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Water Resources Management in Downstream Sub-Watershed of Bengawan Solo for Raw Water Development in Gresik Regency

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Abstract:- Changes in characteristics due to land use change and global warming in the Lower Bengawan Solo Sub-watershed have resulted in a decrease in the availability of water in the watershed. This significantly affected the availability of raw water for drink water for Gresik Regency, as the worst occurred in the extreme dry month of 2018 for four months (June – September). However, this raw water shortage will be fulfilled if the construction of the barrage Sembayat is completed. With the construction of this infrastructure facility, Gresik Regency is planned to get additional raw water services of up to 1,000 liters per second; so that the local PDAM can guarantee the fulfillment of 3K elements (quality, quantity and continuity) throughout the years of service. Currently the raw water shortage in October is proposed to get a water supply of 40% of the total intake for the 1st and 2nd daily tenths Period, while for the 3rd daily tenth period it is 20%. In order to anticipate the condition of decreasing water availability in the downstream Bengawan Solo Sub-watershed, an integrated watershed-based water resource management policy is needed, so that there is a suitability management of one river, one plan and one management from upstream to downstream. This is done in order to maintain the sustainable water supply for many aspects in sustainably.

Keywords:- *water resource management, raw water utilization, continuity.*

I. INTRODUCTION

The quantity of water will affect the ability of raw water services for the people of Gresik Regency. However, the current growth in demand for raw water exceeds the quantity of water. For this reason, it is necessary to develop infrastructure for the continuity of the supply of water resources.

Development of water resources infrastructure in the downstream Bengawan Solo sub-watershed, including the barrage Sembayat, which is planned to be built to overcome water shortages and excess water in this watershed. The hydrological characteristics of the Sembayat weir affect the potential for water availability in both the rainy and dry seasons.

The decrease in availability in the downstream Bengawan Solo Sub-watershed is strongly influenced by changes in the characteristics of the watershed. The decrease in water production was exacerbated by irregular rainfall patterns, especially those related to the duration of extreme dry months as a result of the impact of global warming. Seen in 2018 there was an extreme dry month for 4 (four) months from June to September. Meanwhile, at barrage Sembayat, there is a plan to utilize 1000 liters/second of raw water which will be used to fulfill water needs in Gresik Regency, for this reason, water resource management is needed.

The initial step to assess the optimization of water resources in the Lower Bengawan Solo Sub-watershed is to first examine the existing conditions of existing water resources. The next step is to know the water utilization plan which is then compared with the long-term carrying capacity of water resources. As a final step, principles, policies and strategies for optimizing water resources that are implemented can be formulated so that the availability of water resources can be maintained. The formulation of principles, policies and strategies for optimizing water resources must be based on the initial identification of the condition of water carrying capacity, both in the short and long term. Strategies to optimize water resources to meet water needs are based on existing data and facts so that they are expected to be close to the actual conditions.

Based on the formulation of the problem above, then the purpose of this study.

- Knowing the current condition of the water carrying capacity of the Bengawan Solo Sub-watershed downstream.
- Knowing the existing and planned water use in the downstream Bengawan Solo sub-watershed.
- Knowing the water balance in the downstream Bengawan Solo sub-watershed (the section of the barrage Babat - barrage Sembayat).
- Formulate a strategy for optimizing water resources in the downstream Bengawan Solo Sub-watershed.

The benefits of this research are as follows:

A. Theoretical Benefits:

Produces an approach to calculating water availability and demand for an area by considering the conditions of the downstream Bengawan Solo Sub-watershed.

B. The practical benefits for the Gresik Regency Government are:

- Provide information on the condition of water resources in the downstream Bengawan Solo Sub-watershed in the long term.

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- Provide information on utilization allocation to optimize water availability in the downstream Bengawan Solo Sub-watershed.

