused by natural, non-natural, and/or human factors, resulting in human casualties, environmental damage, property loss, and psychological impacts (Law No. 24 of 2007 concerning Disaster Management, 2007). A disaster is also understood as a serious disruption to the functioning of a community or society on a varying scale, caused by hazardous events interacting with conditions of exposure, vulnerability, and capacity, leading to human, physical, environmental, and economic losses (UNDDR, 2020). Indonesia is a country with a high level of disaster risk due to its geographical position in the Ring of Fire and at the convergence of three tectonic plates, making almost all regions, including Bali Province, vulnerable to geological and hydrometeorological hazards (BNPB, 2023).

As the center of economic activity and tourism in Bali Province, Denpasar City faces tremendous urbanization pressure (As-syakur et al., 2023; Devina & Prabowo, 2025; Suyadnya

et al., 2025). Population growth, land-use change, and development pressures that pay insufficient attention to sustainability have increased disaster vulnerability (Sutrisna et al., 2025). Rapid development often exceeds environmental carrying capacity and ignores disaster vulnerability zoning. Geographically, Denpasar has a high potential risk of various natural disasters, ranging from earthquakes and tsunamis to hydrometeorological events such as floods, extreme waves, and strong winds (Desportes et al., 2024; Dutta et al., 2026). These disasters can cause extensive material losses, particularly damage to residential areas and public facilities (Comerio, 2023; Krichen et al., 2024; Zengin & Aydin, 2023). Damage to housing requires special attention because, if not properly anticipated and planned for, it can lead to a decline in community quality of life (Sandri et al., 2023).

According to Law Number 1 of 2011, housing and residential areas must be organized to ensure the provision of livable and affordable housing in healthy, safe, harmonious, planned, integrated, and sustainable environments. Law Number 26 of 2007 on Spatial Planning likewise mandates spatial planning to safeguard spatial functions and prevent negative environmental impacts arising from land-use activities (Geyer Jr, 2023; Kuncorowati et al., 2024; Permana, 2023; Purba et al., 2025). Identifying the distribution of settlements in disaster-prone areas is therefore a critical first step in disaster risk management. Mapping residential areas located in hazard zones is needed, as identification through such mapping can serve as a reference for disaster mitigation and for minimizing future disaster-related losses (Oktaviana et al., 2020).

The novelty of this study lies in its integrated, multi-hazard approach. It moves beyond single-hazard analysis to provide a holistic picture of settlement vulnerability in Denpasar City by simultaneously analyzing exposure to tsunamis, earthquakes, liquefaction, and floods. By overlaying settlement data with official hazard maps from the Denpasar City Rencana Tata Ruang Wilayah (RTRW) and validating the findings through field surveys, this research offers a more complete and actionable evidence base for urban planners and disaster managers.

Thus, this study has three primary objectives: 1) to identify and spatially map the distribution of residential areas located in zones prone to tsunami, earthquake, liquefaction, and flood hazards in Denpasar City; 2) to quantify the extent of residential areas affected by each type of disaster; and 3) to formulate integrated disaster mitigation strategies tailored to the identified risks and conditions. The benefits of this research are twofold. Academically, it contributes to the literature on urban disaster risk assessment by demonstrating a replicable methodology for multi-hazard settlement exposure analysis. Practically, it provides the Denpasar City government, urban planners, and communities with a crucial spatial decision-support tool for integrating disaster risk reduction into spatial planning, enforcing building codes, planning evacuation routes, and prioritizing areas for structural and non-structural mitigation interventions.

METHOD

The location of this research is in Denpasar City. The city of Denpasar has an area of 12,598 hectares which is administratively divided into 4 (four) sub-districts, 27 villages and 16 sub-districts. The geographical location of Denpasar City is located at $8^{\circ}03'53''$ – $8^{\circ}04'49''$ South Latitude and $115^{\circ}10'23''$ – $115^{\circ}16'27''$ East Longitude. The boundaries of Denpasar City are as follows:

North : Badung Regency
 East : Kabupaten Gianyar
 South : Selat Badung
 West : Badung Regency

