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Handling and Control of Floods in the Pulukan River/Tukad Macro Drainage System in Jembrana Regency

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ABSTRACT

Handling and controlling floods in the river/Tukad macro drainage system as the main discharge is a very complex matter. The engineering dimension (engineering) involves many disciplines. In this study, the analytical review is only on hydrological boundaries, hydraulics, watershed erosion, river engineering, morphology, river sedimentation, handling engineering, and flood control systems. The stages of compiling this research were preceded by the collection of secondary and primary data which were then carried out by analysis. The analysis in this planning is carried out qualitatively, quantitatively, and descriptively. The qualitative description focuses on inventorying the drainage system, determining the zoning of the drainage system based on watershed boundaries, class, and identification of area/area per unit drainage system. The quantitative analysis focuses on hydrological and hydraulic calculations as well as a detailed design of each segment of the drainage channel by the service area of each drainage system. Furthermore, the descriptive analysis focuses on determining the priority scale for the handling of the drainage system which is considered vulnerable to flood hazards in the downstream area. Besides that, it also provides technical and non-technical recommendations for flood management. The results of the analysis of the sedimentation rate of the Pulukan River/Tukad 384.726 tons/ha/year are included in the class of severe erosion hazard because most of the community gardening activities are at an elevation of 25% to 40% which has an impact on the high LS slope factor. The existing cross-sectional capacity of the Pulukan River/Tukad is not able to accommodate the flood discharge planned for a return period of 50 years. From the results of this analysis, it is necessary to carry out flood handling/control using structural and non-structural methods. The Tukad Pulukan Watershed flood management and control program includes; reforestation, river normalization work, river management building, Tukad Pulukan watershed management, community-based watershed management, land use regulation, construction of access road inspections, installation of recording of water level and density of recording stations rainfall.

Keywords: handling; flood; control; macro; drainage.

INTRODUCTION

Rivers are one of the water resources that provide many benefits for human life, but rivers can also cause various problems, and even disasters for life around them, if not managed properly. In line with the increasingly complex dynamics of community life, the role of rivers in the future will become even more complex.

Based on the report (BWS, 2020), there are several rivers located in Jembrana Regency such as Tk. Ijo Gading, Tk. Biluk Poh, Tk. Yeh Sumbul, and rivers located in Buleleng Regency such as Tk. Banyuraras, Tk. Musi, Tk. Banyupoh, Tk. Pulukan is the river that directly empties into the sea and flows continuously throughout the year with a fairly large discharge. In addition, the condition of the river channel has a less strong stratigraphy so it is very likely to experience erosion and is very easily eroded.

River Basin Area is a unitary water system area that is formed naturally, where water seeps or flows through the river and its tributaries. Often referred to as DAS (watershed) or DTA (water catchment area). A watershed is an area where all the water flows into the intended river. This area is generally limited by topography which means it is determined based on surface water flow (Br, 1993).

The flood problems that occurred in the Tukad Pulukan watershed caused some damage; 1) scour occurred on the river bank of SDN 1 Sepang kelod, 2) overflow of river water upstream near the Denpasar - Jembrana bridge inundated the Pekutatan residents' settlement (near the bridge).

The effect of land use on runoff is expressed in the runoff coefficient (C), which is a number that shows the ratio between the amount of runoff and the amount of rainfall. This runoff coefficient figure is one of the indicators to determine the physical condition of a watershed. The cropping pattern in the Tukad Pulukan watershed greatly determines the level of sedimentation that occurs in the river channel and affects the ability of the cross-section to carry the planned flood discharge. Based on the BIG map (2017), land use in watersheds (DAS) in Tukad Pulukan is for forests and shrubs 56%, gardens 20.70%, fields 19.17%, and other land allotments for rice fields and settlements.

From the problems above, the research will analyze the system of the magnitude of discharge handling and controlling floods in the Tukad Pulukan macro drainage in Jembrana Regency. Seeing some of the developments and activities of the community around the Tukad Pulukan watershed, it is necessary to analyze the sediment level which affects the sedimentation process in the river channel and the magnitude of the design flood discharge so that the stages of the flood management and control program can be carried out in the Tukad Pulukan watershed.

RESEARCH METHODS

Materials

The research location "Handling and Controlling Floods in the Tukad Pulukan Macro Drainage System in Buleleng - Jembrana Regency" is a watershed (DAS) located across Buleleng and Jembrana districts. The river Pulukan watershed (DAS) covers an area of 55.22 km2 with a river length of 27.12 km. The bed conditions and the existing Pulukan river cliffs in the study area, especially in the middle and downstream parts, are rocks that break easily and it's made worse by the condition of the river where there was C excavation activity in the past and there are several places in Tukad Pulukan there are still C excavation activities. Changes in river conditions will greatly affect the stability of the bottom and riverbanks and these river conditions will make it easier for scour to occur. The research location can be seen in Figure 1 and the research flowchart used in this study can be seen in the flowchart in Figure 1.