II. LITERATURE REVIEW

A. Availability of Water

Dependable flow is the minimum river flow for a predetermined probability that can be used for irrigation. The probability of being fulfilled is set at 80% (the probability that the river discharge is lower than the mainstay discharge is 20%).

The discharge data used is the debit recording data at the barrage Babat AWLR Station (2007 - 2020). The station was chosen because of the long data availability and it is located near the barrage Sembayat. From the daily discharge data, it is used as initial data to calculate water availability. Water availability is calculated based on SNI 6738 of 2015 concerning the calculation of the river's mainstay discharge with a discharge duration curve.

B. Water Needs

- Raw Water Needs
  Standards for raw water needs according to the Director General of Human Settlements, there are 2 kinds, namely Domestic Water Needs Standards and Non-Domestic Water Needs Standards.
- Irrigation Water
  Needs Irrigation water requirements are influenced by the meteorological conditions of the area concerned and the amount of water required for plant growth. According to Arsyad (2017), water needs for plants are influenced by cropping patterns and types of plants, soil types and soil forms.

C. Water Balance The

Calculation of the water balance will ultimately lead to conclusions regarding:

- The final cropping pattern that will be used for the irrigation network that is being planned.
- The final description of the irrigation project area.

D. Watershed Management (DAS) Watershed

Management patterns are based on an institutional basis, a conceptual basis and an operational basis. Meanwhile, the scope of watershed management includes; water catchment areas, water resource management, maintenance of irrigation infrastructure and facilities, flood control, river environmental management and community empowerment.

III. METHODOLOGY

This research method is descriptive quantitative. Quantitative research was chosen with the consideration that this study uses statistical test equipment and secondary data that are quantitative. In addition, it refers to the theory of water carrying capacity and hydrological theory to guide researchers to find research problems and then analyze the data using quantitative methods.

There are 3 variables in this study, namely the independent variable, the dependent variable and the moderator variable. The water demand (domestic and non-domestic) and the potential of water resources in the downstream of Solo Bengawan River area are called the independent variables, the condition of the water carrying capacity as the dependent variable, while the social conditions of the community and land use patterns are called moderator variables.

The stages of data analysis in this study include: a) data validation, b) sorting types of water use (irrigation and non-irrigation), time and amount of water use, c) calculation of water demand, d) calculation of water availability, e) analysis of water balance and f) analysis of water resources management in the downstream Bengawan Solo sub-watershed.

IV. RESEARCH RESULT

A. Technical Data Barrage Sembayat

Barrage Sembayat was completed in 2016. The operation of the door of the barrage Sembayat is determined by the design upstream water level at an elevation of +0.70 m.

Dam

Type	: Barrage
Width	: 161 m
Height	: 10,9 m
Area	: 15.700 km^2
Capacity	: 10 million m^3
Type	: Vertical Fixed Roller Gate With Flap
Doors	: 7 unit
Width	: 20 m
Height	: 6,3 m

B. Utilization Barrage Sembayat

Characteristics of barrage Sembayat the rainy season occurs from November to April while the dry season occurs from May to September (5 months). In the rainy season, water is abundant and often causes flooding in several locations, so it is necessary to control the flow of water so that it can be used for the dry season.

Utilization of barrage Sembayat as raw water supply, irrigation water and maintenance water supply which also functions as water supply for fish pond cultivation downstream weir and control of floods and seawater intrusion (LSRIP Phase 2; 2015), with details of water utilization as follows:

- Utilization of water in fish farming/ponds downstream of the weir is 2.0 m^3/second, by utilizing river water released downstream of the weir;
- Utilization of irrigation water of 1.53 m^3/second, by utilizing a reservoir of weirs;
- The utilization of raw water in the Gresik Regency area is 1.12 m3/second, by utilizing a weir reservoir.
- *Water Availability Analysis*

Reliable discharge calculation data on the barrage Babat - barrage Sembayat section is obtained from recording the monthly average discharge by PT. Jasa Tirta 1 on the outflow the barrage Babat which is upstream of the barrage Sembayat

