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The Badung River Level Capacity Due to Probable Maximum Flood in Denpasar City

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ABSTRACT

The runoff coefficient in the Badung river basin changes from 0.57 to 0.71 in 2026, especially due to the conversion of rice fields into residential and commercial areas, as well as the reduction of mangrove forests and green open spaces. These changes have resulted in a significant increase in runoff and flooding in the Badung River. The Probable Maximum Flood calculated in 2000 was 485.82 m^3/s, in 2026 it was 764.91 m^3/s. Over the past 26 years, the Badung River has experienced a 57.45% increase in the Maximum Probable Flood. The embankment capacity upstream of Hasanuddin Bridge is 503.579 m^3/s, while downstream of Hasanuddin Bridge the capacity of the Badung River embankment is 482.174 m^3/s. This analysis concludes that flood conditions around Hasanuddin Street are 0.80 m above the average height of the Badung River embankment. Necessary measures in the study area include raising the Badung River embankment by 1.6 meters in flood-affected areas, normalizing the channel slope to 0.009, maintaining the area's flow coefficient at 0.71, and managing and controlling waste in the area. This treatment will increase the capacity of the Badung River in flood-affected areas to 886.360 m^3/sec.

Keywords: capacity; embankment; river; flood; rain.

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1. INTRODUCTION

The flooding in Denpasar City was caused by overflowing surface water, exceeding the capacity of the drainage system [1]. Flooding in the Badung River was not only triggered by extreme weather and climate change, but also exacerbated by massive development practices, including poor urban planning and spatial planning [2]. There are 120 flooding hotspots in Denpasar City, with the worst-affected areas being the Badung Market area and along the Tukad Badung River [3]. Rainfall in Denpasar City ranges between 1,600-1,765 mm/year [4]. Flooding in Denpasar City is caused not only by high rainfall but also by several other factors such as land slope, elevation, land conversion, poor drainage systems, and community waste [5].

As a river that traverses urban areas, the Tukad Badung River, acting as the main drainage system, has become a dumping ground for waste from households, offices, industry, and commerce. This waste not only pollutes the water body but also causes sedimentation, reducing the river's capacity. Observable indicators include the formation of deltas in several locations along almost both sides of the river, and the susceptibility to flooding even when rainfall is not particularly heavy [6].

The Tukad Badung River has also been designated a city tour destination by the Denpasar City Government. The Badung River is expected to offer environmental harmony, beauty, cleanliness, and daily life experiences for the community along the riverbank, which can be enjoyed both through inspection roads and through the riverbed [7].

As a source of raw water, the Muara Nusa Dua Reservoir has been built downstream to collect and treat river water so that it can be reused for various purposes before being discharged into the sea. The Muara Nusa Dua Reservoir plays a very strategic role in regional development efforts, meeting the raw water needs of the southern part of Denpasar City and Badung Regency [8].

This study aims to determine the capacity of the Badung River embankment, based on a probable maximum flood analysis. During the planning process, the Badung River embankment was designed for a flood discharge with a 50-year return period, but the water level in the Badung River has exceeded the existing flood level.

The flood disaster in 2025 is due to the inability of the Badung River to accommodate the flood discharge. This study will conduct a maximum flood analysis, analyze the effect of changes in the runoff coefficient from 2000 to 2026, calculate the current capacity of the Badung River embankment, and formulate mitigation alternatives.

This research will calculate the current flood discharge in the Badung River using rainfall data from 2016 to 2025 and the runoff coefficient, based on the current land use conditions of Denpasar City. This analysis will also compare the current flood discharge to the previous 26 years, analyzed based on rainfall data from 1987 to 1999 and the runoff coefficient based on land use at that time. This will provide an estimate of the increase in flood volume over a 26-year period and the current capacity of the Badung River embankment.

2. RESEARCH METHOD

The research was conducted in Tukad Badung River, Denpasar City by analyzing rain and flooding around the Gajahmada bridge and the Badung Market area, calculating the current embankment capacity, conducting observations and field surveys to see the impacts caused by flooding, then designing river structures, the following approaches will be taken:

2.1. Runoff Coefficient

To calculate the composite runoff coefficient for heterogeneous areas such as the urban region of Denpasar a weighted average method based on the area of each land-use type is employed [25][26].

$$C_{\text{com}} = \frac{\sum(C_i \times A_i)}{A_{\text{total}}} \tag{1}$$

C_i = Runoff coefficient for land-use type i
A_i = Area of land-use type i (m² or ha)
A_{total} = Total area of the catchment basin
C_{com} = Composite runoff coefficient

2.2. Consistency Test

Before using rainfall data, it must first undergo a consistency test, as this can affect the accuracy of the analysis results. The common method used is double mass analysis.This method compares the cumulative rainfall at the test station with the average cumulative rainfall at surrounding reference stations. Data inconsistencies are indicated by deviations from the straight line [24].