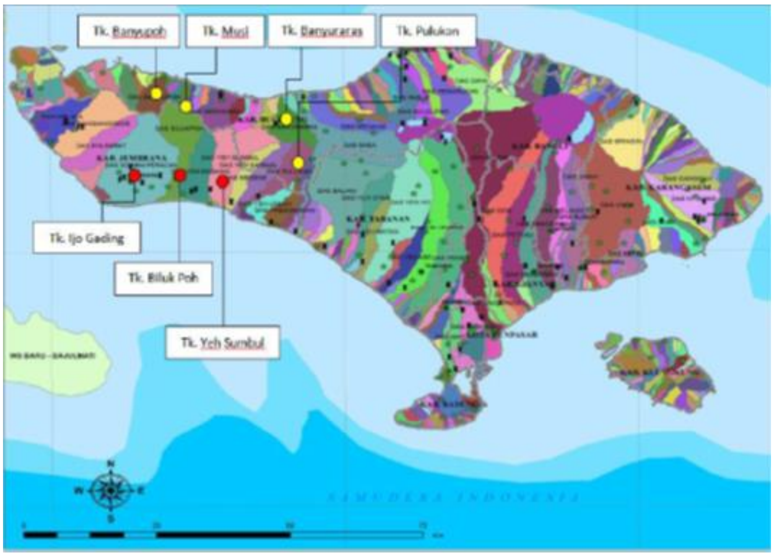

Figure 2. The research location

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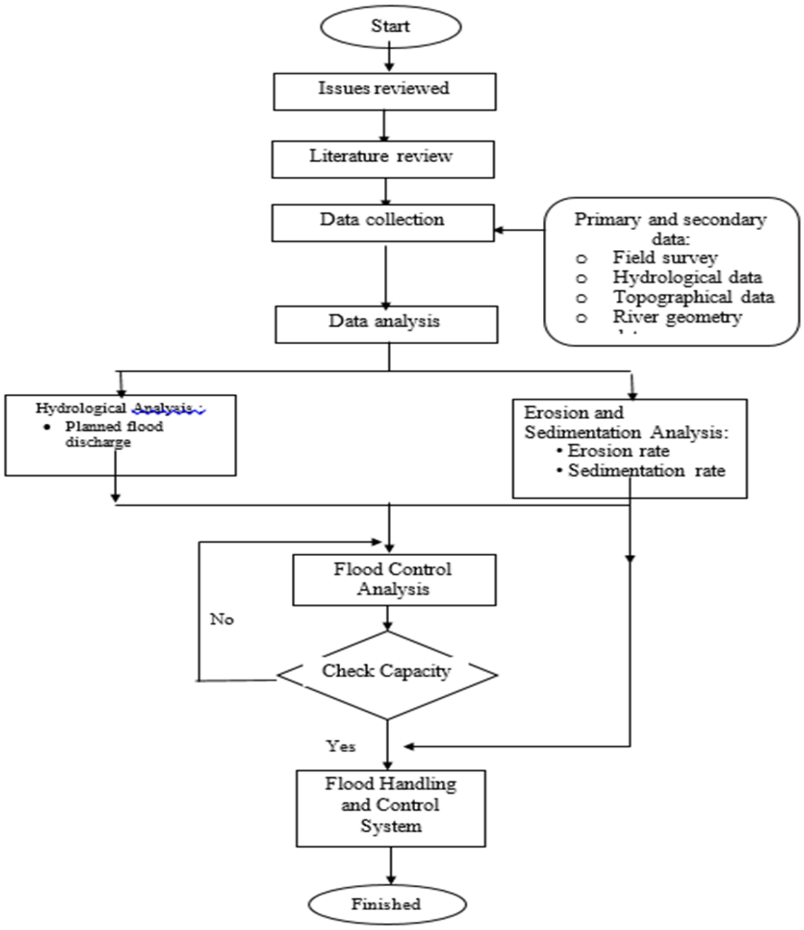

Figure 1. Flow chart

Methods

Types and Data Sources

The type of data collected in this plan consists of primary data and secondary data. Primary data, namely data collected directly by the planning team from survey/observation/measurement activities, is the condition of flood areas in urban and surrounding areas, the area of inundation that must be drained, the condition of the existing drainage system, existing facilities in drainage channels and buildings, and others.

The secondary data in question is data obtained from the results of research by other parties such as previous studies, rain data, river discharge data, flood area data, inundation characteristic data, flood hazard area coverage data, and so on.

Research methods

To meet the data requirements referred to above, data collection activities are carried out using the following procedures:

- Literature review

The literature study is in the form of a literature study on all previous activities and investigations in the field of water resources related to drainage problems. This literature study is intended to establish theories and formulas that are by the data available in the field

- Primary Data Collection Method

  This method can be in the form of field surveys, namely direct observations in the field to obtain primary data at locations deemed necessary, about incomplete data, or if there is a problem that requires re-examination. In addition, this method is also able to identify the characteristics of regional flooding, watershed conditions prone to flooding, flood inundation conditions in urban and surrounding areas, damage to existing drainage systems, both channels and drainage buildings, waste conditions in drainage canals and buildings, drainage facility management systems, and others.

