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Performance Analysis of Flood Control Buildings Mati River Watershed Area

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Abstract

The problem of flooding is a classic problem that befalls almost all regions in Indonesia. Likewise, the area in the Mati River watershed is experiencing problems that are not much different. Moreover, with the existing developments, almost all areas in the Mati River watershed have developed into urban settlement areas which have led to land conversion from agricultural land and green open land to other built-up land. The middle and downstream areas in the Mati River watershed are the main tourist areas in Bali such as Seminyak, Legian, Kuta and parts of the West Denpasar District, Denpasar City. These areas are dense settlements which contribute to increased surface runoff in almost all watershed areas. Several areas in the Mati River watershed are flood-prone areas, namely the Padangsambian area, Jalan Pura Demak area, Monang-Maning, Jalan Dewi Sri and areas in East Kuta. Several river improvements have been made to reduce the impact of flooding, namely changing the permanent weir to a mobile weir, normalizing the channel and building a pumping station which aims to reduce the effects of flooding and stagnant water during the rainy season. Of all the flood management efforts that have been carried out, they have not completely eliminated the potential for flooding in the Mati River watershed area, due to several fundamental problems such as the area being lower than the Mati River water level during flooding and changes in cross-section widening at several points which cannot be done. Therefore, it is very necessary to conduct an evaluation of the effectiveness of the performance of existing flood control structures. This research was conducted using quantitative analysis methods by conducting flood analysis and river capacity analysis. With this analysis, it is known that the pattern of water movement during a flood occurs and its relationship with the performance of existing flood control structures. The results of the research show that the number of flood control buildings in Mati River is four in the form of three steel motion weirs, three of which are Lange, Dadas and Umadwi weirs and one in the form of a pneumatic crest gate weir (estuary weir)/ Lange weir has a capacity 99.18 m^3/second,

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the Dadas weir has a capacity of 03.21 m^3/second and the Umadwi weir has a capacity of 165.23 m^3/second. The performance of each building in Mati River based on the results of calculations with a return discharge of 25 years (Q_{25}) respectively is Lange weir (90.35%), Dadas weir (72.78%), Umadwi weir (88.87%) and estuary weir (140.05%).

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1 Introduction

Flood problems almost always occur in several regions in Indonesia during the rainy season. Likewise, with the conditions that occur in the Mati River watershed, the potential for flooding and waterlogging often occurs in several areas with slightly sloping and low topography. Several attempts have been made to reduce the potential for flooding and waterlogging, BWS Bali Penida (2020), by changing three weirs from fixed weirs to moving weirs, namely the Lange weir in the Monang-Maning area and the Dadas weir and the Umadwi weir in the Padangsambian area. This change was made to accelerate the movement of water flowing downstream at an elevation that can be made lower than before. Other flood control measures are in the form of normalizing the river channel with walls made of precast concrete which is carried out on the Umadwi weir section up to the Sunset Road trash rack and the normalization of the channel in the downstream starting from the Bypass I Gusti Ngurah Rai road to the estuary. The normalization of this channel also aims to increase the speed of water flowing downstream so that the discharge that is passed becomes greater. The flood control structures in the Mati River watershed apart from changes to the weir and normalization of the channel are also a settlement flood control pump in the Padangsambian area and a weir in the form of a pneumatic Crest gate at the mouth of the river. The pump is intended to reduce the potential and inundation of the Padangsambian area and the pneumatic crest gate weir functions to pass water immediately when there is an increase in the volume of water in the river body (Olsen et al., 2012).

From all the efforts made, it is proven that the potential for flooding and stagnant water in the Mati River watershed has decreased. However, at several points/areas, this potential can still be witnessed today. The Jalan Pura Demak area and the Jalan Dewi Sri Kuta area are still areas that are frequently inundated. Seeing this condition, it is very necessary to analyze the performance of flood control buildings that have been made to the potential and future flooding (Rezende et al., 2019; Wu & Shao, 2022). The results of this study are expected to provide answers to the effectiveness of existing flood control structures as well as other necessary technical recommendations so that the Mati River watershed is increasingly free from potential flooding and water stagnation during each rainy season (Mohanty et al., 2020; Hudson et al., 2008). Based on the performance of the existing flood control buildings and their effectiveness in flood management in the Mati River Basin, several things can be formulated as follows: How many flood control structures are there currently in the Mati River Watershed? What is the planned flood discharge and capacity of each flood control building? How is the performance of the current flood control building?