2.3. Design Rainfall Analysis

To analyze the design rainfall for the 50-year return period, several distribution methods are used, including [9]. The Gumbel approach with the following equation:

$$Xt = \bar{X} + K.Sd \tag{2}$$

Sd = Standard deviation

$$Sd = \sqrt{\frac{\sum_{i-n}^{n}\left(X_i - \overline{X}\right)^2}{n-1}} \tag{3}$$

K = Frequency factor

To calculate the E.J. Gumbel Type I frequency factor, use the following formula:

$$K = \frac{Yt - Yn}{Sn} \tag{4}$$

The Log Pearson Type III approach with the following equation:

$$LogXt = LogX + k\sigma$$

Standard deviation

$$\sigma = \sqrt{\sum_{i=n}^{n}\left(\frac{(\log x - \log \ddot{x})^2}{n-1}\right)} \tag{5}$$

Asymmetry Coefficient

$$Cs = \frac{n\sum_{i=1}^{n}(\log x - \log \overline{x})^3}{(n-1)(n-2)(\sigma \log x)^3} \tag{6}$$

2.4. Distribution Selection Analysis

Distribution selection is carried out by comparing the Cs and Ck values in the Gumbel and Log Pearson III distributions. The requirements for the Gumbel distribution are Cs <1.1396 and Ck <5.4002, while the requirements for the Log Pearson III distribution are Cs ≠ 0 [10][22][24].

2.5. Probable Maximum Precipitation (PMP) Analysis

For this PMP analysis, a statistical method is used with the equation [11]:

$$X_m = \overline{X}_n + K_m \cdot S_n \tag{7}$$

2.6. Design Flood Analysis

The planned flood discharge is the amount of discharge that will statistically be equaled or exceeded within a certain return period [22]. To design a building with a high risk of disaster, especially if it involves human loss, a design discharge with no risk of failure is desired. This design discharge is the Probable Maximum Flood (PMF).The approach used in this flood discharge analysis is a hydrological analysis of the Q50 and QPMF design flood discharges, using the Nakayasu method [11].

$$Qp = \frac{CARo}{3,6(0,3Tp + T0,3)} \tag{8}$$

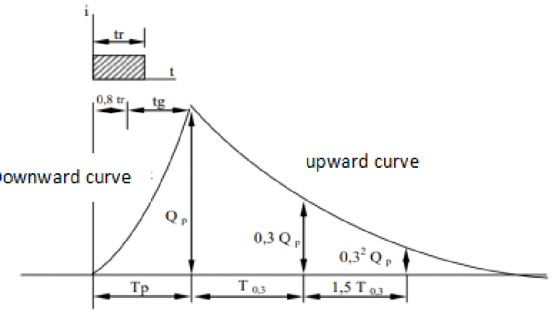

Figure 1. Nakayasu Synthetic Unit Hydrograph

2.7. River Capacity Analysis

The river cross-sectional capacity is determined by the cross-sectional shape, wetted area, hydraulic radius, riverbed slope, and Manning's roughness coefficient. Manning's equation is widely used to calculate the maximum river flow capacity. The water discharge calculation uses the following equation: [8][12].

$$Q=V\times A \quad (9)$$

$$V=K \quad R^{\frac{2}{3}} \quad S^{\frac{1}{2}} \quad (10)$$

Q = discharge (m^3/sec)
A = wet cross-sectional area (m^2)
V = flow velocity (m/sec)
S = channel slope
K = channel roughness

3. RESULTS AND DISCUSSION

3.1. Badung River Flood

The risk of flooding due to land conversion into residential and commercial areas without considering water absorption capacity reduces green open spaces [2].There are 120 flood points in Denpasar City with the worst affected areas being the Badung Market area and along the Tukad Badung river [3]. Based on research results, the determining factor for flood vulnerability in Denpasar City is the rainfall factor. The rainfall class in Denpasar City ranges from 1,600-1,765 mm/year [4].

Figure 2. Flood location in the Badung River

3.2. Causes of Tukad Badung Flooding

Although rainfall is a major factor, it is not the sole cause of flooding. Flooding is exacerbated by increased population density, housing in floodplains, limited water absorption, clogged drainage channels, and poor waste management, all of which are often concentrated in the Tukad Badung area. Generally, the causes of flooding in Tukad Badung are both natural and human-induced.

