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Analysis of the Potential of North Bengkulu's Air Nokan River in the Context of Fulfilling Water Needs for Micro-hydro Power Plants and Irrigation

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Abstract
The Air Nokan River is located in Kemumu Village, Arma Jaya District, North Bengkulu Regency which is thought to have potential for agricultural water resources and Micro Hydro Power Plants (PLTMH). This study aims to calculate on how much water is available in the Air Nokan river, and calculate the water requirement for an irrigation area and the need for water for power generation and then to design and development of the PLTMH. The method of this study is to use various mathematical equations that have been found by previous researchers. The primary data used are river dimensions and flow velocity. The water discharge in the river is calculated using the continuity equation. The mainstay discharge is calculated using the Mock method. Secondary data in the form of rainfall was obtained from three rain measuring stations. Rainfall data is processed using the algebraic average method. Climatological data were obtained from the Meteorological, Climatological, and Geophysical Agency (BMKG) Bengkulu Province. The evapo-transpiration was calculated using the modified Penman method. The results of data processing obtained a cross-sectional area of the river 58 m^2 and a flow velocity of 1.5 m/s so that the river water discharge is 69.6 m^3/s. The maximum discharge required for irrigation purposes is 2.13 m^3/s. The maximum discharge required for power generation is 5.5 m^3/s. The mainstay discharge with the lowest 85% probability in January is 7.63 m^3/s.Based on the results of the analysis, it was concluded that the Air Nokan river can meet the needs of water to flow irrigation canals and power plants.

Keywords: Air Nokan, water balance, agricultural water needs, PLTMH

1. Introduction

Human activities to meet various needs have caused the human need for renewable and sustainable energy to always increase from time to time [1][2]. Economic and industrial progress in Indonesia, ranging from household to industrial scale, has resulted in the need for electrical energy always increasing from year to year. According to the overcome people's dependence on electrical energy [3].

Research on the potential of rivers for hydroelectric power plants has been carried out by researchers [1,4]. The research was conducted on the Myitnge river using GIS and SWAT software. The generator model studied is the run of river (ROR). The results of these studies can increase energy by about 36% from current conditions.

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Other researchers who studied the potential for electrical energy come from irrigation canals [5]. The water discharge in irrigation canals is measured by the float method. The average water speed in the channel is 0.83 m/s. The cross-sectional area of the channel is 36 m2, so the discharge obtained is 29.88 m3/s. The power generated using a crossflow type water turbine is 2342.592 kW.

However, there has been no previous research that examines the potential of rivers for the purposes of two functions, namely electricity and irrigation. Even though the water resources used to turn turbines can also be used to irrigate irrigation areas. So that the use of water in a river becomes more optimal [6,7].

Therefore, this study intends to examine the potential of the Air Nokan river in North Bengkulu district, Bengkulu province as a source of raw water for micro-hydro power generation and to irrigate irrigation areas. The detailed objectives of this study are as follows: i). Calculating how much water is available in the Air Nokan river. ii). Calculating the water requirement for an irrigation area. iii). Calculating the need for water for power generation and iv). Designing buildings for PLTMH.

2. Material and Methods

2.1 Research sites

The research location was carried out on the Air Nokan River, Arma Jaya District, North Bengkulu Regency, Bengkulu Province. The location of the research location is at 3°25'8.28” South Latitude and 102°15'49.46” East Longitude. The research location can be seen in Figure 1.

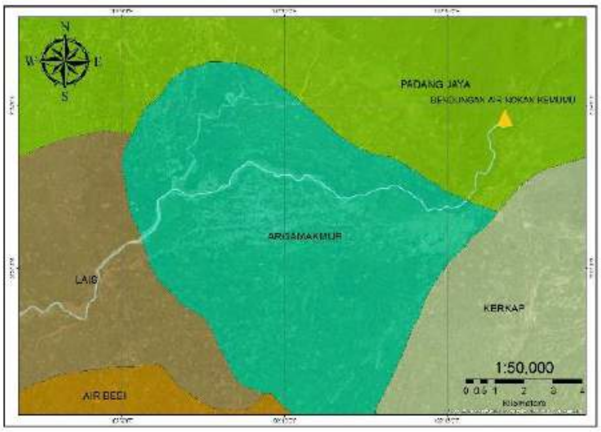

Figure 1. Research sites

2.2 Data Collection

The data used in this study include primary data and secondary data. A description of each data is presented as follows:

a. Primary data

Primary data obtained by direct observation and measurement in the field. The primary data in this study are as follows:

- Dimensions of the cross section of the river;
- Primary channel dimensions;
- The flow velocity of the Air Nokan rivers
- Velocity of water flow in the primary canal.

b. Secondary Data

The secondary data used in this study are as follows:

- Rainfall data obtained from BMKG Bengkulu Province;
- Climatological data obtained from BMKG Bengkulu Province;
- Schematic map of the irrigation network obtained from the North Bengkulu PUPR service;
- Topographic map of the upstream area of the Air Nokan Kemumu irrigation network in North Bengkulu Regency processed from the Google Earth Application.

