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M. A. Sudarmin, F. Maricar and R. T. Lopa

Realtime Flood Propagation on the Downstream of Bili-Bili Reservoir with Hydraulic Routing

Sudarmin M.A[a)], Maricar F, Lopa R.T

Department of Civil Engineering, Hasanuddin University, Makassar, Indonesia

[a)]Corresponding author: azwinsudarmin@gmail.com

Abstract. On January 2019, the biggest flood in the last decade struck Gowa and Makassar. The flood claimed enormous number of victims and caused severe damage to many buildings; this can be anticipated by Flood Routing. This study aims to analyze the flood hydrograph, flood propagation time, and to determine the flood inundation model during the flood downstream of Bili-Bili reservoir. This research was conducted through the three phases: delineation of watershed by using ArcGis 10.6.1, hydraulic routing by using HEC-HMS 4.5, and flood simulation by using HEC-RAS 5.0.7 integrated with RAS-MAPPER. The results indicated that the flood hydrographs occurring in the upstream was 3,319.7 m^3/s and in the downstream was 2.961.4 m^3/s, with the travel time of flooding lasted for 1 hour 44 minutes, as well as a model of realtime flooding in the downstream reservoir of Bili-Bili produced a flood surface area of 52.47 km^2.

INTRODUCTION

The flood disaster had caused serious damages to infrastructures, threatening human lives and affecting the local community [9], generating significant damage disfiguring urban, peri-urban and rural landscapes because of the overflowing of rivers and hydrographic networks following exceptional floods with high intensities [3].

One of the major rivers in South Sulawesi, Jeneberang river, is regarded as an important river in South Sulawesi, extending over 75 km2 and an area of 784.01 km^2 watershed, which originates from mount Bawakaraeng at an elevation of + 2,833.00. During the rainy season in Jeneberang river area, floods often occur, caused by rains that occur continuously for several days, such as those happened in December to January 1976, almost 2/3 of Makassar city and Gowa districts was inundated, this happened due to the overflowing of Jeneberang river in The downstream area of Sungguminasa bridge and the floods that occurred in January 2019 which was the biggest flood disaster experienced by Gowa districts and Makassar city during the last decade, claimed many victims and caused severe building damage, the flood's mainly caused by the overflowing of Bili-Bili Dam and Jeneberang river, as well as heavy rains that occurred for days.

Flood routing provides a way of determining flood flow modifications, where the procedure is utilized to determine the timing and discharge of the flood (flood hydrograph) at a point in the flow based on a hydrograph upstream. Flood routing offers an alternative to control floods, where a trip analysis / tracking of floods is carried out along the river, if the hydrograph in upstream part of the river is revealed, the form of the flood hydrograph in downstream is estimated. There are two types of flood routing, which are hydrological routing and hydraulic routing. In hydraulic routing, a discharge hydrograph is found at a point along the flow. Flood modeling presents an important tool in the assessment of flood risk for both hazard and vulnerability [9].

The flood control has served a pressing issue in regards to establishing the foundation for sound living environment and economic activities [1]. The concept in river management as an effort to prevent flooding is conducted in accordance with the concept of hydraulic engineering [4]. With flood routing, the time and discharge of floods are identified to anticipate the timing and occurrence of the flood itself.

METHOD

This research was conducted from September 2020 to December 2020, situated in the downstream of Bili-Bili reservoir to the downstream of Jeneberang river with a length of 32 km and the following coordinates of: 5 ° 11'34.69 "S, 119 ° 22'52.26" E, and End: 5 ° 16'43.65 "S, 119 ° 35'1.29" E.

The method used in this study is based on several theories found in some literature, as well as simulations utilizing several water management applications. The steps in the preparation of this study are as follows: literature review, data collection, inventory of rivers and water structures, delineation of watersheds using ARC-GIS 10.6.1, while ARC-