- Secondary Data Collection Method

  Secondary data collection is the collection and evaluation of all relevant up-to-date data from relevant agencies. These data are needed to identify the condition of the existing drainage system and how to handle it based on technical studies of available secondary data in the field.

Data Analysis

The method of analysis in this plan is carried out qualitatively (Agusta, 2003; Sarosa, 2021; Wahidmurni, 2017) and quantitative methods (Muhson, 2006). Qualitative analysis focuses on the activities of inventorying the drainage system, determining the zoning of the drainage system based on watershed boundaries, classification of types and levels of drainage networks, and identification of area/area per unit drainage channel system Quantitative analysis focuses on hydrological and hydraulic calculations as well as detailed design of each drainage canal segment according to the service area of each drainage system.

The stages of analysis carried out in the preparation of "Handling and Control of Floods in the Macro Drainage System on the River/Tukad Pulukan are as follows:

Hydrological Analysis

This frequency analysis is based on the statistical nature of past event data to obtain the probability of future rainfall. Assuming that the statistical nature of future rainfall events is still the same as the statistical characteristics of past rainfall events (Suripin, 2004).

In the analysis of rainfall frequency hydrological data are collected, calculated, presented, and interpreted using certain procedures, namely statistical methods. Not all variants of a hydrological variable are located or equal to their average value. Variation or dispersion is the degree or magnitude of the variance around the average value. How to measure the amount of dispersion is called dispersion measurement (SOEWARNO, 1991). As for how to measure dispersion, among others; standard deviation (S), skewness coefficient (Cs), kurtosis measurement (Ck), coefficient of variation (Cv). The magnitude of this statistical parameter largely determines the chosen distribution (Br, 1993) and is followed by the intensity-duration-frequency (IDF) calculation.

The method used in the analysis of the planned flood discharge is the Nakayasu synthetic unit hydrograph (Abdaa & Darfia, 2021).

Using the Nakayasu Synthetic Unit Hydrograph method, several characteristics of the flow area parameters are required. Parameters used in calculations using this method (Br, 1993; SOEMARTO, 1993; SOEWARNO, 1991) :

$$Q_p = \frac{1}{3,6}\left(\frac{A.Re}{0,3Tp+T_{0,3}}\right)$$

$$Tp = t_g + 0,8T_r$$

$$t_g = 0,21L^{0,7}$$ ………for L < 15 km

$$t_g = 0,4 + 0,058L$$ ……....for L > 15 km

$$T_{0,3} = \propto .t_g$$

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$t_r = 0{,}5 t_g \; until \; t_g$

Information:

Qp = flood peak discharge
A = catchment area (km^2)
Re = effective rainfall (1 mm)
Tp = time from the onset of flooding to the peak of the hydrograph (jam)
$T_{0,3}$ = the time from the peak of the flood to 0.3 times the peak discharge (jam)
t_g = unit time of rainfall (jam)
T_r = unit time of rainfall (jam)
α = watershed characteristic coefficients are usually taken 2
L = length of the main river (km)

Erosion

Erosion is the event of moving or transporting soil or parts of land from one place to another by natural media. In erosion events, soil or parts of the soil in one place are eroded and transported which is then deposited in another place. Soil erosion and transport occur by natural media, namely water, and wind.

The process of erosion by water begins when the kinetic energy of rainwater hits the groundwater. The force of this rainwater blow causes the release of soil particles from larger soil clumps (Morgan et al., 1984). The higher the rain intensity, the higher the power generated and the more soil particles are released from the soil clumps. This loose soil will be thrown away along with the splash of water.

Erosion is a function of erosivity and erodibility. The process of erosion is the result of the interaction between climate, topography, vegetation, and human factors on the soil (Arini et al., 2007).

According Smith & Wischmeier (1962) put forward an erosion estimation formula (Universal Soil Loss Equation) that applies to soils in the United States. However, this formula is widely used in other countries, including Indonesia (Banuwa, 2013; Krisnayanti et al., 2018; Lesmana et al., 2020).
The general form of the USLE equation is:

A = R.K.LS.C.P

Information:

A = Average amount of land lost each year (ton/ha/tahun)
R = Rain erosion index (rain erosivity) (KJ/ha)
K = Soil sensitivity index to erosion (soil erodibility)
LS = Factor length (L) and steepness (S) of the slope
C = Plant factor (vegetation)
P = Factor erosion prevention efforts

Sedimentation

Sediment is soil and parts of soil that are transported by water from a place that is experiencing erosion in the form of surface soil erosion, gully erosion, and erosion of cliffs and riverbeds which then enters a body of water. Sediment produced by the erosion process and carried by surface runoff will experience deposition so that the sediment will be deposited in a place where the speed of the water slows down or stops. This process is known as sedimentation (Banuwa, 2013; Rantung et al., 2013).