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with a recording data range of 14 years, with a recording period ranging from 2007 to 2020. The complete data can be seen in the following table:

No.	Tahun	Debit (m^3/dt)											
		Jan	Feb	Maret	April	Mei	Juni	Juli	Agust	Sept	Okt	Nop	Des
1	2007	162.76	345.87	577.92	922.10	132.34	79.65	57.70	15.62	2.27	1.95	86.27	799.03
2	2008	748.24	865.76	1258.74	529.72	214.42	19.71	10.15	7.52	6.51	38.12	551.07	323.23
3	2009	673.74	1313.44	946.15	626.38	333.57	160.95	33.19	16.89	5.74	3.73	54.21	65.13
4	2010	776.67	1117.49	776.67	938.72	885.25	294.03	125.74	70.19	305.42	518.61	775.24	1098.20
5	2011	976.58	1010.91	720.84	940.35	852.36	84.97	109.96	41.40	15.05	18.82	394.49	631.96
6	2012	991.71	904.32	665.01	479.34	152.14	58.37	32.34	10.45	4.26	3.13	132.45	592.45
7	2013	1170.86	1132.49	837.32	1063.62	204.46	359.89	158.52	66.77	32.23	16.46	175.72	945.09
8	2014	663.42	709.74	812.69	641.19	136.33	102.94	67.04	27.12	14.78	5.16	79.15	529.41
9	2015	442.04	1265.37	1041.84	1213.09	320.62	49.01	20.54	13.21	10.14	7.03	26.28	266.84
10	2016	308.36	1137.33	896.22	730.19	210.39	431.20	205.50	51.67	104.76	288.81	558.22	925.87
11	2017	736.99	1380.00	720.40	768.30	216.14	47.60	37.81	21.75	6.77	26.44	392.14	474.05
12	2018	946.45	1143.95	928.01	64.52	43.04	33.16	13.39	4.86	1.83	2.22	26.22	64.29
13	2019	258.42	430.95	837.83	286.54	142.00	14.09	9.17	2.94	0.14	0.28	0.40	75.01
14	2020	242.05	754.04	667.00	571.35	108.19	28.60	18.25	14.52	15.67	21.23	125.99	427.86

Table 1: Discharge Recording Data Monthly Average (barrage Babat)

Based on these data, the calculation of the mainstay discharge of the basic month of planning (basic month) with a reliability of 80% (Q80) is carried out as the basis for the water availability value of the barrage Sembayat. The results of the calculations can be seen in the following table:

Month	Mainstay Debit (m^3/sec)		
	50%	*80%*	*95%*
Januari	678,90	258,42	202,41
Februari	1,064,20	709,74	388,41
March	830,70	667,00	621,47
April	648,60	479,34	175,53
Mei	230,62	132,34	75,62
June	63,05	28,60	16,90
July	33,62	13,39	9,66
August	16,17	7,52	3,90
September	6,90	2,27	0,98
October	7,97	2,22	1,12
November	145,85	26,28	13,31
December	497,15	75,01	64,71

Table 2: Mainstay of Outflow Barrage Babat

C. Rainfall Analysis

Rainfall data needed is daily rainfall data for the last 10 years at influential stations in the irrigation area, to find out which rain stations affect all rain stations in Gresik Regency and Lamongan Regency, from the method approach obtained 14 influential rain stations in Gresik Regency and Lamongan Regency.