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GIS is completed in 5 main stages, of: fill, flow direction, flow accumulation, snap pour point, and watershed, Hydraulic routing simulation using HEC-HMS 4.5. Furthermore, HEC-HMS has increasingly gained popularity and adopted in numerous hydrological studies due to its ability in the simulation of runoff both in short and longtime events, its simplicity to operate, and use of common methods [4]. For watershed modeling, the HEC-HMS model contains the four components of: (1) Basin component; (2) Meteorological component; (3) Control specification; and (4) Input data component (time series, paired data and gridded data) [8]. Basin components are illustrated in Figure 1, including: time series data and input to this component is the discharge data that occurred during the flood events of January 21 at 01.00 a.m. to January 24 at 11.00 p.m. 2019. There are two reservoirs, constructed in the catchment, which is Bili-Bili reservoir located on Jeneberang river, holding 375,000,000 m^3 water flow and Jenelata reservoir located on the tributary Jenelata river [2], which is in the form of data on outflow of Bili-Bili reservoir, illustrated in Figure 2. Jenelata river inflow with hourly time intervals is illustrated in Figure 3, while meteorological component, input on this component contains a meteorological condition with the condition of the shortwave, longwave, precipitation, evapotranspiration, and snowmelt boundary conditions were "None" (no influence on the watershed), and input on replaces missing is Abort Compute (canceling the simulation process if there is inappropriate data), and Control Specification. Thus, this component input contains the start and the end of the time simulation, for the hydraulic simulation routing starts at 1:00 a.m. on January 21, 2019 to 11:00 p.m. on January 24, 2019. HEC-RAS becomes one of the most widely used models to analyze channel flow and floodplain delineation [7]. HEC-RAS simulates the flood routing in the main channel and determines the extent of floodplains [6]. Simulation of inundation with the HEC-RAS 5.0.7 is conducted with the 4 component inputs in the simulation process, which include: terrain, geometries, boundary condition, illustrated in Figure 4, along with unsteady flow analysis, validation of routing, and flood discharge and flood elevation from Bili-Bili dam to other locations.

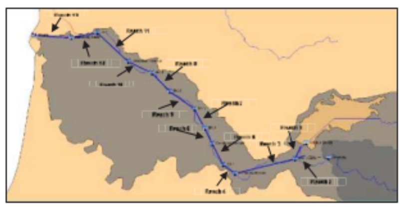

FIGURE 1. Basin Model

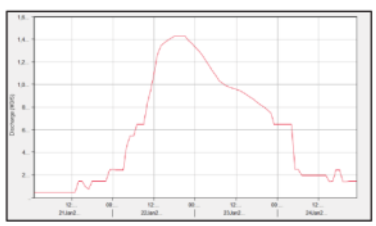

FIGURE 2. Graph of the Relationship between Time and Outflow Discharge of Bili-Bili Reservoir 21-24 January 2019

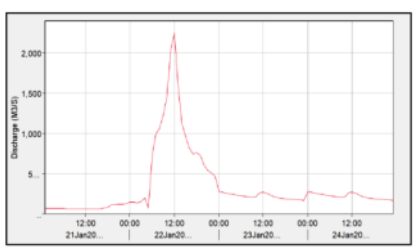

FIGURE 3. Graph of the Relationship between Time and Jenelata River Inflow Discharge from 21-24 January 2019

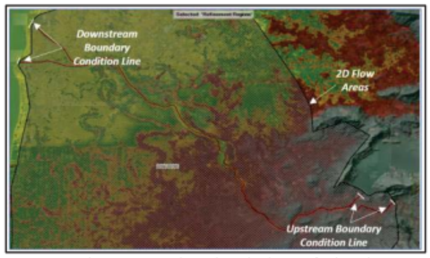

FIGURE 4. Element In the Simulation of Flood HEC-RAS

Secondary data in the study were obtained from the 2 sources, from the ministry of public works and housing of the directorate general of water resources BBWS Pompengan Jeneberang. The research data used as supporting data in this study were hydrological and hydraulics data, in which the hydrological data required in this study include: realtime chronology data of rising water levels, inflow, outflow of Bili-Bili dam, 21-24 January 2019, Jenelata river's inflow discharge, 21-24 January 2019, and flood elevation data along the Jeneberang river and the hydraulic data is required to be inserted in the simulation program, which includes: topographic data, water buildings in the river, and schematic of Jeneberang river network and The DEM (Digital Elevation Model). Data is obtained from The National DEM (DEMNAS), as an integration of altitude data which includes IFSAR (Interferometric Synthetic Aperture Radar) data with a resolution of 5 m and ALOS PALSAR (Advanced Land Observing Satellite - Phased Array type L-band Synthetic Aperture Radar) with a resolution of 11.25 m. With these two types of data, DEMNAS has a spatial resolution of 0.27 arc-second, which is better than SRTM data with a spatial resolution of 1 arc-second [5].

RESULTS AND DISCUSSION

Watershed Delineation

The results of the watershed delineation serve as the basis for the modeling of the watershed model in the Hydraulic Routing Simulation, illustrated in Figure 5.