Literature review
Watershed (DAS)

A watershed, abbreviated as DAS, is an area bounded by heights in the form of hills/hills/mountains so that rainwater that falls on the area eventually empties into the same estuary. On its way to the estuary, the river stem consists of small streams which then merge into larger streams and then become the same river downstream (Apriani, 2005; Dewan Sumber Daya Air Nasional, 2020). In a watershed, the boundaries of the watershed and the riparian areas will be drawn. An overview of the DAS can be seen in Figure 1:

Figure 1 Visualization of the River Basin Area
Source: Apriani, 2017

The shape of a watershed is closely related to the geographical conditions in which the watershed is located. Watersheds on elongated islands may also form watersheds that exist in the elongated area, but on the other hand islands or continents may form watersheds that are round. The shape of this watershed will affect the characteristics of the river, including the characteristics of the flooding it causes. Rivers with an elongated watershed shape have a longer peak flood time, in contrast to rivers with a round watershed shape which has a faster peak flood time (Sutapa, 2006; Rahayu et al., 2017; Hambali, 2017; Fatahilah, 2013). Several forms of existing watersheds such as (Sutapa, 2006):

1) Bird feathers or elongated
   The watershed in the shape of a bird's feather has the characteristics of several streams of water from several tributaries flowing into the main river. The flow of each tributary does not meet each other at the same point. The potential for flooding in this form of watershed is small because the water flows do not directly meet at one point. But if there is a flood, it will last quite a long time
2) Radial (spread)
   Radial watersheds have a watershed shape resembling a fan or circle. The flow of water from several tributaries is concentrated at one point. Major floods often occur at the meeting point of tributaries.
3) Parallel (parallel)
   Parallel watersheds have two main river flow paths which then unite downstream. The potential for flooding in parallel watersheds is high because the water flows meet at one point.
4) Complex
   Complex-shaped watersheds are in one watersheds consisting of three shapes, namely plumage or elongated, radial, and parallel

Specifically, each form of watershed has advantages and disadvantages in terms of river management, both for utilization and flood prevention. The condition and shape of the watershed are one of the basic guidelines for wise river management (Yin & Li, 2001; Birkholz et al., 2014). A complete description of the shape of the watershed can be seen in the following figure 2 which shows the characteristics of each watershed.

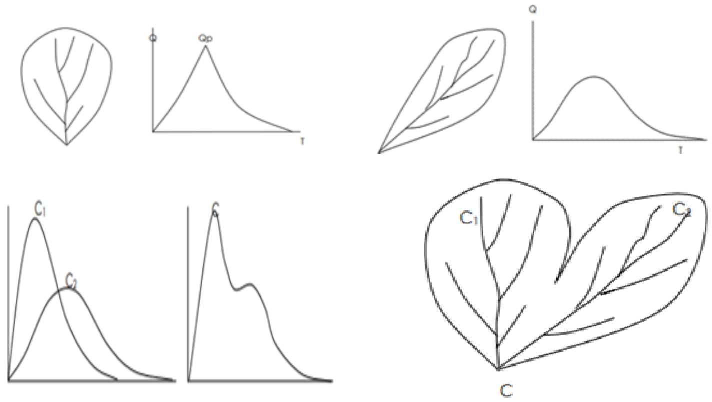

Figure 2. Parallel watershed shape
Source: Sutapa, 2006

Hydrological analysis

Hydrological analysis in a flood analysis is an analysis to determine the amount of design rain, design flood and capacity analysis.

1) Design Rain Analysis
Design rain analysis is an analysis to determine the amount of rain with a certain return period, for example, a two-year return period (R2), R5, R10, R25, R50, R100, etc. The design rainfall is analyzed based on the annual maximum daily rainfall data from each rain station data around the study area. In the design rain analysis, several methods are known, such as Gumbel, Log Person Type III, Log-Normal and so on. Selection of the most appropriate test is selected based on statistical tests (Basuki et al., 2009; Jarwinda, 2021; Ginting & Putuhena, 2016).
2) Design Flood
A design flood is a flood that statistically occurs within a certain return period. This design flood is designed according to construction needs in the field of irrigation engineering, for example, floods with a two-year return period (Q2), Q5, Q10, Q25, Q50, Q100, etc. The results of this flood analysis form the basis for analyzing the capacity of rivers and other flood control structures. Many methods can be used to calculate design floods such as the Nakayasu method, Gama I and the rational method (Sarminingsih, 2018; Gunawan et al., 2020; Utomo et al., 2021; Adoe et al., 2021). Figure 3 shows an analysis of the design flood analysis with the Nakayasu method. Qp is the peak discharge, while TP is the time at which the peak discharge is reached.

