Structural Mitigation of Bila River, Sidrap Regency

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Abstract: Flood is one of the natural disaster occurred in Indonesia. This disaster also occurs in Sidrap Regency every year, in which the high rain intensity and broken embankment are the main causes of this disaster. There are three districts submerged by the inundation of Bila River, namely district of Dua Pitue, Pitu Riawa, and Pitu Riase. This research aims to gain information about floodplain of Bila River and mitigation in reducing the occurring impact on Sidrap Regency. Based on field inventory and HEC – RAS simulation on existing condition, it is known which location points are inundated so that they are causing flood disaster on Sidrap Regency. The result shows that after structural mitigation, which is repairing broken embankment and increasing the height of embankment potentially overflowed, through maintenance and rehabilitation on freeboard height 1.2 m and soil embankment crest wide 5 m, floodplain area are reduced on Q_2 = 23%, Q_5 = 6%, Q_{10} = 3%, dan Q_{20} = 3% . Therefore, structure mitigation need to reduce the impact of flood disaster of Bila River in Sidrap Regency.

Keywords: Structure mitigation, flood discharge, river embankment, HEC – RAS 5.0.7.

1. Introduction

Geographically, Indonesia is situated among 3 tectonic plates, which are Eurasia, Pacific, and Indo-Australia plates, and is also located in ring of fire which makes it become disaster prone area(**Soemambrata et al, 2018**). Disaster is a phenomenon or sequences of phenomena threatening and disturbing society life, caused by natural or non-natural or even human factors, results in casualties, environmental deterioration, property loss, and psychological effects (**National Board for Disaster Management, 2012**). One of the disasters frequently occurring in Indonesia is flood(**Oktapian et al, 2018**).Flood is phenomenon where river water is inundated as it exceeds the riverbed capacity(**Indonesian Government, 2011**). Flood is one of the disasters having the widest reach.Other than that, flood I natural disaster occurring most frequently in the world and affecting averagely 70 million people every year (**Surminski, 2014**). Flood in Indonesia has massive potency when viewed from lowlands topography, where basin and most of its area is ocean. Rainfall in upstream area is able to cause flood in downstream, let alone the lowland area or being only a few meters above sea level(**Suprarto, 2011**).

Flood is also the problem frequently occurring in parts of Indonesia that is able to cause loss like property loss and casualties, then it should have been known flood should be handled seriously(**Kodoatie and Sugiyanto, 2002**).In order to reduce risk of damage and loss by flood, the flood mitigation is needed to be implemented in reality. The solution that can be done is study of river existing condition and its flood characteristics to determine which river segments are potentially flooding to arrange optimal plan based on hydraulic feasibility(**Nanlohy and Istiarto, 2008**).Bila River is one of the river flowing through Sidrap Regency with length ± 15.100 m, width ± 70 m dan depth ± 4 m (**Sidrap Regency Regional Development Planning Agency, 2014**). Sidrap is one of the regency in South Sulawesi Province witharea of 189.8008,70 km^2 consisting of 11 districts, 68 villages dan 38 sub-districts,which is located astronomically on 3°43' - 4°09' SL dan 119°41' - 120°10' EL. Sidrap Regency is one the regency experiencing population increase every year.Total population of Sidrap Regencyin 2018 is 299.123 peoplethen it grows more in 2019 becoming 301.972 people(**Central Bureau of Statistics of Sidrap Regency, 2020**).

Anticipating the increasing population growth and activity development from year to year in terms of land clearing for settlement, plantation, mining, commerce, and industry, they have a hydrological impact on land use, groundwater replenishment, and flood runoff(**Purwanto, 2016**). Impact of those things isenvironmental deterioration including deterioration of drainage basin quality resulting in drought in dry season and flood in rainy season(**Qadri et al, 2016**). According toQadri et al (2016), this condition also occurs on flow ofBila River, which can be marked byphenomenon around Bila Rivernamelyriverbed capacity reduction, flood discharge increase, andinundation of Bila River and its tributary, causing damage to public facility, agriculture area, plantation, and settlement, and disruption of traffic flow on Trans Sulawesi Road, to make matters worse, river flow scourscausecliff damage threateningimportant facilitiesaround the river. According to news released in online media(**Faqih,2019); (Marlin, 2019**)on 9th and 13th ofJune 2019, it was said thatthree districts in Sidrap

Regency, South Sulawesi, was inundated as the result of Bila River (Tanru Tedong) inundation. The inundated districts are Dua Pitue (8 villages), Pitu Riawa (6 villages) dan Pitu Riase (2 villages). The main caused of this flood is that some embankments in riverbanks was broken down and high rainfall intensity, resulting in the inundation.