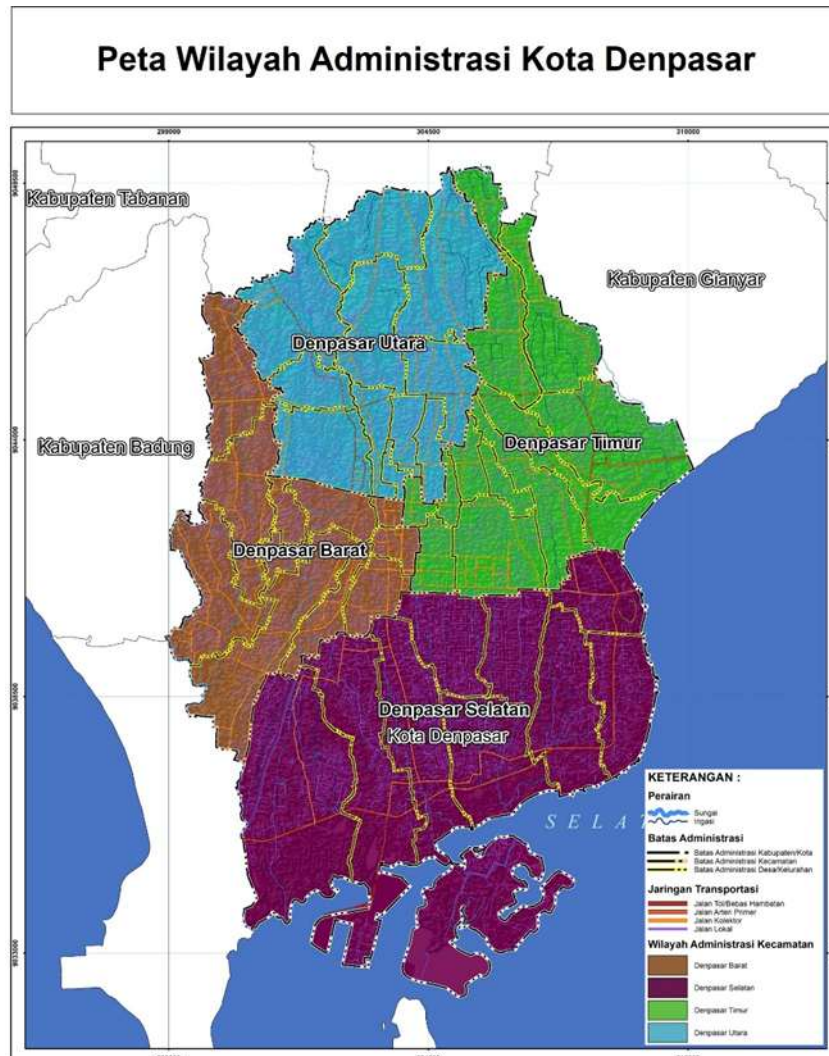


Figure 1. Administrative Boundaries of Denpasar City

This study uses a spatial approach and descriptive analysis. The spatial approach refers to the use of geographic information to understand, analyze and manage disaster risk. This approach uses geospatial maps and technologies to identify vulnerable areas, map potential hazards and plan effective mitigation measures. This spatial approach is very important in disaster risk management because it can provide information related to the location, characteristics and potential impact of disasters. With this information, *stakeholders* and the community can take appropriate actions to reduce risks and improve preparedness.

Descriptive analysis is carried out by describing or describing the data that has been collected as it is without intending to make conclusions that apply to the general or general (Sugiyono, 2014).

The analysis stages that can be carried out include identifying the distribution of residential areas in disaster-prone locations and analysis in the form of handling residential areas in disaster-prone locations in Denpasar City.

RESULTS AND DISCUSSION

The city of Denpasar occupies the eighth position with a Disaster Risk Index in the medium category with a score of 90.13. Based on the Indonesian Disaster Risk Index book, Denpasar City has several disaster threats in the high class such as earthquakes, forest and land fires, extreme waves and abrasion, drought, tsunami, landslides and extreme weather. Meanwhile, regional capacity for disaster risk prevention and management in Denpasar City is still in the medium category. Although the capacity of the Denpasar City area is in the medium category, the *trend* of the disaster risk index every year is decreasing. This decrease reflects an increase in capacity and a decrease in potential vulnerability to disasters in the Denpasar City area. This decline can be caused by an increase in community capacity in Denpasar City, strengthening the early warning system, building disaster-resistant infrastructure and environmental rehabilitation and conservation, as well as collaboration from all levels of *stakeholders*.

Regional Conditions

Physical Condition

Topography

The Denpasar City area has a relatively flat and relatively sloping topography, especially in the southern coastal area with most of the area having a slope of 0-2% to the South and some having a slope of 2-8% and slope slope in some areas, especially on river banks reaching 2-15%. The hills in Denpasar City support the development of the center of government, economy, culture, settlements and infrastructure development with the height of Denpasar City which is 0-25 meters above sea level and 75 meters above sea level.

A. Geology and Soil Type

The Denpasar City Area has several rock classification groups, consisting of Quaternary volcanic deposits that cover most of the Denpasar City Area, around 70% and consists of volcanic rocks such as tufa, breccia, lava, gravel, and sand of varying thickness, namely the northern part >200m and thinning to the south. These formations have the potential to cause resonance of seismic waves and amplification of vibrations when earthquakes occur,

Alluvial sediment is a type of soil or sediment that is formed from material deposited by flowing water, especially rivers. These deposits are usually made up of a mixture of particles such as clay, silt, market and gravel but alluvial deposits are known for their fertility and are often utilized for agriculture. Based on the results of the data, the Denpasar City Area consists of loose materials such as markets and pebbles covering areas along Sanur beach, while alluvial deposits consisting of clay and clay materials occupy areas along Suwung beach. Soil Type In the Denpasar City Area is predominantly yellowish-brown latosol soil, which is a type of soil formed from the weathering of sedimentary and *metamorphic* rocks, with a characteristic reddish-brown to yellow color, as well as a varied organic matter content. and alluvial soil in areas near the coast formed from river, lake and coastal sediments.