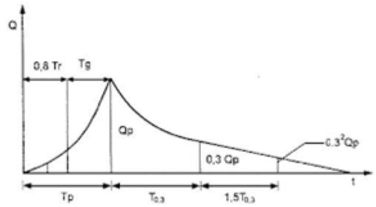

Figure 3. Design flood analysis using the Nakayasu Cythetic Unit Hydrograph (HSS) method
Source: Damayanti, 2022

3) Capacity Analysis
The capacity analysis is an analysis to estimate the amount of discharge flowing in a cross-section either in the river body or in flood control structures (Saputra & Kumar, 2015; Saputra et al., 2018). The capacity analysis is obtained by multiplying the cross-sectional area by the speed of the flowing water:
Q = A.V (m3/s)

Where:
A: cross-sectional area (m2)
V: speed of water (m/s)

Flood Analysis
Flooding in a river is an overflow of water from the river to the surrounding land caused by an imbalance between the capacity of the river and the existing discharge (Findayani, 2018; Santoso, 2019; Bakker, 2009; Beura, 2015; Hamidifar & Nones, 2021).

Conditions of the Mati River watershed

The Mati River watershed is in the western part of Denpasar City, flows from the north around the Sempidi area and flows to the south, and empties into the Benoa Bay Community Forest Park/mangrove. This river has a large watershed upstream and a smaller the downstream as shown in Figure 4.

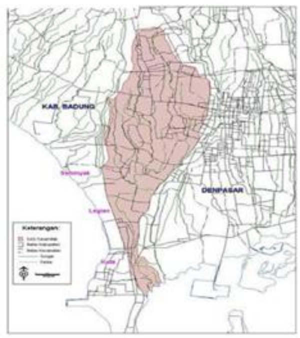

Figure 4. Mati River watershed area
Source: Kerta Arsana, 2019

Mati River is a river flow that does not have a central spring which has the main function as drainage for urban areas. The Mati River divides parts of Denpasar City and Badung Regency with a watershed area of 39.43 km2 and the length of the main river is 22.49 km. The main water source of the Mati River is the remaining wastewater from the irrigation area of the Penarungan irrigation area (BWS Bali Penida, 2020).

2 Materials and Methods

Research design

The stages of the research were carried out with administrative preparations, data collection, observations and field visits, analysis and technical recommendations were carried out.

a) Preparatory work includes preparing correspondence, preparing field and administration teams, planning field visits, observing current flood conditions, observing the condition of flood control buildings as well as planning for searching and collecting data.
b) Data collection includes annual maximum daily rainfall data, river length data, watershed area data, flood conditions that have occurred, government policies in flood management and others.
c) Analysis
    1) Design rain analysis: design rain analysis using the Gumbel method, Pearson Log Type III, Normal Log etc. with various return periods (R2, R5, R10, R25, R50 and R100)
    2) Design flood analysis: design flood debit analysis using the Nakayasu/ Rational method for various return periods (Q2, Q5, Q10, Q25, Q50 and Q100)
    3) Analysis of river capacity with the Manning method
    4) Analysis of government policies in controlling floods in the Mati River watershed
    5) Analysis of the performance of flood control buildings

6) Technical recommendations
The research work steps are outlined in the form of a research flowchart which describes the stages from start to finish sequentially according to the research period. The complete research diagram can be seen in Figure and Figure 5