1. High rainfall.
2. Rivers with very low gradients, slowing the flow of rainwater into the river and potentially causing sedimentation in the drainage channels.
3. Trash and sedimentation reduce river capacity.
4. Inadequate drainage capacity.
5. The influence of tidal waves, disrupting the smooth flow of water into the sea.
6. Ineffective water structures.

Floods are generally caused by rain with extremely heavy intensity that occurs for two consecutive days.

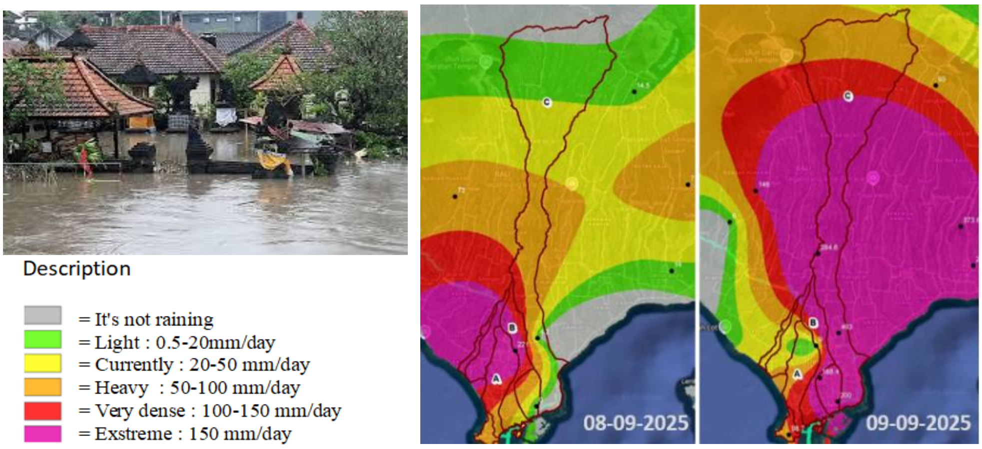

Figure 3. Extreme intensity rain in Denpasar City for two days

3.3. Rainfall Data

The Badung River watershed stretches from its headwaters in Badung Regency (in the north), through the center of Denpasar City, to its outlet in Benoa Bay (in the south). It is characterized by an elongated shape and varying elevations, ranging from low hills upstream to lowlands downstream. The area is experiencing rapid land-use conversion into urban zones and dense settlements. It is subject to high-intensity, short-duration rainfall (urban convective rain) and exhibits orographic variations from north to south.

The calculation of flood discharge in Tukad Badung in 2000 used rainfall data from 1987 to 1999 at four rainfall stations: Oongan, Mambal, Mertagangga, and Dam Badung. The following is the maximum regional rainfall from 1987 to 1999 [13]. The Thiessen Polygon method was used to calculate average rainfall in the Badung River basin. This method assigns coefficients to each rain gauge station based on its closest area of influence [20] [22]. The calculation of average rainfall using data from 1987 to 1999 used data from the Oongan rainfall station with a coefficient of 0.218, the Mambal rainfall station with a coefficient of 0.121, the Mertaganga rainfall station with a coefficient of 0.431, and the Dam Badung rainfall station with a coefficient of 0.230. This rainfall data was used to calculate the flood in 2000.

Table 1. Maximum Daily Regional Rainfall Data from 1987 to 1999

Year	Maximum Rainfall				Regional Rainfall
	Oongan	Mambal	Mertagangga	Dam Badung	
1987	70,00	113,00	135,00	62,00	101,38
1988	120,00	125,00	112,00	57,00	102,67
1989	175,00	169,00	101,00	91,00	123,06
1990	160,00	62,00	116,00	50,00	103,88
1991	75,00	80,00	106,00	60,00	85,52
1992	155,00	76,00	155,00	190,00	153,49
1993	104,00	62,00	71,00	178,00	101,72
1994	125,00	24,00	79,00	160,00	101,00
1995	134,00	39,00	135,00	87,00	112,13
1996	125,00	65,00	133,00	189,00	135,91
1997	91,00	44,20	126,00	154,00	114,91
1998	98,00	54,00	57,24	57,24	65,73
1999	110,00	24,00	110,00	28,66	80,89

The calculation of flood discharge in Tukad Badung in 2026 used rainfall data from 2016 to 2025 at three rainfall stations: Penatih, Mertagangga, and Dam Badung. The following is the maximum regional rainfall from 2016 to 2025. The Thiessen coefficient for calculating the average regional rainfall obtained was 0.290 for the Penatih rainfall station, 0.290 for the Mertagangga rainfall station, 0.310 for the Badung Dam rainfall station, and 0.40 for the Badung Dam rainfall station. The following is the maximum regional rainfall data from 2016 to 2025.

