Alternative model of Sidan Reservoir operation for Ayung River Basin using RIBASIM

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Abstract: Bali Province in the next ten years is feared to experience a shortage of clean water. One effort that can be done to anticipate a shortage of clean water is by constructing Sidan Reservoir. Sidan Reservoir is located in the upstream of the Ayung River Basin. Sidan Reservoir is prioritized to meet raw water needs and it is also calculated to meet the needs of irrigation water in the downstream of the reservoir. The initial stage in this study is to analyze the availability of water as an inflow to Sidan Reservoir using the rainfall-runoff model of the ITB water balance method. Synthetic discharge as the results from the rainfall - runoff model is analyzed as Q_{90} dependable discharge. Furthermore, it analyzes raw water needs and irrigation water needs as an outflow from Sidan Reservoir. After the inflow and outflow are known, Sidan Reservoir operation simulation is carried out in four scenarios with RIBASIM software. Based on the results of the rainfall-runoff model from 2008 to 2017 and the verification with the observational discharge data from 2011 to 2017 showed good model accuracy and the error rate was relatively small with the smallest correlation coefficient of 0.50, as a result the Q_{90} dependable discharge inflow for Sidan Reservoir is obtained of 3.45 m^3 sec^{-1}. The raw water needs up to 2033 is 2.092 m^3 sec^{-1}, besides that it can be used to meet irrigation water needs of 0.35 m^3 sec^{-1}. The simulation results of Sidan Reservoir operation model based on the second scenario obtained a dependability level of 91.7%, the third scenario obtained a dependability level of 100%, and the fourth scenario obtained a dependability level of 87.5%. The third scenario with 100% dependability is the optimum result.

Keyword: reservoir operation, dependable discharge, raw water needs, irrigation water needs, RIBASIM

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* 1 Introduction

In line with the increasing rate of population growth, economic development, and tourism, the need of clean water for domestic water has also increased. On the other hand, the availability of clean water that is ready for consumption for domestic water needs is still limited, so that it has begun to feel a conflict of interest in terms of water utilization. Bali Province in the next 10 years is feared to experience a shortage of clean water. One effort that can be done to anticipate a shortage of clean water is by constructing Sidan Reservoir as a single purpose of reservoir that considered on the standard from Department of Settlement and Regional Infrastructure, 2004. Sidan Reservoir is located in the upstream of the Ayung River Basin. Sidan Reservoir has a surface area on normal water level, which is 0.146 km^2. The effective storage volume of Sidan Reservoir is 3.2 million m^3. The normal water level of Sidan Reservoir is +820.00 m above the sea level (Regional River Office of Bali-Penida, 2018).

Sidan Reservoir is prioritized to meet raw water needs and is also calculated to meet the needs of irrigation water in the downstream of the reservoir. The reservoir is able

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to meet the clean water needs of the people in the Sarbagita area, namely the Denpasar, Badung, Gianyar, and Tabanan. According to Jayada (2017), the area that most felt the impact of clean water shortage is Denpasar. During this time the Regional Drinking Water Company (PDAM) in Denpasar is still supported by small water sources such as Tukad Petanu and Tukad Penet with a small capacity of 200 - 300 liters/second with a percentage of service levels classified as low at 45.07%.

The shortage of clean water is also felt in other districts in the Sarbagita area. Badung is only able to serve clean water needs with a service coverage percentage of 72.18%. Gianyar is only able to serve clean water needs with a service coverage percentage of 70.31%. Tabanan is only able to serve clean water needs with a service coverage percentage of 77.46% (Regional Water Supply Company of Badung, Gianyar, and Tabanan, 2017). This study aims to offer alternative of reservoir operations, because there is no normative operating standard in Sidan Reservoir.

2 Background

2.1 System analysis

One way to model the hydrological cycle is by system analysis. A system is defined as a unified relationship of several components that will form a unit. The hydrological cycle, for example, can be considered as a system which the components are rain, evaporation, surface flow, and other phases of the hydrological cycle. Some phases of the hydrological cycle can be grouped into subsystems (Maidment, 1993; Indarto, 2014).

The hydrological cycle is considered as a system that can be divided into three subsystems (Maidment, 1993; Indarto, 2014).

a. Atmospheric water system consisting of precipitation, evaporation, interception and transpiration.

b. Surface water system consisting of surface run-off, overland flow, subsurface outflow, groundwater outflow, and streamflow.

c. Groundwater flow system consisting of infiltration process, groundwater flow, subsurface flow, and groundwater recharge.