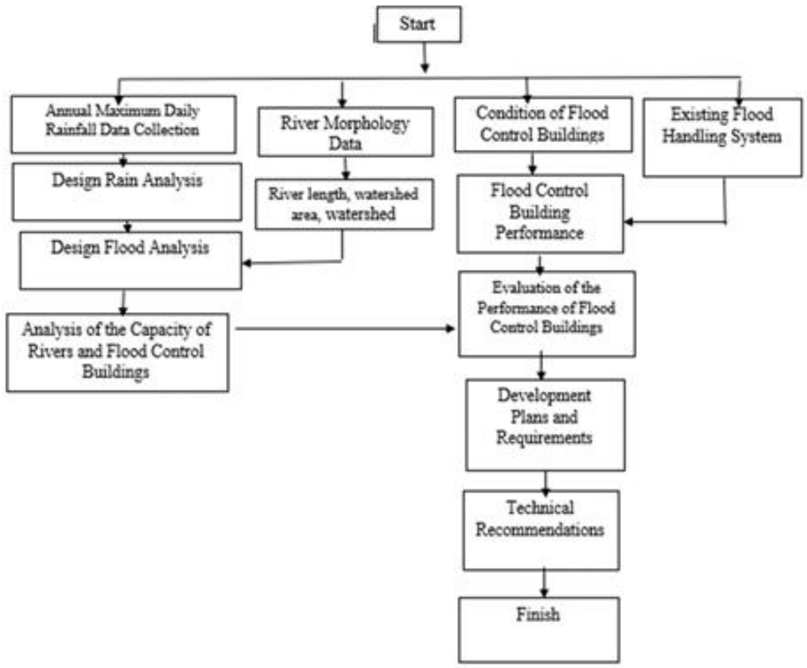

Figure 5. Research flow chart

Surveys, field observations and collections

1) Conduct field surveys to determine the condition of flood control buildings
At this stage, several field visits were carried out to obtain the following data:
a) Areas with potential inundation and flooding
b) Location of flood control buildings
c) Physical condition of flood control buildings
d) Flood control building capacity
e) Performance problem

2) Stages of Analysis
Analysis of the performance of flood control structures is carried out in a continuous and integrated manner with the following stages:
a) Analysis of river morphology
b) Design rain analysis
c) Design flood analysis
d) Analysis of the capacity of rivers and flood control buildings
e) Analysis of government policies in dealing with floods
f) Performance analysis of lava control structures

3 Results and Discussions

3.1 River conditions

Mati River is a river in which the watershed system (DAS) occupies two regency/municipality administrative areas, namely the Badung Regency area in the downstream and upstream parts, while the middle part crosses the Denpasar City area. The land use of the catchment area as a whole is in the form of cultivation land, settlements and urban areas. This area is an area that is developing very rapidly resulting in significant land conversion from agricultural/moor land to residential, commercial, industrial and other uses (Azadi et al., 2018). In general, the topography of the Mati River watershed starts from a rather steep area in the north and empties into the south sea, where the downstream is influenced by tidal currents (Morrison et al., 2002). In general, with a rather flat area downstream, it can be said that there are river bends (meanders) at several points, especially the channel after Jalan Gatot Subroto reaches the estuary. This can be seen in the flow along the Mahendradata road with the winding river channel as evidenced by the many bridges along the Mati River channel. The cross-section of the Mati River from upstream to downstream has a very varied width and depth. The middle part of the Mati River, starting from the upstream to Jalan Gunung Agung, has a cross-sectional profile that is quite wide and deep. Meanwhile, from the Gunung Agung road to the downstream, it has a varied cross-section and shallow and winding river channel. River conditions can be seen in Figure 6.

Figure 6. Mati River condition

3.2 Regional development influence

The development of development in Bali, especially in southern Bali, has resulted in the development of all sectors, especially the tourism sector as the leading sector. The most obvious condition can be seen in the Mati River watershed, where land conversion occurs very quickly (Firman, 2000). Changes in land use have created new problems, namely increased surface runoff which has the potential to cause flooding and stagnant water during the rainy season. Mati River with its typical flat and meandering river has the potential to become inundated and flooded areas during the rainy season. This is because the Mati River is no longer able to accommodate the overflow of floods that occur as a result of the limited capacity of the river.

3.3 Existing drainage system

The Mati River drainage system is a river system with drainage in the western part of Denpasar City (System 3). The river drainage system is divided into two systems, namely:

1) Upstream Tukad Mati System
   The upstream Mati River system includes drainage channels which are strongly influenced by the existence of irrigation areas above it such as discharge from the Penarungan irrigation area (DI), Kapal DI and Mambal DI. Some of this wastewater will burden the drainage system in the Mati River as a whole.