Therefore, flood disaster mitigation is needed to cope with the flood itself in Bila River so that the loss could be lessened. Mitigation is defined as series of attempts to reduce disaster risk, either by physical development (structural) or awareness campaign and capability improvement to deal with the disaster (non-structural)(**National Board for Disaster Management, 2007**). Structural attempt can be objectified by managing inundated area, by constructing dam, weir, river embankment, riverbed dredging, and river normalization. While non-structural attempt is done by mapping potential risk and flooding risk, providing socialization and rescue efforts early warning, making spatial regulation in order that non-environmental friendly land using in flood-prone and water catchment area can be controlled, and giving counseling to society, especially those settling in near flood-prone area(**Indradewa, 2008**).

According to the background, this study purpose to study toward the impact of Bila River floodplain area and flood disaster mitigation to reduce flood disaster impact. This research aims to provide information about floodplain of Bila River and mitigation in reducing occurring impact in Sidrap Regency. The benefit of this research is that this research can be information to the manager to improve flood control structures and also to society living in floodplain area to stay alert in rainy season.

2. Materials and Methods

Bila River is the main location of flood mitigation research in Dua Pitue, Pitu Riawa, and Pitu Riase district, located geographically in between 3^{o}52’49.82” and 120^{o}0’32.07” Sthrough 3^{o}56’18.85” and 120^{o}57’29.81” Ewhich in other words, it starts from Bulucenrana river dan Bila riveruntil 10.7 km to downstream area, as seen in Figs. 1 and 2.

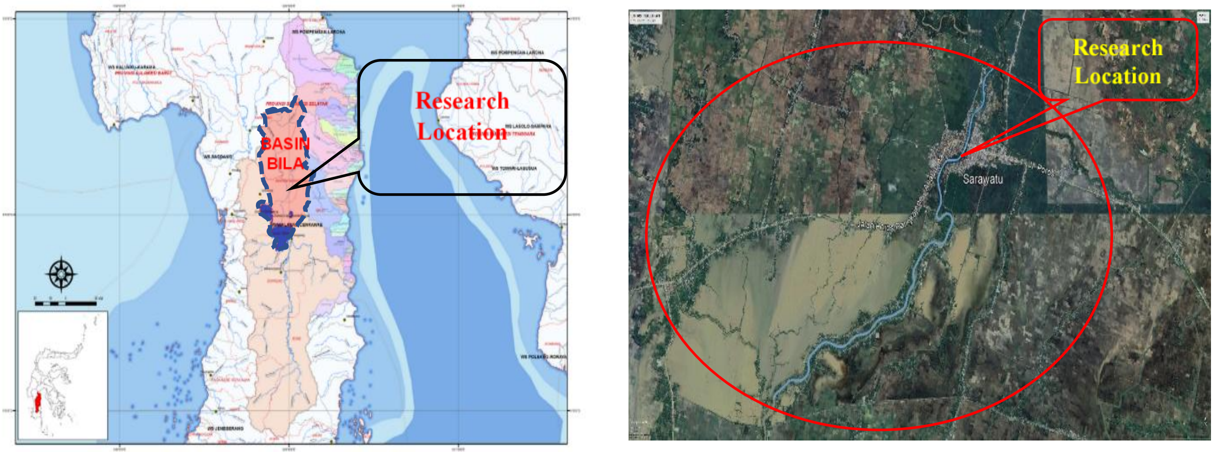

Fig 1: Study Location

The data used in this research includes: Rainfall data obtained from water resources agency, clean water and sanitation directorate, and spatial agency of South Sulawesi Province, from 1994 – 2019. Rainfall stations used in this study are 11 stations, that is Barukku, Bila Riase, E5 Bulucenrana, E6 Dongi, Betao, Tanrutedong, Watang Kalola, Tingaraposi, Salokarajae, Talang Riaja, and Maroangin: Topographical map of Sidenreng, Anabanua, Enrekang, Compong, Belajen, and Bonelemo based onIndonesia geospatial information board (BIG) version: Water elevation map used is obtained from Barukku, Bila Riase, E5 Bulucenrana, E6 Dongi, Betao, Tanrutedong, Watang Kalola, Tingaraposi, Salokarajae, Talang Riaja, and Maroangin from 1994 – 2019. AWLR used in this research is AWLR of Tanrutedong: Soil type data used is FAO – UNESCO Soil Map of Worldin 2007: Land usage data used isLand Usage Map of BIG (Geospatial Information Agency)in 2015 – 2019: Cross and long section data of river for 10 km long and 111 cross sections with approximately 50 metres per section: and Map of DEM around Sub Drainage Basin of Bila obtained from BIG.