Table 2. Maximum Daily Regional Rainfall Data from 2016 to 2025

Year	Maximum Rainfall			Regional Rainfall
	Penatih	Mertagangga	Dam Badung	
2016	67.32	135.00	62.00	85.50
2017	129.50	112.00	57.00	95.25
2018	120.90	101.00	91.00	102.97
2019	115.20	116.00	50.00	89.36
2020	70.60	106.00	60.00	76.98
2021	116.40	155.00	190.00	157.42
2022	174.50	71.00	178.00	144.85
2023	152.30	79.00	160.00	133.39
2024	122.80	135.00	87.00	112.14
2025	121.00	133.00	189.00	151.80

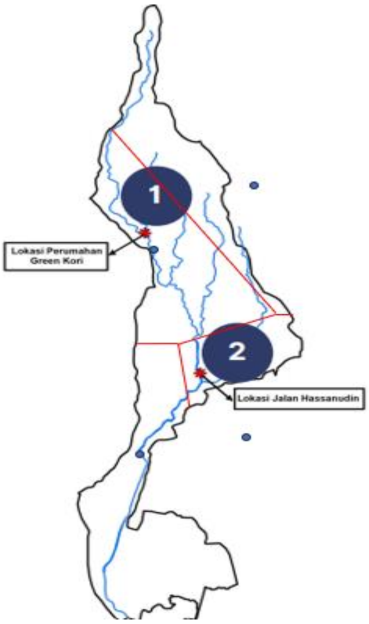

Figure 4. Thiessen Polygon Map

3.4. Rainfall Data Consistency Test

The double mass analysis method describes the cumulative rainfall magnitude of the test station with the average cumulative magnitude of the surrounding reference stations. Data inconsistencies are indicated by deviations from the straight line.

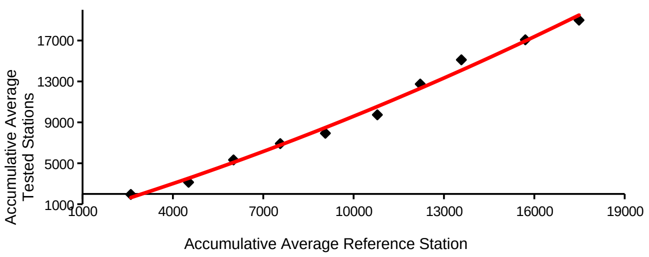

Figure 5. Penatih Station Rainfall Data Consistency Test Graph

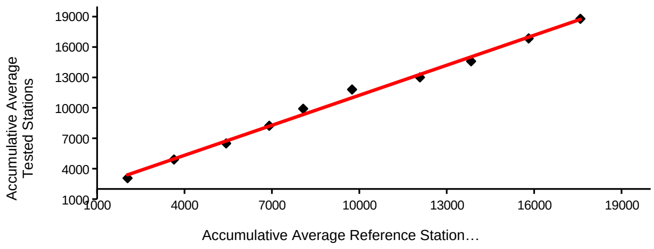

Figure 6. Mertagangga Station Rainfall Data Consistency Test Graph

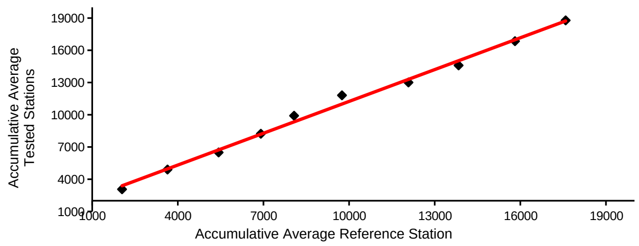

Figure 7. Badung Dam Station Rainfall Data Consistency Test Graph

All rainfall data recorded at the rainfall station is concluded to be consistent. The consistency of the data is shown by the straight line shown in the graph.

3.5. Planned Rainfall and Probable Maximum Precipitation (PMP)

Distribution selection is based on the data distribution testing requirements for using frequency analysis. The design rainfall calculation method is selected based on its basic statistical parameters [11]. Based on the statistical parameter values, it was concluded that the most appropriate frequency distribution for calculating design rainfall in this study was the Log Pearson type III method. The calculated Probable Maximum Flood (PMF) in 2000 was 485.82 m^3/sec, and in 2026, it was 764.91 m^3/sec.