Another analogy that can be considered as a system is the model for river basins. This system consists of inputs (in the form of rain falling into a river basin), natural laws that control the hydrological process, initial conditions, boundary conditions, and outputs. Usually what is used to measure the output of a river basin is a discharge at the estuary. Singh (1995) and Indarto (2014), illustrates the components of a hydrological model in Figure 1.

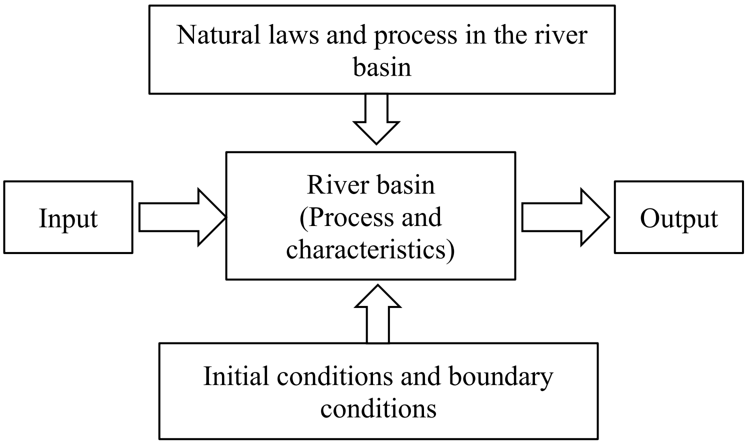

Figure 1 Component of a river basin model (Singh, 1995)

2.2 Inflow analysis

- Rainfall-runoff model of the ITB water balance method

The ITB water balance method is used to calculate the availability of water in the river and the equilibrium of water in paddy fields. The method is chosen because it is more in line with the condition of the river basin, especially in the South Bali region. This is because the difference in discharge fluctuations is not far adrift between the base flow and discharge during the rainy season (Abdullah, 2003; Asdak, 2014).

- Arithmetic mean method

This arithmetic mean method sums up rainfall measurements at several stations with the same time and then divided by the number of rainfall stations. The following is a form of equation from the arithmetic mean method (Soemarto, 1999; Soewarno, 2014; Triatmodjo, 2015).

$$\underline{p} = \frac{p_1+p_2+p_3+\ldots+p_n}{n} \quad (1)$$

Remarks:

$\underline{p}$= regional average rainfall (mm)

$p_1, p_2, p_3, \ldots, p_n$= rain at station 1, 2, 3, ..., n (mm)

n= number of stations

- Thiessen Polygon Method

The Thiessen polygon method is based on a weighted average. This method is used to find the regional average rainfall in the study area. The following is a form of the equation from the Thiessen polygon method (Soemarto, 1999; Soewarno 2014; Triatmodjo, 2015).

$$\underline{p} = \frac{A_1p_1+A_2p_2+A_3p_3+\ldots+A_np_n}{A_1+A_2+A_3+\ldots+A_n} \quad (2)$$

Remarks:

$\underline{p}$= regional average rainfall (mm)

$p_1, p_2, p_3, \ldots, p_n$= rain at stations 1, 2, 3, ..., n (mm)

$A_1, A_2, A_3, \ldots, A_n$= area of station influence 1 , 2, 3, ..., n (km^2)

- Consistency test (multiple mass curves)

The consistency test aims to determine the resilience of rainfall data obtained from rainfall gauge stations. The consistency test used in this study is a double mass curve method (Soewarno, 2014; Triatmodjo, 2015).

- Evapotranspiration by the Modified Penman Method

Evapotranspiration is the total amount of water returned to the atmosphere from bodies of water, soil surface, and vegetation by climate factors and physiological vegetation. The following is a form of evapotranspiration equation using the Modified Penman Method (Soewarno, 2014; Triatmodjo, 2015).

$$Eto = \frac{\beta E_n + Eo}{\beta + 1} \quad (3)$$

Remarks:

Eto= evapotranspiration (mm day^{-1})

E_n=evaporation depth calculated based on net radiation (mm day^{-1})

E_o=evaporation (mm day^{-1})