Based on rainfall data from 14 influential stations for 10 years (2009-2019), the mainstay rainfall (R80) occurred in 2014 with an average rainfall of 1.170,3 mm per year, as follows:

No.	Rain Data		Rain Data Rank	
	Year	R (mm)	Year	R (mm)
1	2009	1,155,4	2019	1106,0
2	2010	2,387,1	2009	1155,4
3	2011	1,357,6	2014	1170,3
4	2012	1,514,9	2018	1312,4
5	2013	1,661,7	2017	1346,7
6	2014	1,170,3	2011	1357,6
7	2015	1,413,8	2015	1413,8
8	2016	1,563,6	2012	1514,9
9	2017	1,346,7	2016	1563,6
10	2018	1,312,4	2013	1661,7
11	2019	1,106,0	2010	2387,1

Table 3: Calculation of Rainfall R80

From these results, it is known that with the mainstay of rain in 2014, the beginning of the dry season occurred in May to the end of October, while the rainy season occurred from the beginning of November to the end of April, as can be seen in the graph below:

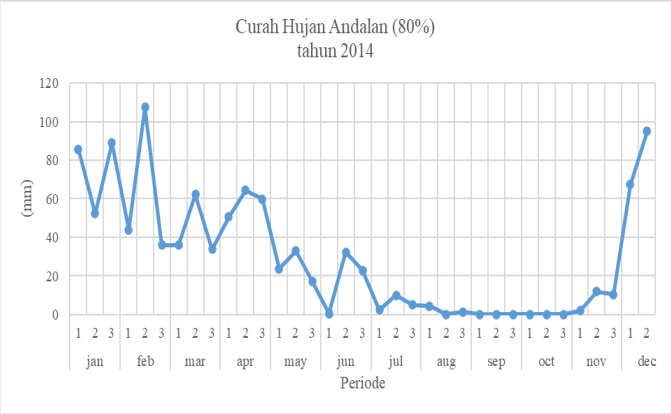

Fig. 1: Mainstay Rainfall Graph

D. Analysis of Irrigation Water Needs

Results of the calculation of needs existing cropping pattern of irrigation areas utilizing barrage Sembayat can be seen in the table below:

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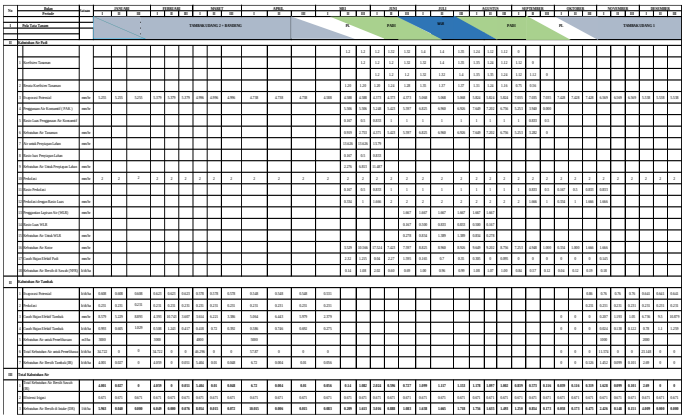

Table 4: Calculation of Irrigation Water Needs with System Patterns Existing Planting

From the calculation results of irrigation water needs in the table above, the average value of water needs every month is taken, this is done as an approach to planting time which is not necessarily the same for each farmer in each field. The results of the irrigation water needs can be seen in the following table:

Month	Number of days	Debit (liter/sec/ha)
Jan	31,00	2,00
Feb	28,00	2,04
Mar	31,00	2,71
Apr	30,00	3,34
Mei	31,00	0,63
Jun	30,00	1,66
Jul	31,00	1,67
Aug	31,00	1,63
Sep	30,00	0,76
Oct	31,00	0,24
Nov	30,00	0,91
Dec	31,00	1,34
Annual Total		**18,93**

Table 5: Irrigation Water Needs

E. Analysis of Raw Water Needs

Based on the identification of the use of raw water for the barrage Sembayat, we get a recapitulation of the water demand pattern of the barrage Sembayat which is categorized into 3 (three) categories based on the season of collection.