Table 3. Planned Rainfall and Probable Maximum Precipitation (PMP)

No	Repeat Period (year)	Design Rain (year 2000) (mm/day)	Design Rain (year 2026) (mm/day)
1	2	75.550	111.073
2	5	100.733	138.507
3	10	117.406	155.855
4	25	138.473	177.063
5	50	154.101	192.449
6	100	169.614	207.608
7	200	185.071	222.633
8	1000	220.874	248.194
9	PMP	410.980	559.355

3.6. Runoff coefficient

The composit runoff coefficient was calculated by multiplying the area of each land use category by its respective runoff coefficient (C), then dividing by the total area of the city. Denpasar City has a total land area of approximately 12,598 hectares [14][15].

With a total area of 12,598 hectares, Denpasar City has a composite runoff coefficient of 0.71. This indicates that 71% of the total rainwater falling across the city immediately becomes surface runoffwhich must be managed by the urban drainage network and rivers while only 29% infiltrates the soil. This high coefficient reflects the prevalence of impervious surfaces, meaning that macro-drainage systems such as the Badung, Mati, and Ayung Rivers require optimal capacity and maintenance to prevent inundation or flooding. In the year 2000, a runoff coefficient of 0.57 indicated that the soil in Denpasar City still possessed a reasonably good capacity (43%) to absorb rainwater.

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The rapid conversion of rice fields into residential areas over the past 26 years has raised the runoff coefficient to 0.71, thereby increasing the potential for peak surface flood discharge unless balanced by improvements to drainage systems and the installation of infiltration wells. The change in the runoff coefficient from 0.57 in 2000 to 0.71 in 2026 is largely attributed to the conversion of paddy fields into residential and commercial areas, as well as the reduction of mangrove forests and green open spaces.

Table 4. Composite Runoff coefficient

No	Land use	Land-use area (A) ha		Runoff coefficient (C)	Effective Runoff Area (CxA	
		Year 2000	Year 2026		Year 2000	Year 2026
1	Settlements & Trade	4,409.30	8,566.64	0.80	3,527.44	6,853.31
2	Rice fields	5,669.10	2,015.68	0.50	2,834.55	1,007.84
3	Commercial Areas & Roads	503.92	1,007.84	0.85	428.332	856.66
4	Mangroves & Open Land	1,637.74	629.90	0.20	327.548	125.98
5	Water Bodies & Swamps	377.94	377.94	0.30	113.382	113.38
	Composite runoff coefficient				0.57	0.71

Table 5. Change in runoff coefficient from 2000 to 2026

Parameter	Condition		Change
	Year 2000	Year 2026	
Runoff coefficient (C)	0.57	0.71	Runoff coefficient increased 24.56%
Water runoff	57%	71%	Surface water increased significantly
Infiltration	43%	29%	Water infiltration decreases drastically

3.7. Probable Maximum Flood

The calculated Probable Maximum Flood (PMF) in 2000 was 485.82 m3/sec, and in 2026, it was 764.91 m3/sec. Over the past 25 years, the Badung River has seen a 57.45% increase in the Probable Maximum Flood. This increase is due to a change in the flow coefficient, from 0.6 in 2000 to 0.7 in 2026. This change in flood discharge is also influenced by increased rainfall intensity. The Probable Maximum Precipitation (PMP) in 2000 was 410.980 mm/day, while in 2026, it was 559.355 mm/day.

Table 6. Planned flood discharge and Probable Maximum Flood (PMF)

No	Repeat Period (year)	Planned flood discharge (year 2000) m^3/sec	Planned flood discharge (year 2026) m^3/sec
1	2	89.32	151.90
2	5	119.08	189.41
3	10	138.79	213.14
4	25	163.69	242.14
5	50	182.17	263.18
6	100	200.51	283.91
7	200	218.78	304.45
8	1000	261.10	339.41
9	PMF	485.82	764.91