β=temperature function

- Dependable discharge based on discharge data

Dependable discharge is the minimum discharge of the river with a certain amount that has the possibility of being fulfilled which can be used for various purposes. The used method in calculating the dependable discharge is the Weibull Method. The following is a form of dependable discharge equation using the Weibull Method (Soemarto, 1999; Triatmodjo, 2015).

$$P = \frac{m}{n+1} 100\% \quad (4)$$

Remarks:

P = probability of Weibull Method (%)

n = number of data

m = serial number of data

- Dependable rain based on rainfall data

Analysis of dependable rainfall is generally used in irrigation planning in calculating effective rainfall. The method used in dependable rain analysis is the basic year method. The following is a form of dependable rain equation using the basic year planning method by standard of Irrigation Network Planning KP-01 (Ministry of Public Works, 2013).

$$R_{80} = \frac{n}{5} + 1 \quad (5)$$

Remarks:

R_{80} = probability with 80% dependable level

n = number of years

2.3 Outflow analysis

- Water needs for land preparation

Water needs for land preparation are total water needs taking into account water needs during preparation land, replacement water due to percolation, and replacement of water layers. The following is a form of water demand equation for land preparation (Irrigation Network Planning, KP-01, 1986, 2013).

$$IR = \frac{M.e^k}{(e^k-1)} \quad (6)$$

Remarks:

IR=irrigation water needs at the paddy field level (mm day^{-1})

M=water needs to replace water loss due to evaporation and percolation (mm day^{-1})

$k= M \times T / S$

Remarks:

T= land preparation period (day)

S= water needs for saturation (assuming 250 mm day^{-1})

- Effective rain

Effective rain is a dependable rainfall that falls in an area and it is used by plants for growth. The amount of effective rainfall for paddy is taken 70% and the amount of effective rainfall for secondary crops is taken 40% with the following equation by standard of Irrigation

Network Planning KP-01 (Ministry of Public Works, 2013):

$$Re - paddy = 0.7x\frac{1}{15}(R_{80}) \quad (7)$$

$$Re - crops = 0.4x\frac{1}{15}(R_{80}) \quad (8)$$

Remarks:

Re = effective rainfall (mm day^{-1})

R_{80}= rainfall which is unlikely to be met by 20%

- Consumptive water needs

In irrigation planning, the value of evapotranspiration is considered as a consumptive water need for plants which the amount is considered equivalent to potential evapotranspiration. The following is a form of consumptive water needs equation using standard of Irrigation Network Planning KP-01 (Ministry of Public Works, 2013).

$$Etc = Kc.Eto \quad (9)$$

Remarks:

Etc = consumptive water needs (mm day^{-1})

Kc = plant coefficient

Eto = evapotranspiration (mm day^{-1})

- Irrigation water needs for paddy

Paddy is a type of plant that requires a lot of water in its growth. The following is a form of irrigation water needs equation for paddy in paddy fields using standard of Irrigation Network Planning KP-01 (Ministry of Public Works, 2013).

$$NFR_1 = Etc_1 + P + WLR + LP - Re \quad (10)$$

Remarks:

NFR_1= water needs for rice (mm day^{-1})

Etc_1 = paddy consumptive needs (mm day^{-1})

P= percolation (mm day^{-1})

WLR= replacement of water layer (mm day^{-1})

LP= water needs for soil cultivation (mm day^{-1})

Re= effective rainfall (mm day^{-1})

- Irrigation water needs for secondary crops

Secondary crops are included in the group of plants that require less water so there should be no inundation in secondary crops area. The following is a form of equation for secondary crops irrigation water needs using standard of Irrigation Network Planning KP-01 (Ministry of Public Works, 2013).

$$NFR_2 = Etc_2 - Re \quad (11)$$

Remarks:

NFR2= water needs for secondary crops (mm hr^{-1})

Etc2= secondary consumption needs (mm hr^{-1})

Re = effective rainfall (mm hr^{-1})

- Domestic water needs

Domestic water needs is the need for clean water used to meet daily household needs. The parameters used in determining the planned level of clean water services include (Department of Public Works, 1996; Ministry of Public Works, 2007):

Consumption of clean water

Consumption of domestic clean water is determined for house connections (SR) of 60-150 lt / person / day and public hydrants (HU) of 20 - 40 lt / person / day.

Number of people per connection

Number of people per house connection is calculated based on the average number of house connections (SR) of 6 people / connection and public hydrants (HU) of 100-200 people / connection.