2) Lower Dead Tukad System
The lower Mati River system is a natural Mati river system with its tributaries namely Tukad Pangkung Muding and Tukad Pangkung Kedampang. The flow system in the estuary of the Mati River is strongly influenced by the tides. Backwater due to sea level and sea tide greatly affects the drainage system on a micro scale, especially for the Kuta area.

3.4 Drainage problems

The Mati River, as one of the main drainage areas in Denpasar City and parts of Badung Regency, has several problems related to inundation and flooding which often occur in this area. Some of the problems that can be conveyed related to drainage problems in this area through literature studies and field observations can be conveyed as follows:

1) Significant changes in land use change in the upstream and middle areas as well as in some parts of the downstream have contributed greatly to increasing surface runoff. The increase in existing water runoff is not matched by an adequate increase in drainage capacity. This condition can be seen from the development of settlements in North Denpasar, the Badung Puspem area, residential areas in Pemogan and Pedungan as well as the development of settlements in the downstream part of Tukad Ayung around the North Denpasar and East Denpasar areas.
2) Settlement development system with Land Consolidation (LC) system from paddy fields has caused a change in the direction of channel use from irrigation canals to drainage canals. This condition can be seen in several housing estates such as Monang-Maning and several housing estates in Padang Sambian, around Pura Demak Street, new settlements and shops along Mahendradata road, settlements around North Denpasar and East Denpasar and in South Denpasar around Pemogan, Pedungan and surround.
3) Topography of a flat area making it difficult to drain the water into the sewer.
This condition can be found in residential areas around Jalan Pura Demak, residential and business areas around Dewi Sri Street, Nakula Street, Renon, Sidakarya, Pedungan and Pemogan and the surrounding areas.
4) There is a narrowing of the river channel, especially in the middle and downstream, so that it often causes flooding
5) The existence of a building that crosses the river which affects the river flow system downstream. Several bridges built over rivers have the potential to cause disturbances to the flow system downstream.
6) High sedimentation rates (Seminyak and Legian areas) in the river channel have a huge effect on reducing the capacity of the river.
7) Disposal of garbage into river bodies
This condition occurs because of low public awareness to participate in maintaining the function of existing drainage channels and rivers.
The existence of garbage that enters the body of the canal or river occurs in almost all existing sections.
8) Effect of tides
This condition greatly affects the disposal of water towards the estuary, especially in micro drainage.

3.5 River channel conditions

The Mati River channel originally had a function as an irrigation canal for several subaks in Denpasar and Badung such as DI Lange, DI Tegeh, DI Dadas, DI Umadwi and DI Ulun Tanjung. The main source of water in the Mati River channel is irrigation drainage from irrigation areas that are upstream or above it, such as DI Penarungan, DI Kapal and DI Mambal.

As a result of developments in the City of Denpasar and the Badung Regency Region such as Sempidi, Kapal, Kuta, Seminyak, Dalung and the surrounding areas, this has resulted in the conversion of agricultural land into very large non-agricultural land which affects increasing surface runoff into the Mati River body. Likewise, the development of the City of Denpasar, demands a lot of land, causing land prices to be very high, including land along the Mati River channel. Regarding the existence of the Mati River channel, some data and facts in the field can be conveyed as follows:

1. The number of complementary buildings that cross the river has the potential to cause disturbances to the flow of the river.
   Along the Mati River channel, there are 21 buildings in the form of 3 (three) motion weirs (Lange weir, Dadas weir and Umadwi weir), 1 (one) trash rack and 17 bridges. Of the existing buildings and bridges, the width of the span varies greatly between 24 meters to 10 meters. The effective width of existing buildings and bridges greatly influences the smooth flow of water downstream.
2. Most of the channel conditions are river walls with stone masonry.
3. Limited River border conditions
   This condition is almost found in all river bodies where the existing borders are very limited so it becomes very difficult to normalize the river sideways to widen the existing river bodies.

3.6 Hydrological analysis

Identification of rain stations in the Mati River basin

The Mati River is located in the western part of Denpasar City and has a length of 22.43 km and a catchment area of 44.67 km2. The rain stations that are influential in the study area are the Sading Rain Station, Kapal in the north, Sanglah and Sumerta Stations in the middle and Ngurah Rai Station in the downstream. Rain data can be seen in Table 1.