To predict sediment yield, the MUSLE (Modified Universal Soil Loss Equation) method is used which is a development of the USLE method. This method does not use the rain energy factor as the cause of erosion but instead uses the surface runoff factor, so MUSLE does not need a sediment delivery ratio (SDR) factor because its value varies from one place to another. The surface runoff factor represents the energy used for crushing and transporting sediment (Rantung et al., 2013). The MUSLE equation is written in the form:

SY = 11,8 $(Q_p V_Q)^{0.56}$ K L S C P

Information:

SY = sediment yield for each rainfall event (ton)

V_Q = flow volume in a rain event (m^3)

Q_P = peak discharge (m3/dtk)

River Crossing Capacity Analysis

To evaluate the cross-sectional capacity of the river and the required cross-sectional dimensions according to the planned flood discharge, use the Hec-Ras 3.1.3 application. HEC-RAS is an integrated software system, designed to be used interactively in a wide variety of task conditions. The system consists of a graphical user interface, separate hydraulic analysis components, management capabilities, and data storage, reporting, and charting facilities (Gunawan, 2018; Pukan et al., 2022, 2022; Syahputra & Rahmawati, 2018).

RESULT AND DISCUSSION

Characteristics of the Tukad Pulukan Watershed (DAS).

Tukad Pulukan Basin has an area of 55.22 km2 and a river length of 27.12 km. For the Pulukan River/tukad in Jembrana Regency the area of the watershed is large and the length of the river is quite long. The shape of the Tukad Pulukan watershed is evenly wide with a relatively long river length which greatly influences runoff under this watershed condition, the peak flood time for this watershed shape is quite long.

The condition and density of ditches and/or canals, and other forms of basins influence the rate and volume of surface runoff. A watershed with a steep slope accompanied by tightly packed ditches/canals will produce a higher surface runoff rate and volume compared to a gently sloping watershed with sparse ditches and basins. The effect of the density of the ditch, namely the length of the ditch per unit area of the watershed, on runoff is to shorten the concentration-time, thereby increasing the runoff rate.

The effect of land use on runoff is expressed in the runoff coefficient (C), which is a number that shows the ratio between the amount of runoff and the amount of rainfall. This runoff coefficient figure is one of the indicators to determine the physical condition of a watershed. Based on the base map (2017), land use in watersheds (DAS) in Tukad Pulukan is for forests and shrubs 56%, gardens 20.70%, fields 19.17%, and other land allotments for rice fields and settlements.

Identification of Flood Problems

- Forest Degradation
  The decline in forest quality due to illegal logging is one of the most common causes of flooding. Deforestation reduces water absorption and can cause disasters such as floods or landslides. At the time of the field survey, there were remnants of tree trunks on the riverbed.
- Land use in watersheds (DAS) in Tukad Pulukan for forest and shrubs 56%, gardens 20.70%, fields 19.17%, and other land allotments for rice fields and settlements. From existing land use, it is still possible to improve the quality of forest vegetation so that the function of the forest can be optimized as a catchment area.
- High rainfall
  Indonesia has a tropical climate so it has two seasons throughout the year, namely the rainy season and the dry season. In the rainy season, high rainfall will result in flooding in the river and if the flood exceeds the river bank, there will be flooding or inundation.
  The next cause of flooding is the high intensity of rainfall in an area. If heavy rains have been protracted for a long time there is a high potential for flooding to occur.
- Conditions of River Cliffs That Are Easily Detached
  Scour occurs along the river flow and generally increases in the bend area which will threaten the stability of buildings and facilities built around the site. Scour at the bend of the river will occur in the initial area of the bend, while deposition starts from the middle of the bend to the

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end of the bend (Bahri & Oemiati, 2021; Djufri, 2017). Scour is sediment transport, namely the displacement of sediment material by flowing water with movement in the direction of the water flow.

The condition of the bed and the existing riverbanks in the study area, especially in the middle and downstream parts, is the rock that is easily separated and it is compounded by the condition of the river which used to have C excavation activity and there are several places in Tukad Pulukan where there is still C excavation activity. Changes in river conditions will greatly impact the stability of the bottom and riverbanks and the condition of this river will be easier for scour to occur. Excavation C is mostly carried out in rivers containing rock-sand and gravel materials. Extraction of this material in many places, because it was not carried out in a planned manner has caused many adverse effects in the form of landslides of buildings upstream and downstream of the collection location.

- Conventional Drainage System

  With this environmentally friendly drainage concept, excess rainwater is not immediately discharged into the nearest river. However, this rainwater can be stored in various locations in the area concerned in a variety of ways, so that it can be directly utilized or utilized in the following season, can be used to fill/conserve groundwater, can be used to improve the quality of ecosystems and the environment, and can be used as means to reduce existing inundation and flooding (Sari et al., 2018; Sutomo, 2017).