- Non-domestic water needs

Based on the technical guidelines for the Drinking Water Supply System (SPAM), non-domestic (commercial, industrial and tourism) water needs in urban and rural areas are 15%-20% of domestic water needs. This study used non-domestic water needs of 15% of domestic water needs (Department of Public Works, 1998; Ministry of Public Works, 2012).

- Water loss

Based on the technical guidelines for the Drinking Water Supply System (SPAM) issued by the Public Works Department, water loss is determined at 20% of domestic and non-domestic water needs, while in rural areas it is 5% (Department of Public Works, 1998; Ministry of Public Works, 2012).

- Evaporation in the reservoir

The construction of a reservoir will result in increased surface area and exceeding the original river area so that evaporation will increase. The following is the form of evaporation in reservoirs equation (Yekti, 2000, 2017).

$$E_i = A_i - Er_i \quad (12)$$

Remarks:

E_i = evaporation in reservoir

A_i = surface area of reservoir inundation in one interval time i (ha)

Er_i = evaporation rate

2.4 Water balance

The water balance can be used to calculate or evaluate the amount of water flow in and out of a hydrological system (river basin, reservoir, surface flow) in a certain period of time (Triatmodjo, 2015).

Water balance is the concept of water balance in reservoir simulation. Water balance is a function of input, output, and reservoir storage. The following is a form of water balance equation in reservoir simulation (Triatmodjo, 2015).

$$I - O = \frac{\Delta S}{\Delta t} \tag{13}$$

Remarks:

I = inflow discharge (m^3 sec^{-1})

O = outflow discharge (m^3 sec^{-1})

$\Delta s / \Delta t$ = change in storage

2.5 Reservoir dependability

In the reservoir operation simulation model, criteria based on dependability of reservoir operations are implemented to achieve optimum results. The following is a form of reservoir dependability level equation (Yekti, 2000, 2017).

$$dependability\ of\ reservoir = \frac{Pe}{n} 100\% \tag{14}$$

Remarks:

Pe = amount of not empty reservoir storage

n = amount of time in one operation

3 Material and Methods

3.1 Research location

Sidan Reservoir is located in the upstream of the Ayung River Basin with coordinates 8° 18'47.40 "LS and 115° 14'51.39" BT. The inundation area of Sidan Reservoir is divided into three administrative regions, namely Badung, Bangli, and Gianyar.

3.2 Scope of research

The scope of this research is:

Domestic water needs for the Sarbagita area include South Denpasar, East Denpasar, West Denpasar, North Denpasar, North Kuta, Mengwi, Abiansemal, Petang, Sukawati, Blahbatuh, Ubud, Tabanan, Marga, and Baturiti.

Irrigation water needs include three irrigation areas in the downstream reaches of Sidan Reservoir, namely the Sengempel Irrigation Area, the Kedewatan Irrigation Area, and the Mambal Irrigation Area.

3.3 Determination of data sources

The needed data in supporting this research are primary data and secondary data.

a. Primary data

Primary data is obtained through surveys or direct observations to the location of research, documentation, and interviews to obtain information regarding the existing conditions at the study site.

b. Secondary data

Secondary data in this study include rainfall data, discharge data, climatology data, the Ayung River Basin map data, irrigation area data, irrigation area scheme data, data on cropping patterns, population data, PDAM service coverage data, technical characteristics of Sidan Reservoir data, and Sidan Reservoir curve data (volume-elevation-area relationship).

3.4 Research procedures

The following will be described in detail about the research flow or procedure in data collection.

a. Conduct surveys or observations directly to the study site.

b. Looking for secondary data needed for data analysis and interviews in several government and private agencies.

c. Perform hydrological calculations to find the inflow and outflow of Sidan Reservoir operation model.

d. Create a scenario that will be used in the simulation of Sidan Reservoir operation model.

e. Input the collected data into the RIBASIM model based on the planned scenario.

f. Do simulation of Sidan Reservoir operation model, the results obtained are in the form of reservoir dependability (Krogt, 2013; Yekti, 2017).

g. Do simulation of water allocation in the Ayung River Basin (Krogt, 2013; Yekti, 2017).

h. Take conclusions and suggestions.

3.5 Model scenarios

In this study, the model has four scenarios that can be seen in Table 1.