B. Climatology and Hydrology

The climate in the Denpasar City Area is generally tropical, characterized by dry seasons and rainy seasons influenced by monsoon winds and interspersed with pancaroba seasons. Based on data from the Meteorology, Climatology and Geophysics Agency in the figures of Denpasar City In 2025 related to the observation of climate elements by month in Denpasar City in January temperature data reached an average of 29.16^{0C}, in February it reached 28.71^{0C}, in March it reached 29.01^{0C}, in April 28.90^{0C}, in May it reached 28.64^{0C}, in June 27.51^{0C}, in July it is 26.93^{0C}, in August it reaches 26.78^{0C}, in September it reaches 27.83^{0C}, in October it reaches 28.74^{0C}, in November it reaches 29.36^{0C} and in December it reaches up to 27.51^{0C}.

The hydrology of Denpasar City is closely related to high rainfall, inadequate drainage systems, and rapid urban growth, which causes floods and inundation in various areas. The Denpasar City area is classified as having 2 classifications of water resources which include surface water and groundwater. Surface water is generally in the form of rivers while groundwater in Denpasar City has different potentials depending on the location and type of aquifer. The city of Denpasar is part of the Denpasar-Tabanan Groundwater Basin (CAT).

Disaster-prone areas

Based on data from the Denpasar City RTRW in 2021-2041, the types of disasters that have the potential to occur in Denpasar City include:

A. Prone to Tsunami Disasters

Tsunami-prone areas in the high category in Denpasar City include South Denpasar District and some areas in East Denpasar District. South Denpasar District areas that have high potential to be affected by tsunami disaster vulnerability include Sanur Kaja Village, Sanur Kauh Village, Sidakarya Village, Renon Village, Panjer Village, Sanur Village, Sesetan Village, Pemogan Village, Pedungan Village and Serangan Village. Meanwhile, areas in East Denpasar District that have vulnerability to tsunami disasters include Kesiman Kertalangu Village, Kesiman Petilan Village, Sumerta Klod Village, and Kesiman Village.



Figure 2. Graph of Tsunami Prone Areas

Source: Analysis Results

B. Prone to Earthquake Disasters

Earthquake-prone areas in Denpasar City include South Denpasar District and some areas in West Denpasar District. The area affected by earthquake vulnerability reaches 3,756.42 Ha (High Category), which can be seen in **Figure 3**. The areas of South Denpasar District that have the potential to be affected by earthquake disaster vulnerability include Sesetan Village, Pedungan Village, Pemogan Village, Sanur Kauh Village, Sidakarya Village, Renon Village, Sanur Village and Serangan Village. Meanwhile, areas that have the potential to be affected by the earthquake disaster in West Denpasar District include Padangsemblian Kaja Village, Padangsemblian Klod Village, Pemecutan Kaja Village, Tegal Harum Village, Tegal Kertha Village and Padangsemblian Village.

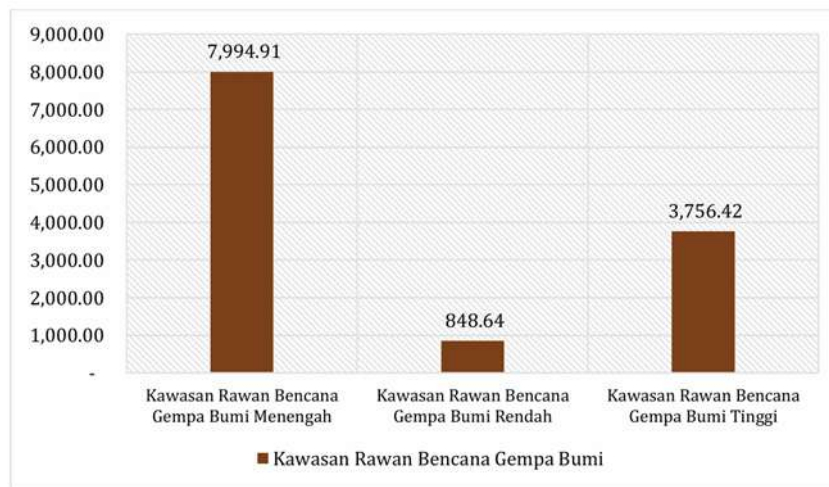


Figure 3. Graph of Earthquake Prone Areas

Source: Analysis Results

C. Prone to Liquefaction Disasters

The area prone to liquefaction disasters in the Denpasar City area includes South Denpasar District with an area of 1,510.47 Ha, which can be seen in **Figure 4**. Areas in South Denpasar District that are affected by the vulnerability of liquefaction disasters include Pemogan Village, Sidakarya Village, Pedungan Village, and Serangan Village.