  Environmentally sound drainage management at the macro-drainage level is by building reservoirs, conservation ponds, and retention ponds. Handling at the micro drainage level by applying bio pores, household infiltration wells, public facilities, and offices.

- Settlements Near Riverbanks

  The cause of the flooding is usually the lack of order in the settlements on the banks of the river. The negative thing that can arise as a result of this is that it can be silting up the river due to the habit of throwing garbage carried out by its residents and dumping it directly into the river. In addition, the condition of the land around the left and right of the building could have subsided and closed the sides of the river. This causes a narrowing of the river flow and prone to flooding

- Narrowing of the River Channel

  The narrowing of the river channel that occurs in the study area is the occurrence of sediment deposition due to local scour on the cliffs and river bed. Narrowing of the channel due to sedimentation generally occurs in the lower reaches of the river and there is widening of the river. This condition is seen from the hydraulic aspects of the low flow velocity and the tendency for sediment deposition to occur. The narrowing of the river channel occurs in the downstream part of Tukad Pulukan.

  Narrowing of the river channel due to garbage, especially during the maximum discharge when the flow carries tree trunks and gets stuck in the bridge pillars. The narrowing of the grooves in the bridge piers often causes flooding and damage around these areas. The condition of the stream carrying tree trunks indicates a decrease in the quality of the forest upstream.

Planned Rainfall

The closest rainfall recording stations to the Tukad Pulukan watershed are the Pulukan rainfall recording stations and the Dapdap Putih recording stations. Sta. Pulukan and Sta. White Dadap. The collection of rainfall data from the two recording stations for 12 years from 2008 to 2019. From the results of the Thiessen polygon analysis, it was found that regional rainfall that affected the Tukad Pulukan watershed was that the Pulukan station gave a weight of 0.174% of the area of the DAS and the Dapdap Putih station was 0.826 % of the area of the Tukad Pulukan watershed. The results of regional rainfall analysis in the Tukad Pulukan watershed (DAS) are shown in Figure 3.

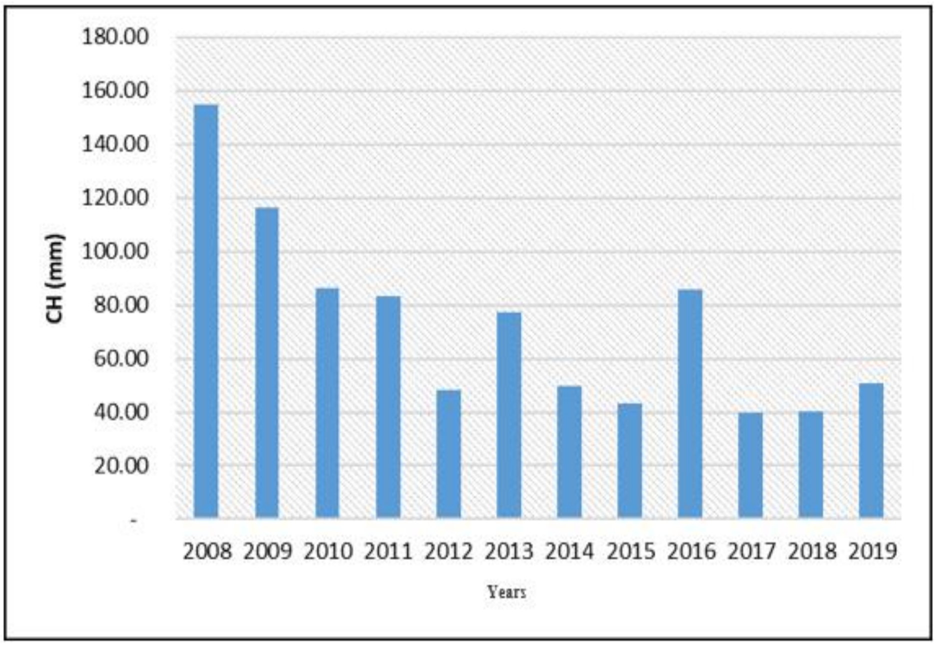

Figure 3. Rainfall in the Tukad Pulukan Watershed Area

Determining the type of frequency distribution is needed to determine whether a data set is suitable for a certain distribution and not suitable for other distributions. To find out the suitability of a particular type of distribution, it is necessary to calculate the statistical magnitude. The results of the analysis show statistical parameters which include; standard deviation (sd) = 34.75, coefficient of sloping (cs) = 1.328, peaking coefficient (ck) = 5.24, coefficient of variation = 0.476. Based on the magnitude, and the statistical parameters, the selection of distribution follows the Pearson Type III log. Table 1 shows the planned rainfall with various return periods

Table 1. Planned Rainfall with Various Return Periods

Return Period Rainfall (R_T)	Rainfall (mm)
R_5	95
R_{10}	120
R_{20}	152
R_{25}	156
R_{50}	186
R_{100}	239
R_{200}	258

Source: Analysis Results

Planned Flood Discharge

The results of the 50-year return period planned flood discharge analysis using the Nakayasu synthetic hydrograph unit method are 244.92 m3/sec. The magnitude of this flood discharge is used to evaluate the capacity of the existing cross-section and to plan the cross-sectional dimensions of the river which are used as the basis for implementing river normalization. Figure 4 shows a unit flood hydrograph with various return periods.