Table 1 Model scenarios

Scenario 1	Scenario 2	Scenario 3	Scenario 4
Before construction of the Reservoir Sidan	After construction of Sidan Reservoir	After construction of Sidan Reservoir	After construction of Sidan Reservoir
Calculating irrigation water needs by following the existing cropping pattern	Calculating irrigation water needs by following the existing cropping pattern	Calculating irrigation water needs with the initial shift of planting in the pattern of planting systems according to alternative plans (A)	Calculating irrigation water needs with the initial shift of planting in the pattern of planting systems according to alternative plans (B) (shifted one next month from the Scenario 3)
Does not calculating domestic water needs (drinking water) and non-domestic water needs (commercial, industrial and tourism) in the Sarbagita area	Calculating domestic water needs (drinking water) and non-domestic water needs (commercial, industrial and tourism) in the Sarbagita area	Calculating domestic water needs (drinking water) and non-domestic water needs (commercial, industrial and tourism) in the Sarbagita area	Calculating domestic water needs (drinking water) and non-domestic water needs (commercial, industrial and tourism) in the Sarbagita area
Dependable discharge Q_{90} as *inflow* to Sidan Reservoir	Dependable discharge Q_{90} as *inflow* to Sidan Reservoir	Dependable discharge Q_{90} as *inflow* to Sidan Reservoir	Dependable discharge Q_{90} as *inflow* to Sidan Reservoir
Return flow comes from discharged residual irrigation water	*Return flow* comes from discharged residual irrigation water	*Return flow* comes from discharged residual irrigation water	*Return flow* comes from discharged residual irrigation water

3.6 Data analysis

Data analysis method used in this study includes calculating regional average rainfall, testing rainfall data, calculating evapotranspiration, calculating rainfall - runoff models, calculating dependable discharge, calculating population projection, calculating water needs consisting of irrigation, domestic and non-domestic water needs, do a simulation with the RIBASIM model.

4 Results and discussion

4.1 Calculating regional average rainfall (Thiessen polygon)

Calculation of regional average rainfall using the Thiessen polygon method shows the minimum annual rainfall in 2015 of 1,891 mm. While the average annual rainfall in 2017 is 3,985 mm.

4.2 Calculating the consistency test (multiple mass curves)

The results of plotting graphs (multiple mass curves) describing rainfall data from the three rainfall observation stations meet the specified requirements and the rainfall data is said consistent.

4.3 Evapotranspiration analysis

Calculation of evapotranspiration shows results that vary each month. Minimum evapotranspiration occurred in June at 3.70 mm day^{-1} and maximum evapotranspiration occurred in October at 4.98 mm day^{-1}.

4.4 Verification of synthetic discharge in Mambal Weir

The parameter values for verification with data discharge of Mambal Weir along 2011 till 2017 show good accuracy by calculating correlation, determination, Mean Absolute Error (MAE), Mean Square Error (MSE) and Root Mean Square Error (RMSE) in Table 2. Moreover the inflow can be used in Sidan Reservoir operation model.

Table 2 Verification in Mambal Weir

Parameter Size		Verification result of discharge ITB water balance model							Target
		2011	2012	2013	2014	2015	2016	2017	
Accuracy	Correlation	0.80	0.80	0.85	0.71	0.81	0.71	0.75	1
	Determination	0.64	0.63	0.72	0.50	0.66	0.50	0.57	1
Error	MAE	0.17	0.41	0.63	0.51	0.59	1.50	0.51	0
	MSE	0.04	0.22	0.46	0.39	0.54	2.51	0.32	0
	RMSE	0.21	0.48	0.68	0.63	0.74	1.59	0.56	0

4.5 Analysis of dependable discharge

Calculation of water potential or water availability as inflow to Sidan Reservoir based on the rainfall-runoff model of the ITB water balance method obtained the dependable discharge Q_{90} of 3.45 $m^3 sec^{-1}$.

4.6 Population projection analysis

Analysis of population projections in South Denpasar using the least square method, East Denpasar using the least square method, West Denpasar using the least square method, North Denpasar using the least square method, Sukawati using the least square method, Blahbatuh using the least square method, Ubud using the least square method, North Kuta using the arithmetic methods, Mengwi using the arithmetic methods, Abiansemal using the arithmetic methods, Petang using the geometric methods, Tabanan using the arithmetic methods, Marga using the geometric methods, and Baturiti using the geometric methods. The results of testing the correlation coefficients in each district are acceptable.