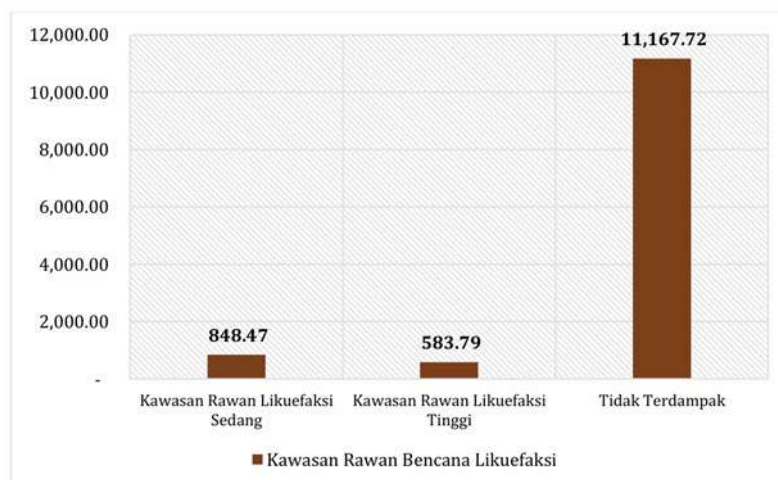


Figure 4. Graph of Liquefaction Disaster-Prone Areas

Source: Analysis Results

Analysis of the Distribution of Housing Locations in Disaster-Prone Areas

The city of Denpasar has vulnerability to disasters, especially natural disasters. The massive construction of housing in Denpasar City does not always consider the aspect of disaster vulnerability, so there are several housing locations built in a high disaster-prone era.

The analysis is carried out by overlaying the map of existing residential areas with maps of disaster-prone areas, so that the distribution and extent of residential areas with the potential for disasters can be known.

Residential Areas in Tsunami Disaster-Prone Areas

A tsunami is a large ocean wave formed due to disturbances from the seafloor, such as tectonic earthquakes, underwater volcanic eruptions, or underwater avalanches that cause large vertical displacement of water volume. Tsunamis can occur from locations close to the monitoring coastline of less than 30 minutes from the source to the coastline of the monitoring and remote locations where the timing to the monitoring coastal area is longer than 30 minutes or the tsunami source has a longer distance. The tsunami danger level can be based on several parameters such as altitude, distance and coastline, slope area and distance from the river (Oktaviana et al., 2020).

Based on the *results of the overlay*, residential areas that are exposed to tsunami disasters are dominated in coastal areas in South Denpasar District and some in East Denpasar District. Based on **Table 1**, it can be seen that South Denpasar District has a considerable impact on tsunami prone with an area of 1,499.26 Ha (89.19%). Meanwhile, in some areas in East Denpasar District, the exposed residential areas reached 179.31 Ha (10.81%).

Table 1. The Area of Residential Areas Affected by the Denpasar City Tsunami Disaster by sub-district.

Districts	Area (Ha)	Percentage (%)
South Denpasar	1.499,26	89.19
East Denpasar	179,31	10.81

Source: Analysis Results

Meanwhile, in **Table 2**, villages/sub-districts with residential areas exposed to high tsunami disasters are in Sanur Kauh Village reaching 324.89 Ha (19.59%).

Table 2. The Area of Residential Areas Affected by the Denpasar City Tsunami Disaster by village/sub-district

Village/Village	Area (Ha)	Percentage (%)
Pemogan Village	9.59	0.58
Sanur Kaja Village	212.59	12.82
Sanur Kauh Village	324.89	19.59
Sidakarya Village	257.63	15.53
Panjer Village	36.37	2.19
Pedungan Village	75.51	4.55

Renon Village	103.25	6.23
Sanur Village	304.04	18.33
Serangan Village	61.24	3.69
Sesetan Village	94.14	5.68
Kesiman Kertalangu Village	63.18	3.81
Kesiman Petilan Village	57.51	3.47
Sumerta Kelod Village	17.48	1.05
Denpasar City	1,658.56	100.00