Month	Period	Raw Water					
		PA Embung Sukodono	*SPAM Brondong*	*Hippam Sidomukti*	*SPAM Karang binangun*	*Raw Water Total*	
		(m^3/sc)					*(million m^3)*
Jan	1	0,23	0	0,01	0,3	1,54	1,33
	2	0,23	0	0,01	0,3	1,54	1,33
	3	0,23	0	0,01	0,3	1,54	1,47
Feb	1	0,23	0	0,01	0,3	1,54	1,33
	2	0,23	0	0,01	0,3	1,54	1,33
	3	0,23	0	0,01	0,3	1,54	1,07
Mar	1	0,23	0	0,01	0,3	1,54	1,33
	2	0,23	0	0,01	0,3	1,54	1,33
	3	0,23	0	0,01	0,3	1,54	1,47
Apr	1	0,23	0	0,01	0,3	1,54	1,33
	2	0,23	0	0,01	0,3	1,54	1,33
	3	0,23	0	0,01	0,3	1,54	1,33
Mei	1	0	0,2	0,01	0,3	1,51	1,31
	2	0	0,2	0,01	0,3	1,51	1,31
	3	0	0,2	0,01	0,3	1,51	1,44
Jun	1	0	0,2	0,01	0,3	1,51	1,31
	2	0	0,2	0,01	0,3	1,51	1,31
	3	0	0,2	0,01	0,3	1,51	1,31
Jul	1	0	0,2	0,01	0,3	1,51	1,31
	2	0	0,2	0,01	0,3	1,51	1,31
	3	0	0,2	0,01	0,3	1,51	1,44
Aug	1	0	0,2	0,01	0,3	1,51	1,31
	2	0	0,2	0,01	0,3	1,51	1,31

ISSN No:-2456-2165

	3	0	0,2	0,01	0,3	1,51	1,44
Sep	1	0	0,2	0,01	0,3	1,51	1,31
	2	0	0,2	0,01	0,3	1,51	1,31
	3	0	0,2	0,01	0,3	1,51	1,31
Oct	1	0	0,2	0,01	0,3	1,51	1,31
	2	0	0,2	0,01	0,3	1,51	1,31
	3	0	0,2	0,01	0,3	1,51	1,44
Nov	1	0,23	0,2	0,01	0,3	1,74	1,51
	2	0,23	0,2	0,01	0,3	1,74	1,51
	3	0,23	0,2	0,01	0,3	1,74	1,51
Dec	1	0,23	0	0,01	0,3	1,54	1,33
	2	0,23	0	0,01	0,3	1,54	1,33
	3	0,23	0	0,01	0,3	1,54	1,47

Table 6: Raw Water Needs for the Barrage Babat - Barrage Sembayat Section

F. Storage Capacity Analysis Storage

Capacity analysis is intended to determine the graph of storage capacity at a certain elevation range according to the technical data of the reservoir, this is done as the basis for calculating the water balance for the simulation process of storage capacity and drop down at the reservoir of barrage Sembayat. The equation for the curvature of the Long Storage capacity of the barrage Sembayat is y = 6E+06x – 285714 R2 = 1.

Month	**Irrigation Water Needs**		**Month**	**Irrigation Water Needs**	
	m^3/sec			*m^3/sec*	
	Plan	Realization		Plan	Realization
Jan	12.59	12.59	Jul	10.53	7.55
	12.59	12.59		10.53	7.55
	12.59	12.59		10.53	7.55
Feb	12.85	12.85	Aug	10.25	4.90
	12.85	12.85		10.25	4.90
	12.85	12.85		10.25	4.90
Mar	17.08	17.08	Sep	4.78	1.89
	17.08	17.08		4.78	1.89
	17.08	17.08		4.78	1.89
Apr	21.06	21.06	Oct	1.48	1.48
	21.06	21.06		1.48	1.48
	21.06	21.06		1.48	1.48
Mei	4.00	4.00	Nov	5.72	5.72
	4.00	4.00		5.72	5.72
	4.00	4.00		5.72	5.72
Jun	10.46	10.46	Dec	8.41	8.41
	10.46	10.46		8.41	8.41
	10.46	10.46		8.41	8.41