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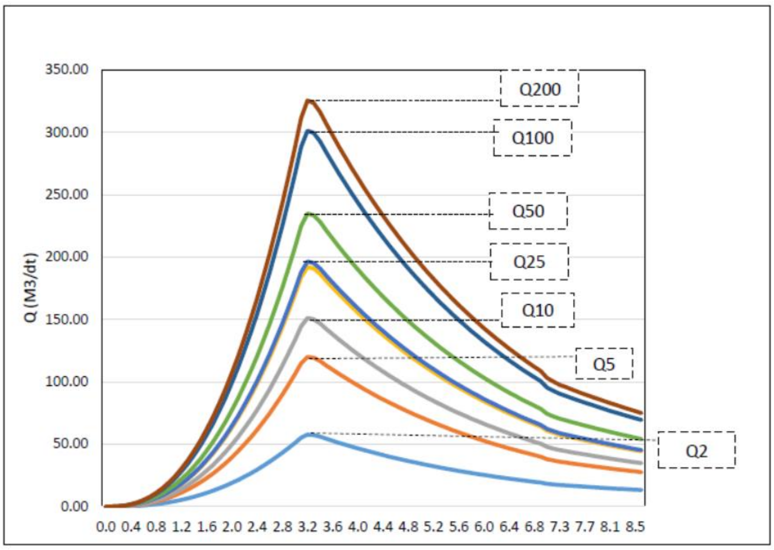

Figure 4. Tukad Pulukan Flood Hydrograph

Erosion and Sedimentation Levels

Based on the classification of erosion hazard, the analysis results of the sedimentation rate in the Tukad Pulukan watershed show 384.726 tons/ha/year including the class of severe erosion hazard. The heavy class hazard that occurred in the Tukad Pulukan watershed was because most of the gardening community's activities were at an elevation of 25% to 40% which had an impact on the high LS slope factor. To reduce the sedimentation rate, it is necessary to regulate land use according to the slope level of the watershed, monitor community activities to minimize the sedimentation rate, and improve the quality of vegetation in the watershed so that the upstream part of the watershed functions as a conservation area.

Evaluation of Existing Sectional Capacity and Planned Sectional Dimensions

Measurement of the topography of the Pulukan River/tukad starts from sta 0+00 which is located 3800 meters upstream of the Denpasar-Gilimanuk national bridge and downstream of the bridge to the estuary along 1400 meters with a total measurement of 5200 meters. The width of the existing Pulukan River/tukad is (20 – 50) meters with a non-uniform cross-sectional width. The slope of the river bed/Pulukan river bed is quite good and at some points, there is a relatively flat slope due to the influence of sediment deposits.

Hec-Ras also shows that at some points the cross-section is unable to accommodate the planned flood discharge with a return period of 50 years. The results of the Hec-Ras analysis for the Pulukan River/tukad are shown in Figures 5 to 7.

Normalization of the river/Tukad Pulukan maximizes the existing width and the required height of the embankment. The condition of the cliff/river wall/Tukad Pulukan is a material that is easily separated and handling must be done with the strengthening of the cliff wall.

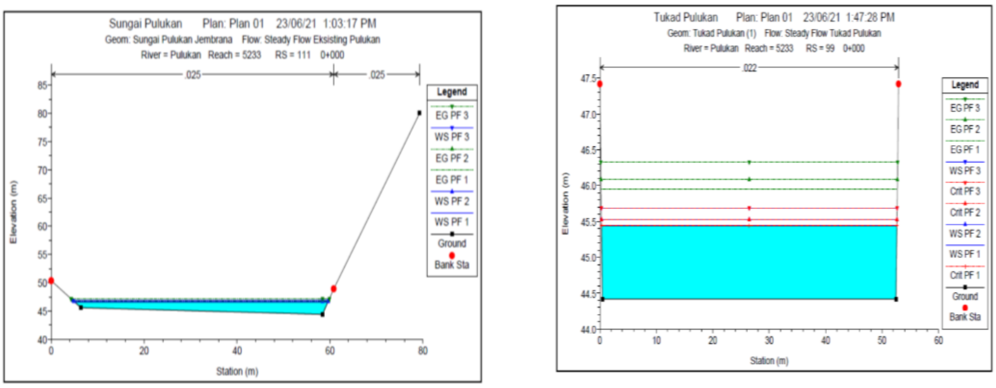

Figure 5. Flow profile on the existing section and after normalization at Sta 0+00