Source: Analysis Results

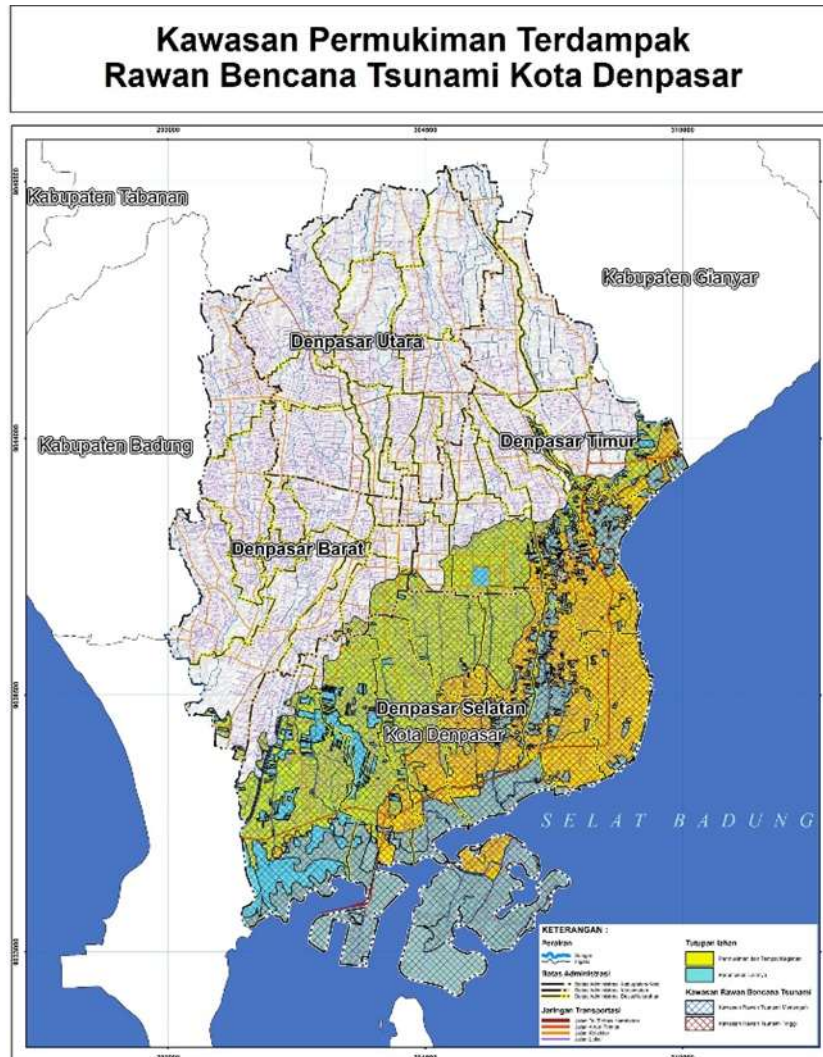


Image 5. Map of the Distribution of Residential Areas Affected by Tsunami Disasters

Source: Analysis Results



Figure 6. Conditions of Affected Residential Areas Prone to Tsunami Disasters

Source: Survey Documentation

Residential Areas in Earthquake Disaster-Prone Areas

An earthquake is an event that releases energy that causes a sudden shift in the interior of the earth. In general, earthquakes that cause severe damage are earthquakes resulting from collisions between earth's plates and active faults. Population growth, infrastructure development and groundwater exploration that tend to be uncontrolled can lead to degradation of subsurface structures. This can have an impact on infrastructure buildings, especially buildings with high weights as a result of vibrations caused by earthquakes (Firdaus et al., 2021).

The city of Denpasar is close to the subduction zone of the Indo-Australian plate and the Eurasian plate, which is part of the Pacific ring of fire. Its location near the subduction zone can cause the city of Denpasar to be affected by tectonic earthquakes that can be felt even though the epicenter is usually in the sea, but the earthquake felt is not too strong and causes great damage. The city of Denpasar often experiences shocks from small to moderate earthquakes whose center is in the surrounding waters or other parts of Bali. However, the earthquake felt in Denpasar City was generally mild and did not cause serious damage.

The potential danger of earthquake disasters in Denpasar City occurs in almost all areas in Denpasar City. Based on the results of the *overlay*, there are 3 (three) sub-districts that are highly exposed to earthquake prone, namely West Denpasar District, South Denpasar District and North Denpasar District. The area of residential areas exposed to earthquake prone reached 2,213.91 Ha, which can be seen in **Table 3**.

Table 3. The Area of Residential Areas Affected by the Denpasar City Earthquake

Districts	Area (Ha)	Percentage (%)
West Denpasar	810.62	36.61
South Denpasar	1,268.46	57.30

North Denpasar	134.83	6.09
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Source: Analysis Results

Meanwhile, in **Table 4**, villages/sub-districts with residential areas exposed to high earthquake disasters in Padangsembian Village reached 341.66 Ha (15.43%).