Table 7: Irrigation Water Needs Plan and Realization

ISSN No:-2456-2165

Scenario	Month	Period	SPAM Brondong	SPAM Karang binangun	SPAM Gresik	Fulfillment Percentage
			Liter / second			%
Short-term	Oct	1	80	120	400	40%
		2	80	120	400	40%
		3	40	60	200	20%
Long-term	Oct	1	200	300	1000	100%
		2	200	300	1000	100%
		3	200	300	1000	100%

Table 8: Results of Alternative Water Balance Analysis 2 Sections of the Barrage Babat– Barrage Sembayat

From the results of the analysis of alternative water balance 2 for the short-term scenario in October period 1 and 2 have the same value, namely SPAM Brondong 80, SPAM Karangbinangun 120, SPAM Gresik 400 with the percentage of fulfillment reaching 40%. Meanwhile for period 3 SPAM Brondong 40, SPAM Karangbinangun 60, SPAM Gresik 200 with the percentage of fulfillment reaching 20%.

For the long-term scenario in October 1, 2 and 3 have the same numbers, namely SPAM Brondong 200, SPAM Karangbinangun 300, SPAM Gresik 1000 with the percentage of fulfillment reaching 100%.

V. CONCLUSION

The availability of water resources in the downstream Bengawan Solo Sub-watershed cannot meet the 100% raw water utilization plan if the barrage Karangnongko has not been built. The intake of raw water after the construction of the Karangnongko Dam can be fulfilled throughout the year, but before the construction of the barrage Karangnongko only in October it cannot be fulfilled, it is proposed that it can only be 40% of the total intake for October periods 1 and 2, while for period 3 it is 20%.

Strategies that can be done to optimize water resources in the downstream Bengawan Solo Sub-watershed include; reduce the need for irrigation water by regulating cropping patterns, taking an inventory of legal and illegal use of pumps along the river section between the barrage Babat and barrage Sembayat, establishing a cropping pattern according to field conditions and installing discharge measuring instruments for irrigation water collection.

REFERENCES

[1.] Abduh, M. (2007). Konstruksi Ramping untuk Mencapai Konstruksi yang Berkelanjutan, Prosiding Seminar Nasional “Sustainability dalam Bidang Material, Rekayasa dan Konstruksi Beton”. Bandung.
[2.] Asdak, C, 2010. Hidrologi dan Pengelolaan Daerah Aliran Sungai, Gadjah Mada University Press, Yogjakarta.
[3.] Arsyad, 2017 Modul Kebutuhan Air, Pusat Pendidikan Dan Pelatihan Sumber Daya Air Dan Konstruksi
[4.] D, N, Khaerudin, 2007. Kajian Potensi Air dan Pengembangan Sumberdaya Air DAS Sembayat (Pengembangan Wilayah Utara Kabupaten Gresik, Buana Sains, vol, 7, no, 1, pp, 33–42.
[5.] Handiyatmo, 2010. Pedoman Penghitungan Proyeksi Penduduk Dan Angkatan Kerja Badan Pusat Statistik, Jakarta –Indonesia
[6.] Hidayat, 2013. Kajian Optimalisasi Dan Strategi Sumber Daya Air Di Kabupaten Rembang. Universitas Diponegoro, Semarang.
[7.] Jasin, M. I. 2013. Pengembangan Sistem Penyediaan Air Bersih Untuk Zona Pelayanan IPA Pilolodaa Kota Gorontalo.
[8.] Kurniawan, 2015. Permasalahan Ketersediaan Air dan Solusinya. Jurnal Sipil Statik Vol.1 No.12, November 2013 (801-806) ISSN :2337 – 6732
[9.] Pratama, 2014. Konsep Pengembangan Wilayah Daerah Aliran Sungai (DAS) Bengawan Solo. ITS, Surabaya.