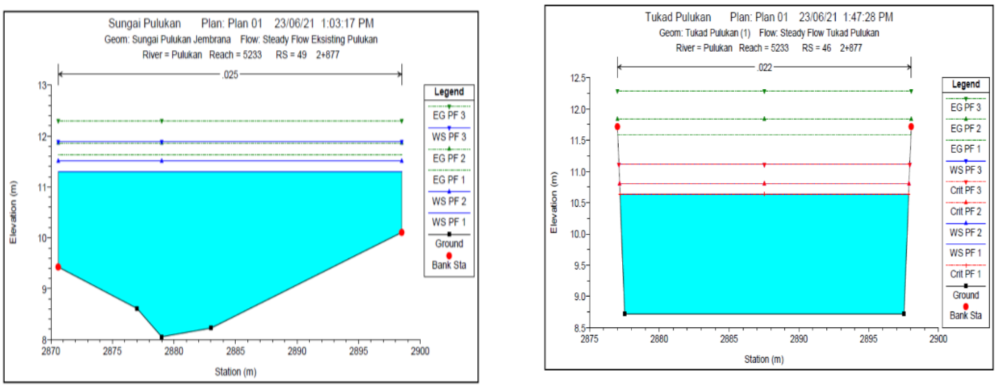

Figure 6. Flow profile at existing section and after normalization at Sta 2+877

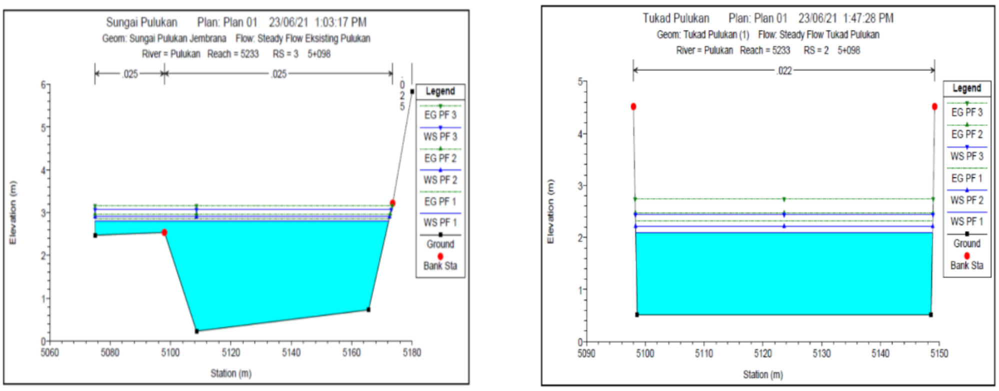

Figure 7. Flow profile at existing section and after normalization at Sta 5+008

Flood Handling and Control Program

- **Implementation of Reforestation**

Reforestation is carried out, especially for vegetation that does not fulfill the function of a conservation plant. This conservation plant has function as a store of water reserves, and a protector of humans and also various animals. By replanting the deforested forests, supplies of

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air, water, and natural disasters can be prevented. The benefits of implementing this reforestation are:

- Prevents soil erosion that can be caused by wind and also rainwater in a row.
- Preserving soil fertility that can be used as agricultural land.
- Maintain soil structure so as not to damage.
- Keeping the diversity of animals to remain sustainable.
- Keeps the air clean and healthy, especially for living things on Earth.
- Make the soil firm so that the risk of landslides can be avoided.
- Reducing the effects of air pollution and global warming.
- Preserving natural resources or natural resources that already exist in the forest and can be used to increase productivity

▪ **River Channel Normalization**

River normalization is an activity that aims to safely pass the planned flood discharge (Qdesign) by checking the capacity of the river and straightening the river channel accompanied by strengthening the cliffs and stabilizing the river bed, so that no runoff/overflow occurs. The design flood discharge is the design discharge in a river or in a natural channel with a certain return period which can be flowed without endangering the surrounding environment and is obtained from hydrological data analysis.

Flood handling using normalization is carried out on river sections whose capacity is no longer sufficient for the flood discharge that passes through. The normalization that will be carried out depends on the shape of the cross-section. The cross-sectional calculation is adjusted to the design flood discharge or Qdesign, which can then be found with the dimensions of the design cross-section that can accommodate the planned flood discharge. The dimensions of the channel to be determined are the width, wet section height, slope, and guard height.

The normalization of the river was carried out 300 meters north of the Denpasar-Jembrana main road bridge downstream. With the normalization of the Tukad Pulukan river channel in the downstream section, this is adjusted to the flood discharge planned for a return period of 50 years.

▪ **Control Building**

To protect the cliffs on the left and right sides of the river, after the implementation of normalization, a regulatory structure is needed in the form of slope reinforcement. To avoid overflow of water at the flood discharge, an embankment is needed. The implementation of the construction of regulatory buildings is by the river normalization implementation path.