Table 4. The Area of Residential Areas Affected by the Denpasar City Earthquake by Village/Village

Village/Village	Area (Ha)	Percentage (%)
Padangsembian Kaja Village	88.57	4.00%
Padangsembian Kelod Village	219.40	9.91%
Tegal Harum Village	44.83	2.02%
Tegal Kertha Village	75.92	3.43%
Padangsembian Village	341.66	15.43%
Pemecutan Village	40.23	1.82%
Pemogan Village	171.91	7.77%
Sanur Kauh Village	231.21	10.44%
Sidakarya Village	225.65	10.19%
Pedungan Village	180.42	8.15%
Renon Village	10.56	0.48%
Sanur Village	252.00	11.38%
Serangan Village	61.24	2.77%
Sesetan Village	135.46	6.12%
Kaja Cutting Village	134.81	6.09%
Ubung Village	0.02	0.00%
Denpasar City	2,213.91	100.00%

Source: Analysis Results

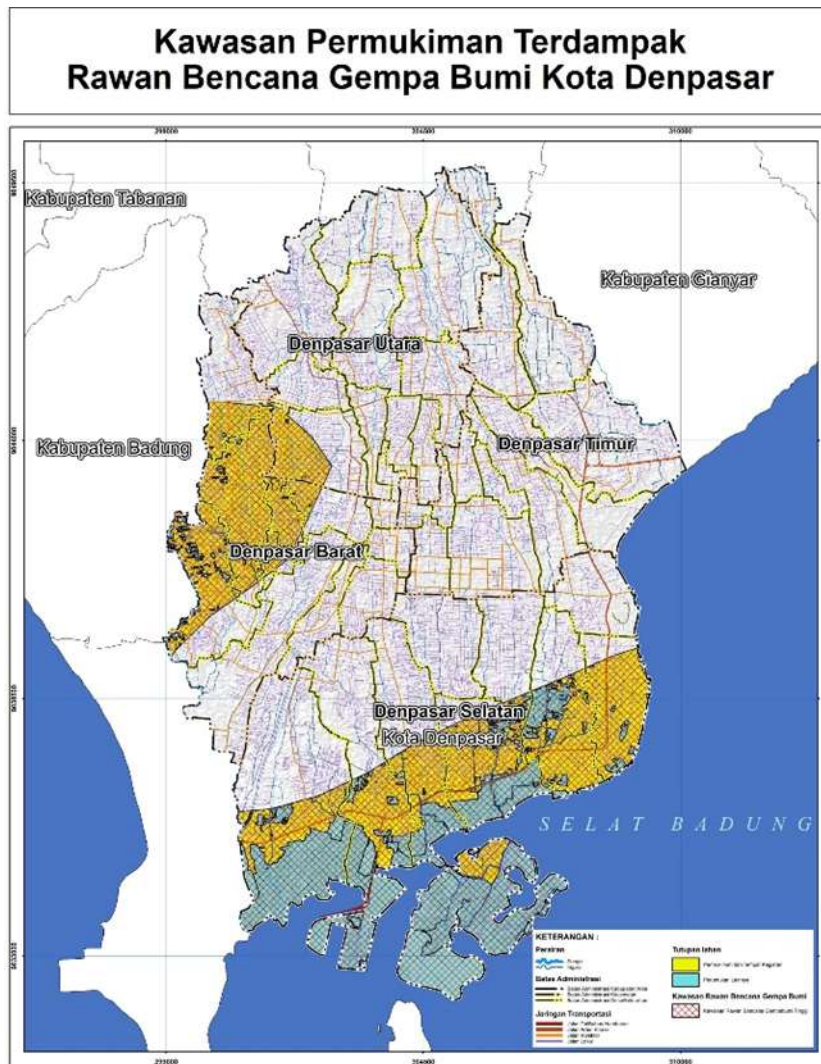


Figure 7. Distribution Map of Residential Areas Affected by Earthquake Disasters
Source: Analysis Results



Figure 8. The Condition of Affected Residential Areas Prone to Earthquake Disasters
Source: Survey Documentation

Residential Areas in Likuefakasi Disaster-Prone Areas

Liquefaction is a geological process in which dense soils, especially sandy and water-saturated soils, experience a decrease in strength and rigidity due to vibration or shock such as what occurs during earthquakes. As a result, the land is not able to support buildings or structures on it.

The potential for liquefaction disasters in Denpasar City covers some areas in South Denpasar District, especially in Pemogan Village, Sidakarya Village, Pedungan Village, Serangan Village and Sesetan Village. The area of residential areas that have the potential to be affected by liquefaction disasters reaches 159.57 Ha with medium and high categories. The following is the distribution of residential areas affected by the liquefaction disaster.