Table 1
Rainfall Station In Mati River Watershed

No.	Tahun	Staisun Ngurah Rai	Staisun Sanglah	Staisun Kapal	Hujan Rerata Daerah
1	2003	110	98	103	104,30
2	2004	199	102	95	138,70
3	2005	184	110	75	129,10
4	2006	82	120	124	106,00
5	2007	92	177	81	114,20
6	2008	192	160	80	148,80
7	2009	147	155	100	135,30
8	2010	126	77	120	109,50
9	2011	231	148	102	167,40
10	2012	139	228	97	153,10
11	2013	99	136	163	129,30
12	2014	78	80	112	88,80
13	2015	120	143	166	140,70
14	2016	142	110	100	119,80
15	2017	117	102	130	116,40
16	2018	116	95	154	121,10
17	2019	96	190	109	128,10
18	2020	115	74	218	133,60
19	2021	109	75	239	137,80
20	2022	145	112	124	128,80

Source: meteorologi, Climatologi And Geofisika Denpasar Offive, 2022

Rain data consistency and validity test

Testing the consistency and validity of rain data needs to be done to obtain uniform distribution of rain data at each station for different years of observation of rain data. In testing the consistency and validity of the rain data, two methods were carried out, namely the outliner method and the so-called adjusted partial sums (RAPS) method.

Design rainfall

Design rainfall is the amount of rainfall that is calculated to occur in a certain area in a certain return period. In this case, the design rainfall will be calculated for the return period of 2 years, 5 years, 10 years, 25 years, 50 years and 100 years. The data used is regional rainfall data in the Mati River watershed area. The method used in the rainfall analysis of this design is the Log Pearson Type III method as presented in Table 2.

Table 2
Results of Design Rain Analysis Using Pearson Log Type III Method

No	Time cycle (T) (Year)	G	Extrapolation (Xt) (mm)
1	2	0,0251	125,36
2	5	0,8505	143,46
3	10	1,2737	153,73
4	20	1,5659	161,25
5	25	1,7121	165,15
6	50	1,9813	172,58
7	100	2,2260	179,62
8	200	2,4452	186,17
9	1000	2,9016	200,59

Source: Analysis

Design flood

Design flood is the maximum discharge in a river or canal with a predetermined return period. If the design flood is used as the basis for planning, the flood that occurs can be channelled without endangering the stability of the building. Based on the analysis of the planned rainfall from the maximum daily rainfall data, it can be calculated the magnitude of the planned flood discharge with return periods of 2, 5, 10, 25, and 50.

In the process of determining or analyzing flood discharge, the first step is to construct a unit hydrograph. Where the unit hydrograph is the transformation of rain data into discharge data. In this study, the calculation of the Nakayasu Unit Hydrograph is used. The following is the calculation of Nakayasu's HSS (Synthetic Hydrograph Unit) and the results can be seen in Figure 7.

Watershed and Rainfall Parameters
The following are the parameters of the DAS and Mati River Rainfall:
Watershed area (A) = 22.26 km2
River Length (L) = 22.43 km
Unit rain height (Ro) = 1 mm
Coefficient (α) = 2.5

Calculation of peak time (tp) and time lag (tg)
Time coefficient (Ct) = 0.553
Peak Time (Tp) and Time Lag (Tg):
- Tg = 0.4 + (0.058 * L)
= 1.70 hours
- Tr = 0.75 x Tg
= 1.28 hours
- Tp = Tg + 0.8 Tr
= 2.72 hours
- T0.3 = α x Tg
= 4.25 hours
- Tp + T0.3 = 6.97 hours
- Tp + T0.3 + 1.5 T0.3 = Tp + 2.5T0.3 = 13.35 hours

Calculation of Peak Discharge (Qp)
$Qp = (A \times Ro)/(3.6\ (0.3\ Tp + T_{0.3}))$
$Qp = 2{,}448$