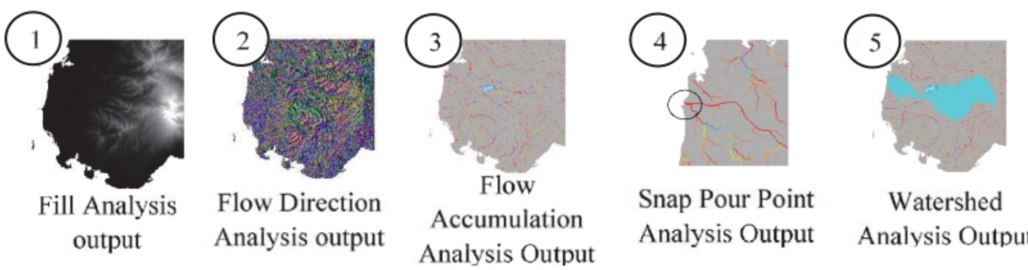

FIGURE 5. Analysis Results with ARC-GIS

Hydraulic Routing

The time of routing from The Bili-Bili Reservoir to The Confluence, Bissua Weir, Kampili Weir, Twin Bridge, Karet Weir, and estuary were set as 4 minutes, 14 minutes, 20 minutes, 57 minutes, 1 hour and 29 minutes, and 1 hour and 44 minutes. The time of routing is obtained from Time of Peak on each the location, illustrated in Table 1.

TABLE 1. Global Summary HEC-HMS Realtime Flood Propagation 21-24 January 2019

Hydrologic Element	Drainage Area (KM^2)	Peak Discharge (M^3/S)	Time of Peak	Volume (M^3/S)
Bili-Bili Reservoir	382.2562	1426.9	22Jan2019, 19:00	197,628.3
Jenelata River	221.1400	2248.7	22Jan2019, 12:00	113,535.9

Hydrologic Element	Drainage Area (KM^2)	Peak Discharge (M^3/S)	Time of Peak	Volume (M^3/S)
Confluence	603.3962	3319.7	22Jan2019, 12:04	307,971.4
Bissua Weir	603.3962	3284.4	22Jan2019, 12:14	304,536.4
BS.1	603.3962	3250.7	22Jan2019, 12:17	301,385.2
Kampili Weir	603.3962	3217.9	22Jan2019, 12:20	298,286.3
BK.1	603.3962	3185.1	22Jan2019, 12:25	295,151.6
BK.2	603.3962	3152.4	22Jan2019, 12:32	291,971.5
BK.3	603.3962	3120.3	22Jan2019, 12:36	288,929.6
BK.4	603.3962	3087.8	22Jan2019, 12:48	285,632.1
Twin Bridges	603.3962	3055.7	22Jan2019, 12:57	282,464.7
JK.1	603.3962	3023.6	22Jan2019, 13:15	279,046.5
Karet Weir	603.3962	2992.5	22Jan2019, 13:29	275,813.9
Estuary	603.3962	2961.4	22Jan2019, 13:44	272,534.9

The graph of the hydraulic routing simulation results indicates the peak of the flood hydrographs that occurred in upstream (3,319.7 m3/s), and in downstream (2.961.4 m3/s) shifted from 12:00 pm to 13:44 pm, with routing time from the flood that occurred on January 21-24 2019 lasted for 1 hour and 44 minutes illustrated in Figure 6.

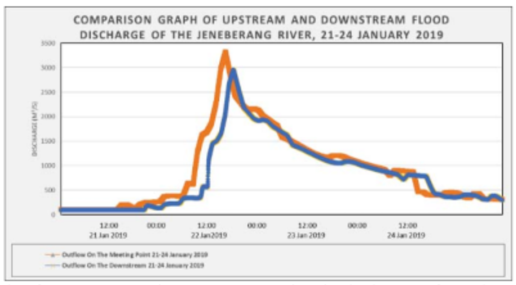

FIGURE 6. Comparison Graph of Upstream and Downstream Flood Discharge of Jeneberang River, 21-24 January 2019

Flood Inundation Simulation

A Model of real time flooding in the downstream reservoir of Bili-Bili was recorded from 21 to 24 January 2019 generating a flood surface area of 52.47 km2, illustrated in Figure 7.

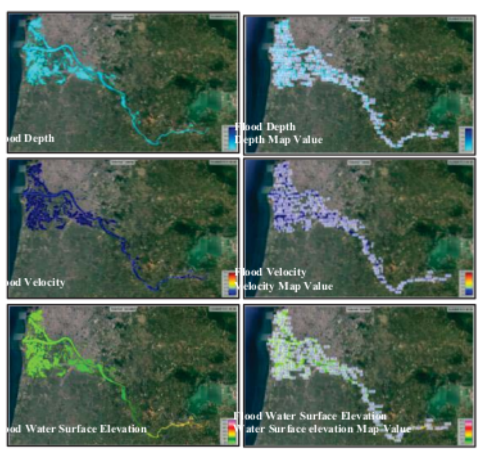

FIGURE 7. Simulation of HEC-RAS Flood (RAS-MAPPER)

The results of the flood simulation were obtained three information, comprising: depth, velocity, and water level elevation, illustrated in Table 2.