Table 5. The Area of Residential Areas Affected by the Liquefaction Disaster in Denpasar City

Village/Village	Area (Ha)	
	Height	Medium
Pemogan Village	-	23.87
Sidakarya Village	0.19	18.21
Pedungan Village	8.55	38.19
Serangan Village	34.12	27.12
Sesetan Village	0.29	9.02
Total	43.15	116.41

Source: Analysis Results

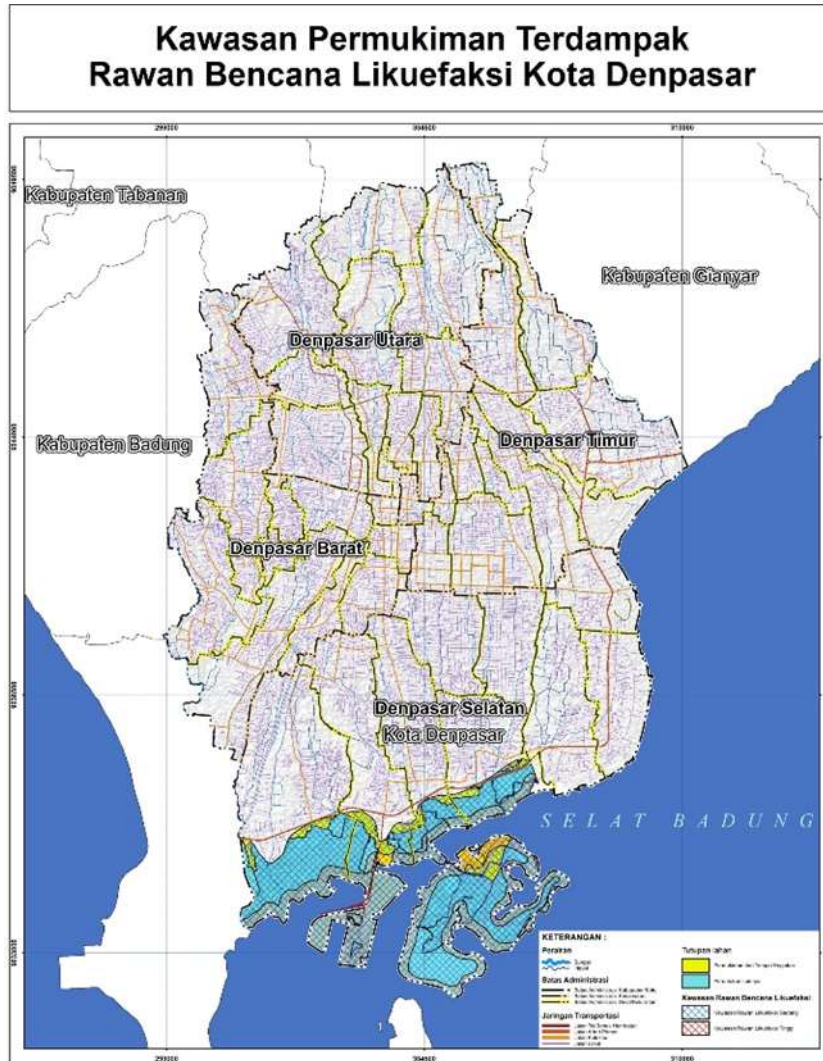


Figure 9. Distribution Map of Residential Areas Affected by Liquefaction Disasters
Source: Analysis Results



Figure 10. The Condition of Affected Residential Areas Prone to Liquefaction Disasters
in Serangan Village
Source: Survey Documentation

Residential Areas in Flood-prone Areas

The determining factors for Benjir's vulnerability in Denpasar City are rainfall, land use, soil type, and slope. Rainfall and land use factors are priorities in determining flood vulnerability in Denpasar City (Chyntia Angelina et al., 2022). According to (Irmayanti et al., 2020), Denpasar City experienced a significant flood disaster due to uncontrolled space utilization and development activities as well as the topographic condition of Denpasar City downstream vulnerable to flood disaster risk. In addition, the problem of flooding in Denpasar City is also caused by the condition of drainage channels due to siltation due to sediment, limited inspection roads along the channel, channels that are clogged with garbage, main discharges that have a relatively low slope so that they can accelerate sedimentation, and relatively small channel slopes.

Based on the results of the overlay, residential areas affected by flood disasters in Denpasar City include West Denpasar District, South Denpasar District, East Denpasar District and North Denpasar District. The area of residential areas affected by this flood disaster reaches 1,399.83 Ha. The following is the distribution of residential areas that are prone to flooding according to villages/sub-districts in Denpasar City.

