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Analysis of Tsunami Hazard Potential in North Bali due to The Flores Back Arc Thrust Earthquake Using TOAST

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INTRODUCTION AND MAIN RESULTS

Research on tsunamis in northern Bali is limited; however, records indicate that the 1815 event (M~7.0–7.3) resulted in the deaths of 10,253 people in Buleleng–Singaraja. Easywave-TOAST simulations indicate eastern Buleleng faces a major warning with a 3.43 m run-up and 1 min ETA, while western Buleleng has a 1.92 m run-up and 4.5 min ETA. Population exposure: 2,831/km² east, 1,683/km² west.

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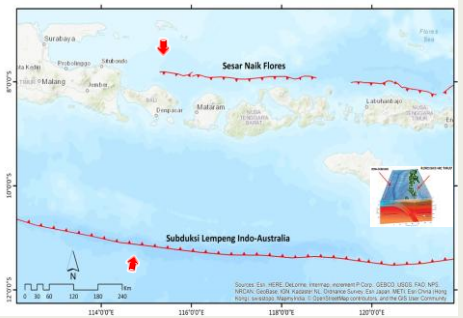
Introduction

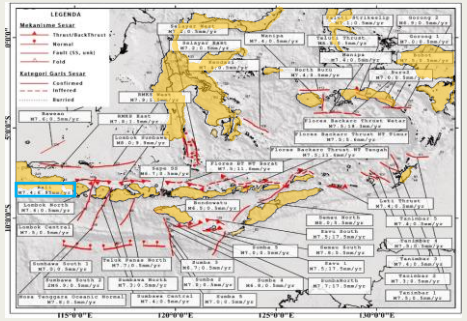
Bali is one of the regions in Indonesia that is prone to earthquakes. Bali is flanked by two earthquake sources, namely the subduction zone in the south of Bali, which is the meeting point of two plates.

The Indo-Australian plate moving from south to north and the Eurasian plate moving from the north to the south. The northern part of Bali has a back-arc thrust zone that stretches from northern Bali to Flores.



The Flores Fault stretches across the northern sea of Bali Island through Buleleng Regency. The end of the Flores Fault is located right above the northern sea in Buleleng Regency (McCafrrey et al., 1987).

The potential magnitude of the earthquake from the Flores backarc thrust The Bali segment is M7.4 with a movement of 6.95 mm/year (Pusgen 2017).

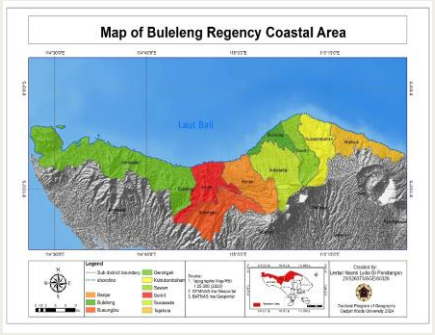


This study uses TOAST (Tsunami Observation and Simulation Terminal) modeling to predict tsunami run-up, forecast zones, and estimate time of arrival.

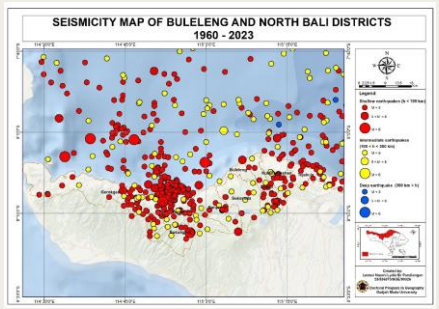
Methods/Data

Total of coastal area: 996.33 km². The coastal area consists of 7 sub-districts: Gerogak, Seririt, Banjar, Buleleng, Sawan, Kubutambahan, and Tejakula. Total Population: 676,590 people. Population density: 604 people/km².

Seismicity map of Buleleng Regency and North Bali using earthquake data from USGS, BMKG, and ISC for the period from 1960 to 2023. The map reveals a high level of seismic activity in Buleleng Regency, with shallow earthquakes dominating the landscape (red circle).



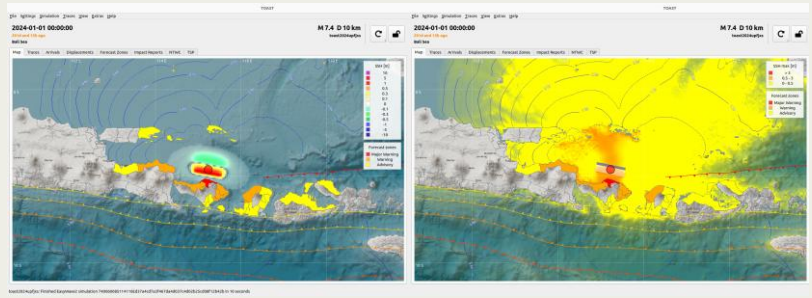
The scenario is due to the Bali segment referring to the BMKG tsunami catalog (416-2018) and the National Earthquake Center (PUSGEN, 2017).



This study uses TOAST (Tsunami Observation and Simulation Terminal) modeling to predict tsunami run-up, forecast zones, and estimate time of arrival.

Results

SSH (Sea Surface High) is the height of the sea surface below the reference ellipsoid. This SSH can determine the sea surface contours and the surface waves' wind or gravity characteristics.