TABLE 2. Hydraulic Routing Simulation Recapitulation

Location	Depth (m)			Velocity (m/s)			Water Surface Elevation (m)		
	min	max	average	min	max	average	Min	max	average
Confluence	2.928 21/01/19 04:50	7.623 22/01/19 12:10	5.163	0.015 21/01/19 04:50	5.632 22/01/19 12:10	2.245	38.522 21/01/19 04:50	43.212 22/01/1 9 12:10	40.755
Bissua Weir	0.811 21/01/19 13:30	4.878 21/01/19 09:00	2.537	0.087 21/01/19 09:20	4.248 22/01/19 12:20	2.675	23.825 21/01/19 13:30	27.889 21/01/1 9 09:00	25.552
BS1	2.681 21/01/19 13:00	8.618 21/01/19 10:40	4.996	0.082 21/01/19 17:30	3.994 22/01/19 12:30	1.873	19.058 21/01/19 13:00	24.994 21/01/1 9 10:40	21.369
Kampili Weir	0.76 21/01/19 13:00	4.631 22/01/19 12:40	2.984	0.133 21/01/19 15:10	3.449 22/01/19 12:30	2.168	13.859 21/01/19 15:10	17.729 22/01/1 9 12:40	16.082
BK1	6.675 21/01/19 18:30	13.598 21/01/19 13:00	8.799	0.029 21/01/19 15:20	3.496 22/01/19 12:40	1.436	8.777 21/01/19 18:30	15.7 21/01/1 9 13:00	10.902
BK2	5.738 21/01/19 18:40	9.926 22/01/19 13:00	7.502	0.04 21/01/19 15:10	1.722 22/01/19 12:50	0.938	8.673 21/01/19 18:40	12.861 22/01/1 9 13:00	10.437
BK3	3.104 21/01/19 19:00	8.214 22/01/19 13:10	5.524	0.465 21/01/19 16:30	3.144 22/01/19 12:50	1.562	5.253 21/01/19 19:00	10.36 22/01/1 9 13:10	7.672
BK4	3.824 21/01/19 17:50	8.204 22/01/19 13:30	6.070	0.102 21/01/19 17:50	1.742 22/01/19 13:10	0.868	5.031 21/01/19 17:50	9.411 22/01/1 9 13:30	7.277
Twin Bridges	3.505 22/01/19 00:50	5.789 22/01/19 13:40	4.448	0.137 22/01/19 03:20	3.655 22/01/19 13:30	2.332	5.664 22/01/19 00:50	7.947 22/01/1 9 13:40	6.606
BK1	2.181 22/01/19 00:40	5.102 22/01/19 14:00	3.555	0.039 21/01/19 23:00	2.188 22/01/19 13:40	1.468	0.352 21/01/19 23:00	5.456 22/01/1 9 14:00	3.901
Karet Weir	2.156 24/01/19 23:00	4.01 22/01/19 14:40	3.150	0.634 22/01/19 01:10	1.541 22/01/19 14:00	1.092	0.938 24/01/19 23:00	2.795 22/01/1 9 14:40	1.933
Estuary	1.366 22/01/19 03:50	3.132 22/01/19 21:10	2.297	1.242 24/01/19 23:00	2.181 22/01/19 21:00	1.759	-1.142 22/01/19 04:00	0.624 22/01/1 9 21:10	-0.211

Validation

Flood hydrographs from the hydraulic routing simulation results utilizing HEC-RAS and HEC-HMS in this study was validated by employing data on Karet Dam, the results of the flood hydrograph on Karet Dam on January 22, 2019 at 4.30 p.m. are illustrated in Table 3.

TABLE 3. Field data comparison with simulation results on January 22, 2019 at 4.30 p.m

Data Types	Field Data	Simulation Results	Difference	Deviation (%)
Discharge (m3/s)	2160	2130.3	29.7	1.375
Elevation (m)	2.5	2.747	0.247	1.84

Description: Field Data obtained from Weir Operational Officer of Karet Weir

CONCLUSIONS

Hydrograph flood with hydraulic routing on downstream Bili-Bili reservoir from Bili-Bili Dam to other locations are reduced due to runoff out of the river body which resulted in a flood inundation, which is renowned as the peak of the flood hydrograph of Bissua Weir, Kampili Weir, Twin Bridge, Karet Weir, and estuaries which are 3.284.4 m^3/s, 3.217.9 m^3/s, 3,055.7 m^3/s, 2.992.5 m^3/s, and 2.961.4 m^3/s. Time of flooding on downstream Bili-Bili reservoir from

Bili-Bili Dam to Bissua Weir with propagation time was 14 minutes, Bili-Bili Dam to Kampili Weir with propagation time was 2[illegible] minutes, Bili-Bili Dam to the twin bridge with propagation time was 57 minutes, Bili-Bili Dam to Karet Weir with propagation time was 1 hour and 29 minutes, and Bili-Bili Dam to the estuary with propagation time was 1 hour and 44 minutes. The flood model produced by outflow discharge of Bili-Bili Dam and inflow of Jenelata river produces a fairly wide inundation of 52.47 km^2.

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