▪ . **Management of the Tukad Pulukan Watershed (DAS).**

Watershed management is a human effort to regulate the reciprocal relationship between natural resources and humans in the watershed and all its activities, to realtotainability and harmony of ecosystems and increase the use of natural resources for humans in a sustainable manner, a watershed management plan is prepared to maintain and restore its carrying capacity (PP No. 37 of 2012). Furthermore (Asdak, 2007), an ecosystem is an ecological system consisting of components that integrate to form a unit. The main components of a watershed (DAS) include vegetation, land, and water, where water acts as a binder of linkages and dependencies between the main DAS/sub-DAS components.

Integrated watershed management is a form of participatory management of various parties with an interest in utilizing and conserving natural resources at the watershed level. This participatory management requires mutual trust, openness, a sense of responsibility, and a sense of interdependence among stakeholders. Likewise, each stakeholder must have a clear position and responsibility that must be played.

- **Community-Based Watershed Management**

  The management of natural resources contained in the watershed must be community-based. This approach is known as the bottom-up by positioning the local community and land owners as the subject of activities to tackle forest and land damage. Local people know best about the origin of land status, land use patterns, and how to cultivate and care for them. The local wisdom of the community needs to be emphasized in conserving nature and water sources.

  Community-based management needs to receive support from the central, provincial, district/city governments and officials in the field by their functions and authorities must facilitate the community with the aim of 1) increasing administrative capabilities in managing organizations, 2) providing technical capabilities in watershed management starting from planning, implementing, maintenance to monitoring and evaluation, 3) improving the quality of human resources, 4) providing market and capital information in increasing competitiveness and post-harvest business development.

- **Land Use Arrangements**

  Based on Government Regulation Number 16 of 2004 concerning Land Use, it is explained that land use is the same as the pattern of land use management which includes control, use, and utilization of land in the form of consolidation of land use through institutional arrangements related to land use as a unified system for the benefit of society fairly.

  Watershed land use arrangements are intended to regulate land use, by the existing spatial planning pattern. This is to avoid uncontrolled land use, resulting in damage to the watershed which is a rainfed area (Syafii, 2009). The regulation of land use in the watershed is intended to improve the hydrological conditions of the watershed, so that it does not cause flooding during the rainy season and drought during the dry season and to reduce the excessive erosion rate of watersheds, so that it can reduce the rate of sedimentation in the downstream river channel (Bhakti, 2008).

- **Making Access Road Inspection**

  The inspection road is accessible for river maintenance as well as being able to add public space near the settlements of residents who live near the river. Making an access road for river inspection will make it easier for the relevant agencies to maintain the river.

  The use of the inspection road is very important to be applied at the level of the secondary channel as well as at the main sewer. If the application of river inspection road access will facilitate maintenance and rehabilitation. For field conditions, it is still possible to apply inspection roads because land use is still dominated by irrigated land.

- **Recording of River Water Level**

  The installation of a water level recording device is intended to determine the position of the water level (or flow depth) of a river at the hydrometry station located at a certain time. The definition of time in this case is related to the period of measuring/recording the water level. Measurements can be made at certain hours or continuously (continuous). For the first thing, you can use a scaled estimating board or often referred to as a manual measuring device.

  Installation of river water level observation at several river water level observation posts. A minimum of 2 river water level monitoring posts are needed, the first is the upstream post and the second is in the secured area. Both of these posts have a relationship between river water level and flood discharge in the form of a table or graph. So if the flood water level at the upstream post is known, it can determine the magnitude of the flood water level and future flood discharge and the arrival time of the flood at the downstream post.

- **Density of Rain Recording Stations in the DAS.**

  The rain station network has a relatively important function, namely to reduce the variability of the magnitude of events or reduce uncertainty and increase understanding of measured and interpolated quantities [4]. Network density is expressed in one station per certain area. In planning a network, there are two important things to consider, namely: the number of stations needed and the location of the stations.

The rain station network is the area of influence of each rain station. Network density is based on technical and economic aspects with the required level of accuracy to achieve optimum network density. Every existing rain station network needs to be reviewed regularly every operating period to improve data quality.

CONCLUSION

The results of the analysis of the sedimentation rate in the Tukad Pulukan watershed show 384,726 tons/ha/year including the class of severe erosion hazard. The heavy class hazard that occurred in the Tukad Pulukan watershed was because most of the gardening community's activities were at an elevation of 25% to 40% which had an impact on the high LS slope factor. To reduce the sedimentation rate, it is necessary to regulate land use according to the slope level of the watershed, monitor community activities to minimize the sedimentation rate, and improve the quality of vegetation in the watershed so that the upstream part of the watershed functions as a conservation area. The existing dimension of Tukad Pulukan has a river/tukad width of (20 – 50) meters with non-uniform cross-sectional width. The slope of the river bed/Pulukan river bed is quite good and at some points, there is a relatively flat slope due to the influence of sediment deposits. Hec-Ras also shows that at some points the cross-section is unable to accommodate the planned flood discharge with a return period of 50 years. The Tukad Pulukan Watershed flood management and control program includes reforestation, river normalization work, river management building, Tukad Pulukan watershed management, community-based watershed management, land use regulation, construction of access road inspections, installation of recording of water level and density of recording stations rainfall.

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