4.7 Analysis of domestic and non-domestic water needs

The total water needs show in Table 3 for region of Sarbagita up to 2023 are 1.622 $m^3 sec^{-1}$, up to 2028 are 1.853 $m^3 sec^{-1}$, and up to 2033 are 2.092 $m^3 sec^{-1}$.

Table 3 Domestic and non-domestic water needs

No	District	Domestic and Non-Domestic Water Needs ($m^3 sec^{-1}$) Year 2023	2028	2033
1	South Denpasar	0.409	0.479	0.549
2	Denpasar Timur	0.163	0.181	0.200
3	Denpasar Barat	0.323	0.370	0.417
4	Denpasar Utara	0.202	0.227	0.253
5	North Kuta	0.080	0.098	0.117
6	Mengwi	0.125	0.136	0.148
7	Abiansem	0.069	0.073	0.078
8	Petang	0.005	0.005	0.004
9	Sukawati	0.108	0.125	0.142
10	Blahbatuh	0.029	0.033	0.039
11	Ubud	0.041	0.044	0.047
12	Tabanan	0.016	0.029	0.046
13	Marga	0.040	0.039	0.038
14	Baturiti	0.013	0.013	0.012
	Total raw water needs	1.622	1.853	2.092

4.8 Irrigation water needs

The Sengempel irrigation area, initial paddy planting begins in December and the average irrigation water needs is 0.028 $m^3 sec^{-1}$. The area of Sengempel Irrigation Area is 47 ha.

The Kedewatan Irrigation Area, the calculation results of irrigation water needs in the first cropping pattern, averaging 2.127 $m^3 sec^{-1}$ with 2,835 ha of paddy fields. While the calculation results of the second planting pattern, average irrigation water needs are 0.340 $m^3 sec^{-1}$ with an area of 505 ha of paddy fields. The total irrigation water needs in the Kedewatan Irrigation Area is 2.467 $m^3 sec^{-1}$.

The Mambal Irrigation Area, the calculation results of irrigation water needs in the first cropping pattern, averaging 1.471 $m^3 sec^{-1}$ with a paddy field area of 1,861 ha. Then the calculation result of the second cropping pattern, the irrigation water needs averaged 0.647 $m^3 sec^{-1}$ with a paddy field area of 947 ha. Then the calculation result of the third cropping pattern, irrigation water needs averaged 0.161 $m^3 sec^{-1}$ with 224 ha of paddy fields. The total of irrigation water needs in the Mambal Irrigation Area is 2.279 $m^3 sec^{-1}$.

4.9 Sidan Reservoir operation with RIBASIM model

Sidan Reservoir operation model based on the second scenario shows the simulation results in the form of a non-empty reservoir storage of 22 half-monthly time periods, with a dependability level of 91.7%. In this second scenario there is a failure period twice, namely in the second period of October and the first period of November. The third scenario shows the simulation results in the form of a non-empty reservoir storage of 24 half-monthly time periods, with a level of dependability by 100%. In this third scenario there is no failure period throughout the year. The fourth scenario shows the simulation results in the form of a non-empty reservoir storage of 21 half-monthly time periods, with a dependability level of 87.5%. In the fourth scenario, there is a failure period three times, namely in the first period of October, the second period of October, and the first period of November.

The simulation results of Sidan reservoir operation with the RIBASIM model in the form of maximum inflow to Sidan Reservoir are 10.0 m^3 sec^{-1}, the average discharge is 4.1 m^3 sec^{-1}, and the minimum discharge is 1.0 m^3 sec^{-1}. Throughout Sidan Reservoir operation simulation, on average it is still able to meet the raw water needs for the Sarbagita region at 2.0 m^3 sec^{-1}. The following is Sidan Reservoir operation in Figure 2.