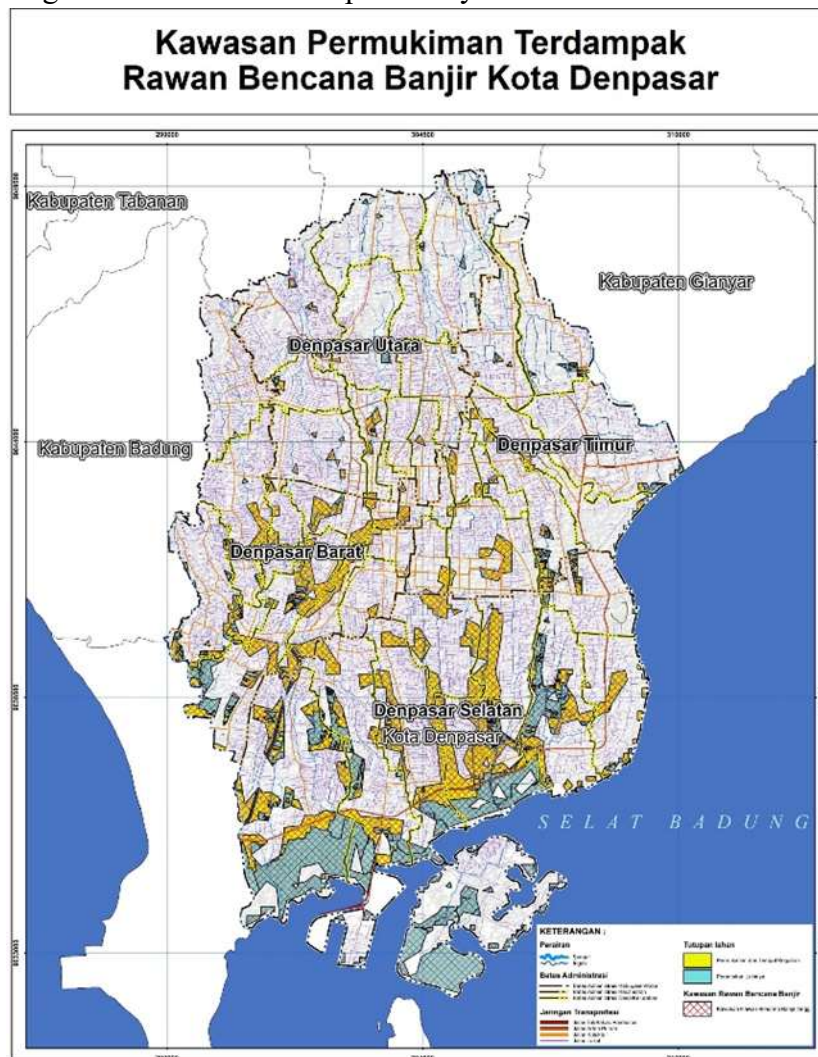


Figure 11. Distribution Map of Residential Areas Affected by Flood Disasters

Source: Analysis Results

Analysis of Disaster Mitigation Strategies in Residential Areas in Denpasar City

Disaster mitigation can be translated in the context of spatial planning as a tool to prevent/avoid hazards, reduce vulnerability levels and increase resilience (Irmayanti et al., 2020). Mitigation can be carried out through three stages, namely before the incident (pre), during the occurrence of the disaster and after the occurrence of the disaster.

Residential areas affected by disasters need to be directed to be relocated to safer locations and in accordance with the criteria for the location of residential areas, including:

- a. In accordance with the Denpasar City regional spatial plan or the applicable spatial planning detail;
- b. Not a protected area;
- c. It is not a protected paddy land zone;
- d. It is not a zone with a high level of disaster vulnerability;
- e. Have convenience in the provision of infrastructure, facilities and public utilities; and
- f. In accordance with the capacity of the land, carrying capacity and carrying capacity.

Based on Ministerial Regulation Number 13 of 2023 concerning Minimum Service Standards for Public Works and Public Housing, article 9 paragraph (3) states that the provision and rehabilitation of livable houses for disaster victims is carried out through:

- a. Home rehabilitation is given to recipients whose houses meet the criteria for light and moderate damage.
- b. The redevelopment is given to recipients whose houses meet the criteria for severely damaged houses.
- c. Resettlement is given to service recipients whose houses meet the criteria for light, medium and severe damaged houses by having a Regent/Mayor Decree regarding the relocation of disaster victims.
- d. Rental house access assistance is given to service recipients who do not have proof of ownership of legal land and/or building rights.

Disaster mitigation strategies that can be carried out by the Denpasar City government and the community include:

- a. Provision of disaster evacuation routes and sites and the installation of early warning systems;
- b. Development of building construction that minimizes disasters in accordance with legislation;
- c. Implementation of building safety policies as evacuation sites;
- d. Providing easy and reachable accessibility from various directions in the event of a disaster;
- e. Development of housing development and residential areas that are limited and still maintain coastal boundaries;
- f. Strengthening the building structure in accordance with the provisions of the requirements;
- g. Provision of disaster evacuation systems such as early warning systems, disaster warning signs and information boards, evacuation routes, shelters or protection buildings, temporary evacuation sites and final evacuation sites.

CONCLUSION

The city of Denpasar is vulnerable to disasters, especially natural disasters. The massive construction of housing in Denpasar does not always take disaster vulnerability into account, resulting in several residential areas being developed in highly disaster-prone zones. Disaster-prone areas in Denpasar include zones at risk of tsunamis, earthquakes, liquefaction, and floods. Therefore, appropriate mitigation efforts are needed so that, when disasters occur, the resulting damage can be minimized. Given the continuous expansion of residential areas in Denpasar, which allows some developments to occur within disaster-prone zones, settlement planning must consider criteria for housing locations that comply with the existing regional spatial plan and other relevant guidelines or regulations.

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