Hydrograph Curve
The following is the calculation of the Nakayasu hydrograph curve:
Curve Up
$0 < t < Tp$ □ $0 < t < 2.72$
$Qt = Qmax\ (t/Tp)2.4$
Stage I Descending Arch
$Tp < t < (Tp + T0.3)$ □ $2.72 < t < 6.97$
$Qt = Qmax\ (0.3)^{((t-Tp) + 0.5\ T0.3) / 1.5\ T0.3)}$
Stage II Descending Arch
$(Tp + T0.3) < t < (Tp + 2.5T0.3)$ □ $6.97 < t < 13.35$
$Qt = Qmax\ (0.3)^{((t-Tp) + 0.5\ T0.3) / 1.5\ T0.3)}$
Stage III Descending Arch
$t > (Tp + 2.5T0.3)$ □ $t > 13.35$
$Qt = Qmax\ (0.3)^{((t- Tp) + 1.5\ T0.3)/(2\ T0.3))}$

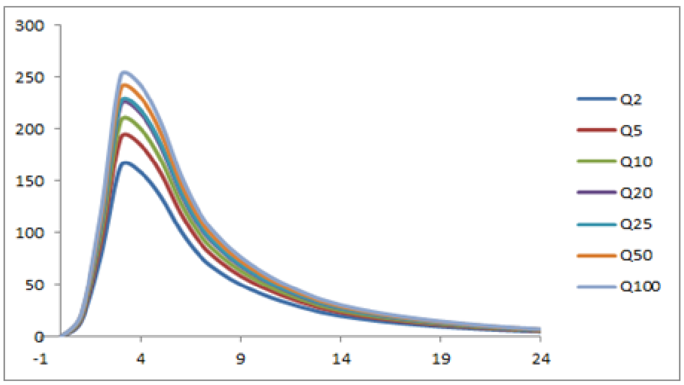

Figure 7. Flood Hidrograf of Mati River

River hydraulics and capacity analysis

Capacity analysis is carried out to determine the capacity of each river segment. The results of this analysis are then compared with the existing discharge plans. From this analysis, the capacity of the existing river bodies will emerge. In the analysis of the capacity and hydraulics of the river, it is calculated that the river body is clean from garbage and sediment so during the operation and maintenance of the river, the cleaning of garbage and sediment in the river is one of the concerns in flood control. Analysis of the capacity of the Mati River is simulated with a flood discharge every 25 years. This return period consideration was chosen based on the type of river with a typical urban river, the risks that might occur and seeing the realistic condition of the river channel that currently exists in the field. The complete calculation results are as in Table 3.

Table 3
Analysis Capacity of Mati River

No.	Point	B (m)	H (m)	Capacity (m^3)	Q_{25} (m^3)	Information
1	Gatot Subroto Bridge	20	4	354,15	90,18	Not Fllod
2	Gunung Agung Bridege	15	4	223,52	95,12	Not Fllod
3	Mahendradata Bridge	16	3,5	199,19	97,25	Not Fllod
4	Resimuka Bridge	10	3	89,57	102,25	Not Fllod
5	Mahendradata Bridge	12,5	3,5	147,33	103,56	Not Fllod
6	Mahendradata Bridge	23	5	320,14	106,72	Not Fllod
7	Lange Dam	10	3	99,19	109,78	Flood
8	Buana Raya Bridge	11	3	102,31	112,31	Flood
9	Mahendradata Bridge	24	3	258,88	113,63	Not Fllod
10	West Teuku Umar Bridge	23	1,5	102,21	117,88	Flood
11	Mahendradata Bridge	11	3,5	91,54	116,08	Not Fllod
12	Dadas dam	10	3	93,21	128,08	Not Fllod
13	Gunung Soputan Bridge	15	5	245,4	185,11	Not Fllod
14	Umadwi dam	18	3,5	165,23	185,93	Flood
15	Sunset Road Bridge	24	4	307,12	216,92	Not Fllod
16	Trash Rack	24	4	307,12	216,92	Not Fllod
17	Nakula Bridge	13	4	147,89	209,44	Flood
18	Sri Rama Bridge	20	4,5	297,77	210,54	Not Fllod
19	Patih Jelantik Bridge	17	5	207,36	254,73	Flood
20	Raya Kuta Bridge	25	5	433,49	258,71	Not Fllod
21	Blambangan Bridge	26	4,5	310,14	286,83	Not Fllod
22	Hotel Lavender Bridge	18	6	255,06	293,8	Flood
23	By Pass Ngurah Rai Bride	24	7,5	405,29	297,97	Not Fllod
24	Estuary Dam	45	5	405,29	297,97	Not Fllod