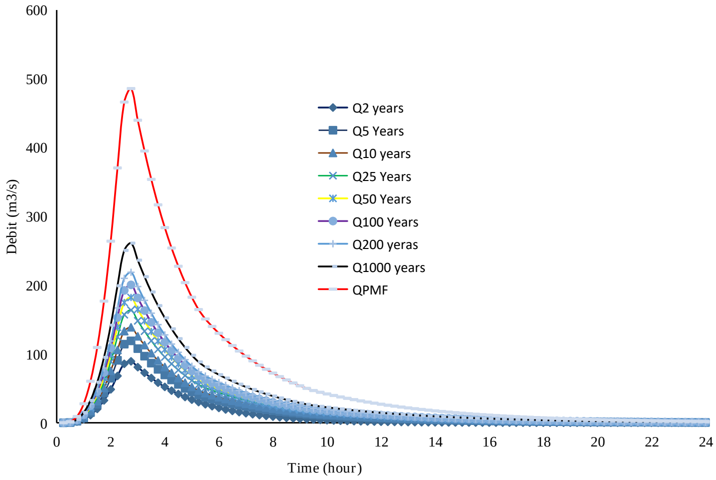

Figure 8. Badung River Flood Hydrograph in 2000

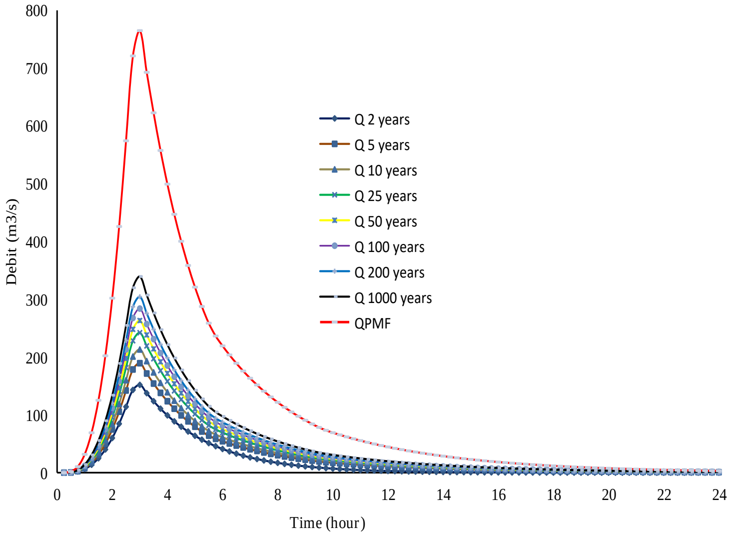

Figure 9. Badung River Flood Hydrograph in 2026

3.8. Badung River Embankment Capacity

The river width upstream of the Hasanuddin Bridge is 15.45 m with an average embankment height of 3.0 m. The river width downstream of the Hasanuddin Bridge is 19.14 m with an average embankment height of 2.54 m [16].

During the Probable Maximum Flood, the Badung River discharge was 764.91 m^3/s. The current average height of the Badung River embankment is 3 meters, with a river width of 15.45 meters.The embankment capacity upstream of the Hasanuddin Bridge was 503.579 m^3/s, while downstream of the Hasanuddin Bridge, the Badung River embankment capacity was 482.174 m^3/s.

The analysis also shows that the water level in the Badung River during the Probable Maximum Flood is 3.80 meters. The water flow velocity during this maximum flood is 11,310 m/second upstream of the Hasanuddin Bridge and 10,865 m/second downstream of the Hasanuddin Bridge. This analysis concludes that the capacity of the Badung River embankment is inadequate to accommodate the maximum flood discharge.

To increase the capacity of the Badung River embankment, the embankment height was increased from 3.0 meters to 4.60 meters. The embankment guard height was 0.80 meters, and the river slope was set at 0.009. Other necessary measures in the study area include normalizing the channel slope to 0.009, maintaining the area's flow coefficient at 0.71, and managing and controlling waste in the area [23]. Effectively utilizing water resource structures on the Badung River, such as the Mertagangga weir, the Mergaya weir, and the trash rack, are being implemented. This treatment will increase the capacity of the Badung River in flood-affected areas to 886.360 m^3/sec [17][18].

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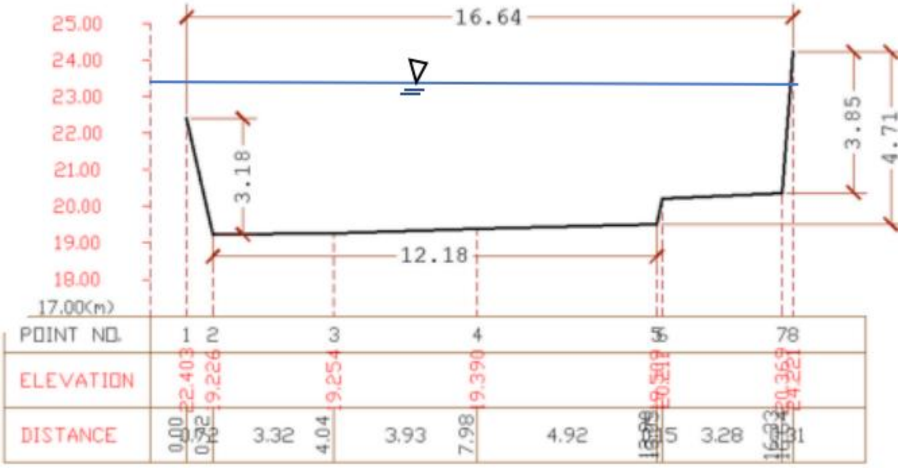