Hydrological Analysis

This analysis uses data obtained from relevant agencies, in the form of rainfall data, hydrometric network (rainfall station), topographical data, and data of TMA AWLR. From the data,analysis will be carried outto obtaindesign flood flow.Maximum Daily Rainfall for every year will be tested for their consistency using Double-Mass Curves method.After that, distribution of area rainfall is carried out. According to(**Suripin, 2004**), if the area of River Basin is about 500 – 5000 km^2, then Thiessen Polygon method is used. Then in this study, area rainfall distribution uses Thiessen polygon method.

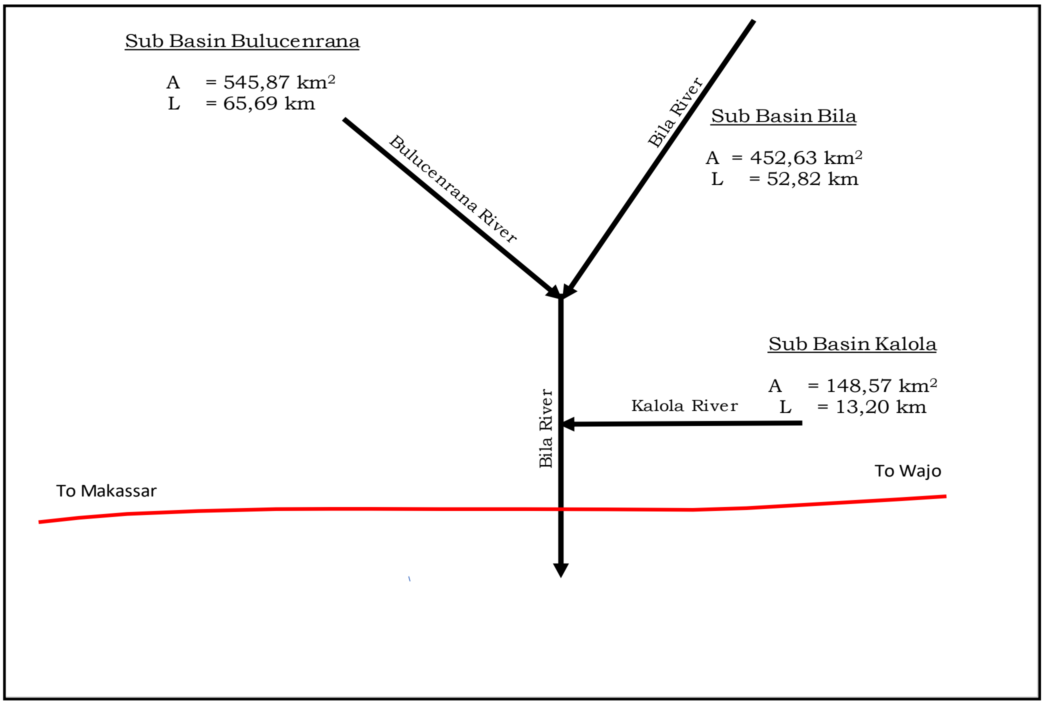

Fig 2: River SchematicInBila Drainage Basin

Frequency distribution analysis in this research will be calculated using Log Pearson III dan Gumbel method, in where the methodwill be chosen in accord with Chi-SquareandKolmogorov-Smirnov test. According to(**Triatmodjo, 2014**), best distribution is the one which gives lowest maximum ΔP value.Then in this study, design rainfall intensity is analyzed using Mononobe formula due to daily rainfall data being the only available data.Mononobe formula is only used in terms that short-term rainfall data is unavailable (only daily rainfall data available) (**Suripin, 2004**).Design flood discharge uses Synthetic Unit Hydrograph (SUH) due to BilaRiver Basin (BRB)categorized as bigriver basin. SUH is the derivation from unit hydrograph derived according to river data of the similar basin or nearest one having similar characteristics (**Kamiana, 2011**).In this study design flood discharge calculation uses 4 method, namely Nakayasu Synthetic Unit Hydrograph (NSUH), SUH of ITB II, SUH of SCS Curve Number (HEC-HMS), and AWLR. Design flood discharge is chosenusingCreager diagram.

Analysis of Existing Condition and Flood Disaster Mapping

Reviewed condition is damage condition occurring toward flood control building. From the condition, it is shown that Bila River undergoes decreasing performance. Existing damage will then be attached along with the documentation.For flood disaster mapping in this research, HEC – RAS 5.0.7 is used. The needed data are river section data, DEM data, and design flood discharge with period of 2, 5, 10, and 20 years on flood disaster mapping, elevation and area of floodplain in Bila River. If Bila River is not able to contain design flood discharge then the proper strategy to it is doing mitigation structurally so that it can contain the flood discharge. This design is carried out using*HEC-RAS 5.0.7.*

3. Results and Discussions

Hydrological Analysis

Before carrying out analysis of flood control building condition and flood mapping, the thing that should be done is to do hydrologic analysis to be inputted to *HEC-RAS 5.0.7* to know the location where runoff occurs.After passing consistency test, rainfall distribution, frequency analysis (Log Pearson III and Gumbel Type 1), dispersion, Goodness of Fit (GOF) testandrainfall intensity analysisthen design flood discharge of Bila River Basinis obtained asfollows Referring to Figure 4, it is shown that among all four methods in 1000-years period the closest one to C = 100 value is SCS Curve Number method (*HEC – HMS*) and is recommended for reference for optimization of river building performance if river normalization is carried out,considering that design discharge of SCS method is greater than other methods.