North Bali Earthquake & Tsunami Scenario (M 7.4, 22 November 1815 – Worst Case). Eastern Buleleng (Buleleng, Sawan, Kubutambahan, Tejakula): Run-up height 3.43 m, ETA 1 min. Western Buleleng (Gerogak, Seririt, Banjar): Run-up height 1.92 m, ETA 4.5 min.

No	Sub-district/ Status Level	Total Area (km²/per sq.km)	Population (thousand)	Population Density (per sq.km)
	Eastern Buleleng (Major Warning)			
1	Buleleng	46,94	153.930	519
2	Sawan	92,52	84.760	916
3	KubuTambahan	118,24	71.760	607
4	Tejakula	97,68	77.080	789
	Total	**355,38**	**387.530**	**2.831**
	Western Buleleng (Warning)			
5	Gerogak	356,57	101.140	284
6	Seririt	111,78	98.380	880
7	Banjar	172,60	89.540	519
	Total	**640,95**	**289.060**	**1.683**

Forecast Zones		Run up (m)	Estimated Time of Arrival
MAJOR WARNING			
BALI	**Eastern Buleleng**	3,432	0:01:00
	Buleleng		
	Sawan		
	Kubutambahan		
	Tejakula		
WARNING			
BALI	**Western Buleleng**	1,921	0:04:30
	Gerogak		
	Seririt		
	Banjar		

Tsunami Hazard Zones MAJOR WARNING Zone: 4 sub-districts, 355.38 km²; 387,530 people (density 2,831/km²). WARNING Zone: 3 sub-districts, 640.95 km², 289,060 people (density 1,683/km²)

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Appendix.

The scenario is based on the Flores back-arc thrust earthquake originating from the Bali segment, as referenced in the BMKG tsunami catalog (416-2018) and the National Earthquake Center (PUSGEN, 2017).

Faults	Strike (km)	Length (km)	Width (km)	Source Location Earthquake		*Magnitude* (Mw)	*Dip* (°)	*Rake* (°)	*Depth* (km)
				Latitude (°LS)	Longitude (°BT)				
Reverse	280,954	74,47	26,54	7,849	115,23	7,4	30	90	10

Tsunami wave propagation simulation

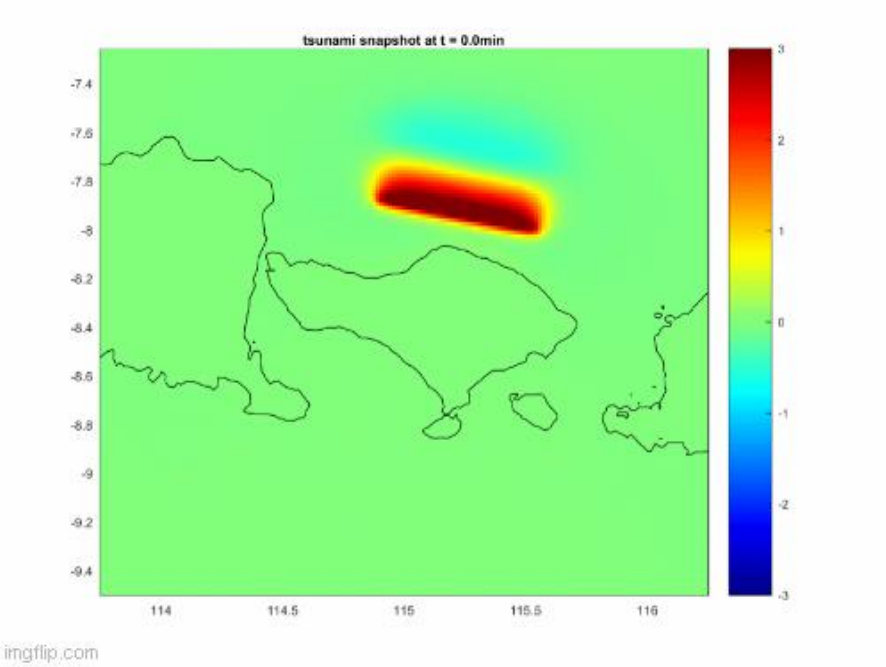

Table Result of Easywave Simulation Forecast Zone with TOAST Modeling

Easywave		*Run up* (m)	ETA
MAJOR WARNING			
BALI	Eastern Buleleng	3,442	0:01:00
WARNING			
BALI	Western Buleleng	1,921	0:04:30
BALI	Northern Karang Asem	1,636	0:02:00
NTB	Northern – West Lombok	0,728	0:10:00
NTB	Mataram City	0,583	0:17:00
BALI	Klungkung	0,581	0:22:15
BALI	Southern Karang Asem	0,580	0:10:45
JATIM	Situbondo	0,523	0:09:45
ADVISORY			
NTB	Southern - West Lombok	0,419	0:16:15
JATIM	Sumenep	0,394	0:15:15
BALI	Denpasar - Sanur Beach	0,393	0:34:15
NTB	Northern - East Lombok	0,388	0:17:15
BALI	Klungkung Nusapenida Island	0,362	0:20:45
NTB	Sumbawa	0,352	0:29:30
NTB	Eastern – East Lombok	0,348	0:34:15
NTB	Northern Sumbawa	0,329	0:27:15
NTB	Bima	0,265	0:32:30
BALI	Gianyar	0,237	0:30:45
BALI	Badung - Kuta Beach	0,232	0:38:30
SULSEL	Center Lombok	0,227	0:33:45
SULSEL	Maros	0,212	1:31:15
JATIM	Probolinggo	0,205	1:29:15

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