Figure 10. Cross-section upstream of the Hasanudin Bridge

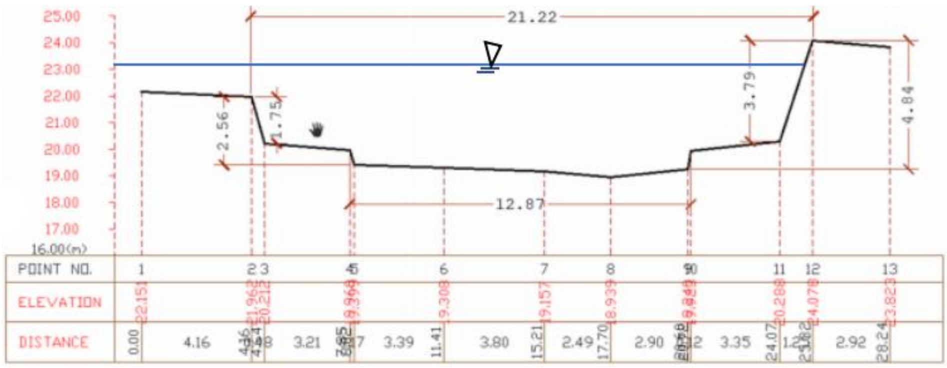

Figure 10. Cross-section downstream of the Hasanudin Bridge

4. CONCLUSION

The Probable Maximum Precipitation (PMP) in 2000 was 410.980 mm/day, while in 2026, it was 559.355 mm/day. The calculated Probable Maximum Flood (PMF) in 2000 was 485.82 m^3/sec, and in 2026, it was 764.91 m^3/sec.This increase occurred due to a change in the runoff coefficient, from 0.57 in 2000 to 0.71 in 2026. The 24.56% change in the coefficient was largely due to the conversion of paddy fields into residential and commercial areas, as well as the reduction of mangrove forests and green open spaces.

To increase the capacity of the Badung River embankment, the embankment height was increased from 3.0 meters to 4.60 meters. The embankment guard height was 0.80 meters, and the river slope was set at 0.009. Other necessary measures in the study area include normalizing the channel slope to 0.009, maintaining the area's flow coefficient at 0.71, and managing and controlling waste in the area. Effectively utilizing water resource structures on the Badung River, such as the Mertagangga weir, the Mergaya weir, and the trash rack, are being implemented. This treatment will increase the capacity of the Badung River in flood-affected areas to 886.360 m3/sec [19][21] [23]. Needs improvement due to the limited duration of rainfall data, lack of discharge calibration, the use of the one-dimensional Manning equation, failure to account for tidal effects, and sediment.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

REFERENCES

[1] M. H. E. S. Harahap, “Causes & impacts of extreme flooding in Denpasar Bali 10 September 2025,” *Antara News*, Sep. 2025.

[2] F. Ramadhan, “Walhi: Poor Spatial Planning and Land Conversion Cause Bali Floods,” Media Indonesia, Denpasar City, Sep. 2025.

[3] Y. C. A. Sanjaya, “Foreign Media Says about Bali Floods: 9 People Died, Called an Unusual Disaster,” *Kompas.com*, Sep. 2025.

[4] D. Ayu and C. Angelina, “Spatial Analysis of Priority Factors for Flood-Prone Areas in Denpasar City, Bali Province,” vol. 11, no. 2, pp. 145–152, 2022.

[5] I. A. D. Giriantari and A. G. U. Sistem, “Flood Potential Analysis in Denpasar City Using the Analytical Hierarchy Process Method,” *Maj. Ilm. Technol. Elektro*, vol. 17, no. 2, pp. XX–XX, 2018, doi: 10.24843/mite.2018.v17i02.p10.

[6] R. Vichotama, R. Haribowo, and T. B. Prayogo, “Water Quality Analysis of Tukad Badung, Denpasar, Bali Using the QUAL2Kw Program,” *Jurnal Teknologi dan Rekayasa Sumber Daya Air*, vol. 1, no. 1, pp. 40–51, 2021, doi: 10.21776/ub.jtresda.2021.001.01.04.

[7] M. Witari, “Management of Badung River as a City Tour Attraction Using a Participatory Development Model,” Jurnal Kepariwisataan, vol. 6, no. 1, pp. 146–152, 2007, doi: 10.52352/jpar.v6i1.20.