Analysis of Existing Condition and Flood Disaster Mapping

Flood control building of Bila River began to operate in 1997, but overtime this building underwent decreasing rate in performance term, in which certainly will affect flood control building performance. Decrease of functions is influenced by erosion of earthwork embankment, trash disposal in river, as well as some damages occurs to masonry wall which will finally affect Bila River performance in containing the occurs flood discharge. With such conditions, it is concluded that this building undergoes performance decrease.

Kinds of damage in every section of the embankment as said above are then measured and summed up. The inventory results of flood control building physical condition can be seen in Table 1 as follows.Based on Table 1 above, it is known that in the embankment of earthwork and masonry for 10.7 km long, the damage is about 251.86 m long.After the data of flood discharge, existing river measurement and land use knownthen flood stage water elevation and floodplain area can be analyzed using *HEC-RAS*.Here is the result for simulation of floodplain area and elevation.

TABLE I Peak Standard Width Of Earthwork Embankment

Design Flood Discharge	Peak Width
(m^3/s)	(m)
< 500	3
500 - 2000	4
2000 - 5000	5
5000 - 10000	6
5000 - 10000	7

Flood Disaster Mitigation

Based on simulation results of HEC- RAS for existing condition, it is known Bila River is not capable of containing design flood discharge therefore flood disaster mitigation is urgently needed.Based on location reviewed of Bila river, it is very difficult to conduct non-structural mitigation due to some lands are already converted into high-density residential area and agricultural area which is the main income of Sidrap Regency, so that the most proper mitigation is structural mitigation, through broken embankment repair and raising the embankment elevation potentially inundated by maintenance activity and rehabilitation, given the condition that there are already existing embankment in Bila River. In this research, rehabilitated embankment is expected to contain flood discharge to 20-years period,with freeboard height and peak width based on the following Table 2.

TABLE II Standard Freeboard Height Of Embankment

Design Flood Discharge	Freeboard Height
(m^3/s)	(m)
< 200	0.6
200 – 500	0,8
500 – 2000	1.0
2000 - 5000	1.2
5000 - 10000	1.5
>10.0000	2.0

Design flood discharge Q_{20} = 3929.30 m^3/s, then freeboard height used is 1.2 m with peak width 5 m for earthwork embankment. However for paired embankment, it is impossible to do it standardly due to existing but permanent building, so that paired embankment is constructed with steep slope, narrow peak, and depend on local condition (**Sosrodarsono and Takeda, 2002; Sosrodarsono and Tominaga, 1994; Lukman et al, 2020; Deni et al, 2019**).The following is simulation result of floodplain area and elevation after rehabilitation.After rehabilitation Bila River is now able to contain 20-years period design flood discharge.After conducting structural mitigation, flood inundation area is reduced on Q_2 = 23 %, Q_5 = 6 %, Q_{10} = 3 %, and Q_{20} = 3 %.Although embankment on Bila River has been rehabilitated, flood might keep occurring due to Bulucenrana River and Kalola River also contributes to flood disaster impact in Sidrap Regency.

4. Conclusions

The chosen flood discharge in Bila river is using HSS SCS Curve Number method (HEC–HMS) according to Creager diagram was foundthe total discharge of the three rivers is : Q_2 = 1718 m^3/s, Q_5 = 2658.50 m^3/s, Q_{10} = 3330.90 m^3/s, and Q_{20} = 3929.30 m^3/s.Surveying and field investigation show that flood control building of Bila river undergoes performance drop due to some damages on embankment caused by slope erosion and collapsed paired embankment with total damage 251.86 m long. Furthermore, according to simulation result of HEC - RAS there is inundation 1373.92 m longwitha height of 0.2 m – 2.9 m above embankment. Inundation area of $Q_2$is 42.865 km^2, Q_5 51.080 km^2, Q_{10} 55.157 km^2, and Q_{20} 58.522 km^2.The most proper mitigation strategy in Bila River is structural mitigation which is damaged embankment repair and elevating potentially inundated embankment through maintenance and rehabilitation with freeboard height 1.2 m and embankment peak width 5 m. With the structure mitigation done, there is reduction in inundation area with period of Q_2= 23 %; Q_5 = 6 %; Q_{10} = 3 %; and Q_{20} = 3 %.

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