From the analysis carried out, it shows that if it is simulated with Q25 of the 24 existing segments, nine segments experience overflow. These segments are:

1) Ngurah Rai (surfer girl) bridge section - Blambangan bridge
   The overflow at this point was caused by the reduction of the river body behind the Levender hotel and the accumulation of sediment. Potential inundation in the south of the Police Housing Complex to the south of Samudra Kuta Field.
2) Jalan Raya Kuta Bridge - Patih Jelantik Bridge
   The overflow at this point is caused by sedimentation in the river body. Potential inundation on Dewi Sri road.
3) Nakula-Sunset Road Bridge Section
   The overflow at this point was caused by the bottle neck on the Nakula bridge road and sedimentation that occurred in the river channel. Potential inundation in the Legian area.
4) Section of the Dadas Dam-Umadwi Dam
   Overflow at this point is due to the narrow width of the Dadas weir. Potential inundation around Padangsambian.
5) Bridge Section Mahendradata-West Teuku Umar Bridge. The overflow at this point was caused by high enough sedimentation so that the clearance of the Teuku Umar Barat bridge was very limited. Potential puddles around Jalan Pura Demak.
6) Mahendradata Road Bridge Section - Buana Raya Road Bridge
   The overflow at this point is caused by the narrow width of the Buana Raya bridge. Potential puddles around Jalan Buana Raya.

7) Lange Dam Section – Bridge on Mount Resimuka Road
   This overflow was caused by the narrow width of the Reimuka bridge and sedimentation. Potential for inundation around the Monang-Maning National Housing Complex.

The results of this analysis indicate that the characteristics of the Mati River which is flat, meandering, sedimentation and limited borders have the potential for more frequent floods during the rainy season. Even though the difference between river capacity and Q25 is not that big, this should be considered in terms of reducing water inundation and flooding in the study area (Martines et al., 2022).

3.7 Flood control

The Mati River is the river that most often experiences flooding and waterlogging in its watershed area compared to Tukad Badung and Tukad Ayung due to the flat condition of the river. This condition has the consequence of sedimentation and meandering flows. Likewise, the winding channel causes 13 bridges and 3 weirs in this river segment which unknowingly contributed to the occurrence of floods and waterlogging.

In an effort to protect the river bed from being eroded, it is very necessary to secure the river bed in the form of making masonry trunks which are installed along the channel which already has masonry walls. The proposed masonry is 0.5-0.8 m wide and 0.5-0.6 m high. The addition of these suitcases does not significantly reduce the capacity of the river because the capacity is still close to the previous capacity. The results of the capacity analysis with cooperative buildings are as follows:

Based on the results of the capacity analysis of each flood control structure, it can be said that only the weir in the estuary is still safe to control flooding while the other three weirs, namely the Lange, Dadas and Umadwi weirs, are unable to pass floods with a return period of once every 25 years with performance in below 100%. The results of the performance analysis of flood control buildings can be seen in Table 4.

Table 4
Performance of flood control buildings Mati River

No.	Flood Control Building	Capacity (m^3/dt)	Q_{25} (m^3/dt)	Performance (%)
1	Lange Dam	99,19	109,78	90,35
2	Dadas Dam	93,21	128,08	72,77
3	Umadwi Dam	165,23	185,93	88,86
4	Estuary Dam	420,31	300,12	140,04

Source: Analysis

4 Conclusion

Some of the things that can be concluded from the analysis that has been carried out on the flood control structures in the Mati River are as follows:

a) The number of flood control structures in the Mati River is four in the form of three steel weirs, three in the form of Lange, Dadas and Umadwi weirs and one in the form of a pneumatic crest gate weir (estuary weir).
b) The Lange weir has a capacity of 99.18 m3/s, the Dadas weir has a capacity of 03.21 m3/s and the Umadwi weir has a capacity of 165.23 m3/s.
c) The performance of each building in the Mati River based on the results of calculations with a 25-year return period discharge (Q25) respectively is Lange weir (90.35%), Dadas weir (72.78%), Umadwi weir (88.87 %) and estuary weir (140.05%)

Conflict of interest statement
The authors declared that they have no competing interests.

Statement of authorship
The authors have a responsibility for the conception and design of the study. The authors have approved the final article.

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