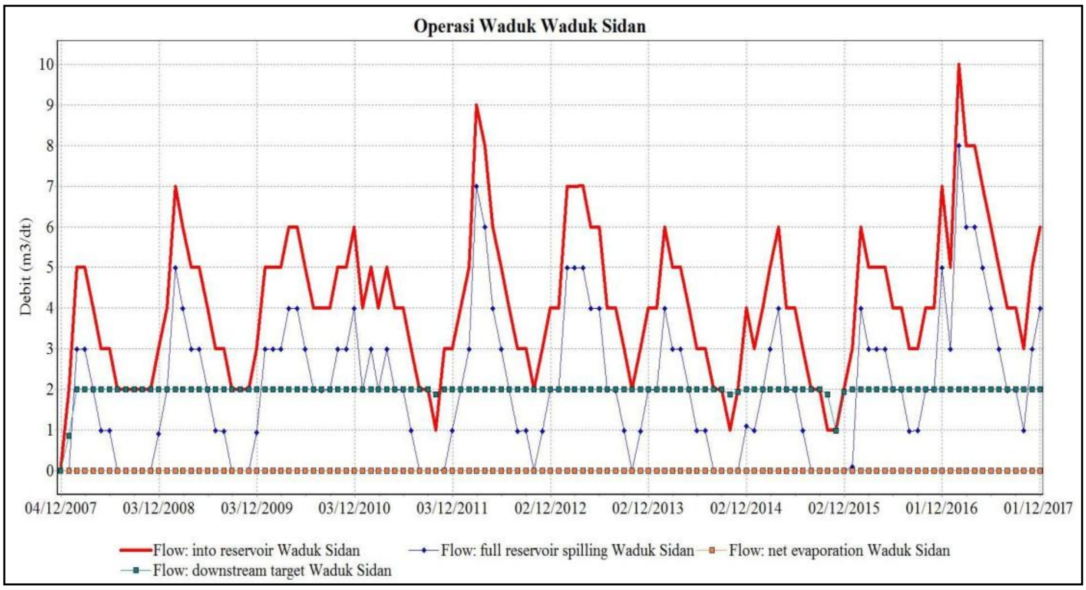

Figure 2 Sidan Reservoir operation

4.10 Water balance with the RIBASIM model

Schematization of the model is important in the RIBASIM simulation. The following is a description of schematization after Sidan Reservoir is constructed in Figure 3.

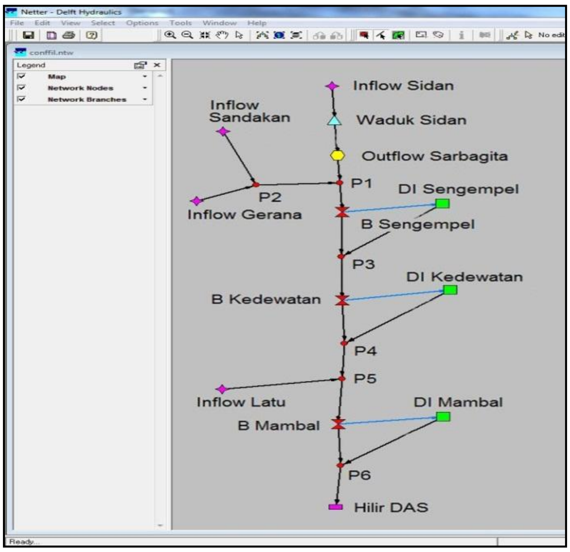

Figure 3 Schematization of the RIBASIM model

Inflow from the reservoir upstream of 4.12 m^3 sec^{-1}, the inflow of Sandakan, Gerana and Latu Weir is 8.47 m^3 sec^{-1}, and inflow of the entire return flow is 1.28 m^3 sec^{-1}. The discharge to the downstream of the Ayung River Basin modeled at 6.78 m^3 sec^{-1} has a ratio of 92.90% to the average observation discharge in the downstream of the Ayung River Basin. Outflow to the Sengempel Irrigation Area is 0.04 m^3 sec^{-1}, in the Kedewatan Irrigation Area is 2.43 m^3 sec^{-1}, and in the Mambal Irrigation Area is 2.64 m^3 sec^{-1}, outflow for raw water in the Sarbagita area is 2.00 m^3 sec^{-1}.

The dependability level of the Sengempel Weir in the first scenario is 100%, the dependability level of the Kedewatan Weir is 85%, and the dependability level of the Mambal Weir is 85%. The second scenario, the level of dependability in the Sengempel Weir is 95%, the dependability level of the Kedewatan Weir is 57.5%, and the dependability level of the Mambal Weir is 71.7%. The third scenario, the level of dependability in the Sengempel Weir is 95%, the dependability level of the Kedewatan Weir is 57.5%, and the dependability level of the Mambal Weir is 69.2%. The fourth scenario, the level of dependability in the Sengempel Weir is 95%, the dependability level of the Kedewatan Weir is 59.2%, and the dependability level of the Mambal Weir is 64.2%.