[8] M. F. J. et al., “Spatiotemporal Variability of Channel Roughness and its Substantial Influence on Flood Propagation,” Earth's Future, vol. 12, no. 7, Jul. 2024, doi: 10.1029/2023EF004257.

[9] C. D. Sumarto, *Engineering Hydrology*, 2nd ed. Malang, Indonesia: Erlangga, 1999.

[10] Y. Harjono and Widhiastuti, “Hydrology and Hydraulic Analysis of the Kali Pacal River Basin, Bojonegoro,” *Civil Engineering*, vol. 13, no. 1, pp. 16–23, 2019, doi: 10.21776/ub.tekniksipil.2019.013.01.3.

[11] B. R. Sri Harto, *Hydrological Analysis*. Jakarta, Indonesia: Gramedia Pustaka Utama, 1993.

[12] V. T. Chow, D. R. Maidment, and L. W. Mays, *Applied Hydrology*. New York, NY, USA: McGraw-Hill, 1988.

[13] Region III Denpasar Meteorology, Climatology, and Geophysics Agency, “Daily weather forecast and climate analysis for Denpasar City,” BMKG Region III Denpasar, Denpasar, Indonesia, Tech. Rep., 2026. Available: https://balai3.bmkg.go.id/ [Accessed: Aug. 26, 2026]

[14] BPS-Statistics of Denpasar City, “Denpasar Municipality in Figures 2026,” BPS-Statistics of Denpasar City, Denpasar, Indonesia, vol. 34, Feb. 2026. Available: https://denpasarkota.bps.go.id/ [Accessed: Aug. 26, 2026].

[15] Denpasar City Regional Government, “Regional Regulation of Denpasar City Number 8 of 2021 concerning Denpasar City Spatial Plan for 2021–2041,” Regional Gazette of Denpasar City, Denpasar, Indonesia, No. 8, Dec. 2021. Available: https://jdih.denpasarkota.go.id/ [Accessed: Aug. 26, 2026].

[16] Ministry of Public Works, “Drainage system assessment and flood control in Denpasar City 2025,” Ministry of Public Works, Tech. Rep., 2025. [Online]. Available: https://www.pu.go.id. [Accessed: Aug. 09, 2026].

[17] K. K. Khatua and B. Mahakul, “Flood in Mahanadi delta stage II area - A case study,” in *Proc. Nat. Sem. on Disaster Management*, UCE, Burla, Orissa, 1999.

[18] Paimin, I. B. Pramono, Purwanto, and D. R. Indrawati, *Watershed Management Planning System*. Bogor, Indonesia: Center for Conservation and Rehabilitation Research and Development, Ministry of Forestry, 2012.

[19] I. B. P. Adnyana and I. W. G. E. Triswandana, "Analisis debit banjir dan kapasitas tanggul Tukad Badung di Kota Denpasar," *Jurnal Ilmiah Teknik Sipil*, vol. 24, no. 2, pp. 112–119, Jul. 2020. Available: Jurnal Ilmiah Teknik Sipil Unud. doi: 10.24843/JITS.2020.v24.i02.p03

[20] S. Sosrodarsono and K. Takeda, *Hydrology for Irrigation*. Jakarta, Indonesia: PT Pradnya Paramita, 1985.

[21] C. A. Siwi, A. Binilang, and F. Halim, “Capacity analysis of the Makalu River in Southeast Minahasa Regency against flood discharge for specified return periods” (in Indonesian), *Jurnal Sipil Statik*, vol. 6, no. 4, pp. 199–210, 2011.

[22] P. D. H. Ardana *et al.*, “Design flood discharge analysis in the Tukad Mati watershed” (in Indonesian), *Jurnal Teknik Gradien*, vol. 14, no. 2, pp. 58–70, Oct. 2021, doi: 10.47329/ teknikgradien.v13i2.761

[23] H. Nugroho, *Aplikasi Hidrologi (Hydrology Applications)*. Jogjakarta, Indonesia: Jogja Global Media, 2008.

[24] Soewarno, *Hydrology: Application of Statistical Methods for Data Analysis*. Bandung, Indonesia: Nova, 1995.

[25] S. A. Brown, S. M. Stein, and J. C. Warner, *Urban Drainage Design Manual*, Hydraulic Engineering Circular No. 22, 3rd ed., Publication No. FHWA-NHI-10-009, Federal Highway Administration (FHWA), Washington, DC, USA, 2009.

[26] S. Javadinejad, R. Dara, and N. Dolatabadi, “Runoff coefficient estimation for various catchment surfaces,” *Resour. Environ. Inf. Eng.*, vol. 3, no. 1, pp. 145–155, 2022, doi: 10.25082/REIE.2021.01.005.

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