4.11 Summary of the scenario before and after the reservoir construction

The conditions before the construction of Sidan Reservoir only accounted for irrigation water needs, while the conditions after the construction of Sidan Reservoir would take into account the needs of irrigation, domestic water, and non-domestic water. The following is a scenario summary table before and after the construction of Sidan Reservoir.

Table 4 Summary of scenarios before and after the reservoir construction

Description of	Unit	Conditions before the construction of reservoir	Conditions after the construction of reservoir		
		Scenario 1	Scenario 2	Scenario 3	Scenario 4
Reservoir dependability level	%		91.7	100	87.5
Reservoir operation failure	Month / week to		Oct II and Nov I	No	Oct I, Oct II, and Nov I
The Sarbagita outflow of raw water	Million m^3		62.03	62.03	62.03
Outflow to the Sengempel irrigation area	Million m^3	1.74	1.64	1.34	1.51
Outflow to the Kedewatan irrigation area	Million m^3	105.16	79.71	76.58	81.04
Outflow to the Mambal irrigation area	Million m^3	97.28	85.25	83.14	81.69
Discharge to downstream of the Ayung River Basin	Million m^3	244.14	209.29	213.71	211.19
Inflow into Sidan Reservoir	Million m^3	130.05	130.05	130.05	130.05
Inflow from the Sandakan Weir	Million m^3	12.63	12.63	12.63	12.63
Inflow from the Gerana Weir	Million m^3	136.39	136.39	136.39	136.39
Inflow from the Latu Weir	Million m^3	118.20	118.20	118.20	118.20
Return flow total	Million m^3	51.04	41.65	40.27	41.06

4.12 Verification of the RIBASIM model

Verification result of the RIBASIM model in the Mambal Weir shows the accuracy of a good model and meets the requirements also the error rate is relatively small. The following is a table showing the verification of the RIBASIM model in the Mambal Weir.

Table 5 RIBASIM model verification in Mambal Weir

Year	Description (discharge m^3 sec^{-1})	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	r	MAE	MSE
2011	Measure	14.26	16.63	12.06	12.40	10.66	8.92	8.40	7.44	6.73	6.85	7.70	8.13	0.55	0.60	0.49
	Model	10.01	5.49	13.94	5.10	5.04	0.00	0.00	0.00	0.00	1.33	7.46	7.02			
2014	Measure	10.61	7.65	6.95	7.12	7.88	6.25	6.33	5.75	4.64	4.28	5.30	8.27	0.66	0.59	0.43
	Model	14.01	11.49	12.94	12.10	5.04	5.07	0.00	0.00	1.12	2.33	9.46	9.02			
2015	Measure	6.20	5.36	7.36	6.56	7.14	5.62	5.13	4.80	4.71	4.31	4.13	5.03	0.66	0.75	0.90
	Model	11.01	9.49	18.94	13.10	13.04	2.83	3.46	4.05	4.12	4.33	12,46	10.02			
2016	Measure	3.86	5.97	5.37	4.59	4.34	4.44	5.65	5.07	4.39	5.20	9,47	9.49	0.50	0.73	0.73
	Model	10.01	6.49	9.94	9.10	0.00	2.07	0.00	0.00	3.27	0.00	13.46	9.02			
2017	Measure	10.59	17.86	12.05	12.45	10.10	8.41	8.38	7.14	6.54	8.59	10.60	10.58	0.61	0.53	0.35
	Model	10.01	9.49	15.94	15.10	5.04	2.07	2.46	0.76	1.12	1.33	16.46	13.02			

5 Conclusions

The calculation of water potential or water availability as inflow to Sidan Reservoir based on the rainfall-runoff model of the ITB water balance method obtained the dependable discharge Q_{90} of 3.45 m^3 sec^{-1}. Moreover, the calculation of raw water needs to meet domestic and non-domestic water in the Sarbagita area in the 15-year projection up to 2033 obtains the results of raw water needs of 2.09 m^3 sec^{-1}. As a result, Sidan Reservoir operation model based on the second scenario obtained a dependability level of 91.7%, the third scenario obtained a dependability level of 100%, and the fourth scenario obtained a dependability level of 87.5%. Finally, the Sidan Reservoir operation is chosen on the third model with the highest dependability.

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