2.3 Data Processing

The stages of data processing in this study are as follows:

a. Determine water availability

The availability of water is determined by measuring river width, water table depth, flow velocity, and primary canal dimensions. Then discharge is calculated using the continuity equation.

b. Conducting rainfall analysis with semi-monthly periods using the algebraic average method. The mathematical equation is presented below [4,8]:

$$P_{i,n} = \frac{1}{n}(P_1 + P_2 + \cdots . + P_n) \qquad (1)$$

Where :

P = Regional average rainfall (mm)

$P_{i,n}$ = Rainfall at station i,n (mm)

n = Number of rain gauge stations

c. Analysis of evapotranspiration using the following equation [4]:

$$E_{to} = E_t - c \qquad (2)$$

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Where :
E_{to} = Potential evapotranspiration (mm/day)
E_t = Actual evapotranspiration (mm/day)
c = Change factor in weather conditions

Calculation of excess water (water surplus) uses the following equation [5,9]:

$$W_s = (P - E_a) + S_s \quad (3)$$

Where :
W_S = Excess water (mm/month)
P = Monthly rainfall (mm/month)
E_a = Actual evapotranspiration (mm/month)
S_S = Land storage

Calculation of the total surface runoff is determined by the final value of the total run off as a component forming the river discharge (stream flow). It is determined using the following equations [7,10]:

$$T_{ro} = B_f + D_{ro} + S_{ro} \quad (4)$$

Where :
T_{ro} = Total *run off* (mm/month)
B_f = Base flow (mm)
D_{ro} = Direct runoff (mm)
S_{ro} = Storm Runoff (mm/month)

Calculation of Mainstay Discharge uses the following equation [5]:

$$Q = \frac{(T_{ro} \times C_a)}{(Days)} \quad (5)$$

Where :
Q = Mainstay discharge (m^3/sec)
T_{ro} = Total *run off* (mm)
C_a = Area (km^2)

d. Analysis of agricultural water needs was carried out using the cropping pattern method (paddy-paddy-secondary crops). The value of water needs is obtained through the following stages. The need for irrigation water at the rice field level in land preparation uses the following equation [11]:

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

Where :
IR = Need for irrigation water at the rice field level (mm/day)
M = Water requirement to replace water loss (mm/day)
e = 2.7183
k = Constant

Calculation of effective rainfall using the following equation [11,12]:

$$R_e = R_{et} x \frac{1}{15} R_{80} \quad (7)$$

Where :
R_e = Effective rainfall (mm/day)
R_{80} = 80% reliable rainfall (mm/day)
R_{et} = *Re* Plant Persentage

Calculation of plant water needs using the following equation [8]:

$$NFR = E_{tc} + WLR + P - R_e \quad (8)$$

Where :
N_{FR} = Water requirement in paddy fields (mm/day)
E_{tc} = Plant evapotranspiration (mm/day)
WLR = Water layer recharge (mm/day)
Re = Rice effective rainfall (mm/day)
P = Percolation (mm/day, with a value range of 1-3 mm/day.

Calculation of water intake needs using the following equation [8]:

$$DR = \frac{NFR}{8{,}64 \times EI} \quad (9)$$

Where :

DR=Water withdrawal requirement (lt/sec/are)
EI = Irrigation efficiency (0.65)

e. Planning for a PLTMH includes: First, determining the effective fall height and the power generated according to the PLTMH classification based on SNI 8396:2019. Second, the planning of several components of the PLTMH building, namely intake buildings, settling pond, conveyance channels, and head pond [13].

3. Results and Discussion

3.1. Water Discharge Available

The results of discharge measurements in the river and in the primary canal are presented in Table 1.

Table1. Measurement Results Discharge Data.

Overview	Area (A) (m^2)	Speed (v)	Discharge (m^3/sec)
River	58	1.5	69.6
Primary Channel	6.6 x 2.1	2.1	13.86

Available river water discharge is 69.6 m^3/s.

The measured water discharge in the primary canal with channel dimensions 6.6 m (wide) and 2.1 m (high), the flow rate is 2.1 m/s, the available discharge is 13.86 m^3/s.

3.2. Rainfall Analysis

The rainfall analysis in this study used rainfall data from the three Kemumu, Argamakmur, and Baturoto rain posts. Rainfall data from each of the three rain posts are shown in Table 2.

Table 2. Average Rainfall Results for the 2009-2021

Month	Period	Year												
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Jan	1	216.0	231.7	204,3	285.3	274.3	181.7	100.3	247.0	201.7	53,3	390.7	338,3	102,3
	2	232.7	36.0	71.7	18,7	247,3	213.0	411.3	232.0	82.0	96.3	83.0	305,3	165.0
Feb	1	103,7	263.0	111.0	157,3	391.0	98.0	357,3	254.0	210.7	97.0	140.7	310.0	97.0
	2	125.7	296.0	4,3	168.7	143.7	135.3	219.7	269.3	310.7	200.0	101.7	136.7	182.0
Mar	1	113,7	424.0	173.7	100.7	67.0	215,3	210.0	355.7	255,3	217,7	326.7	411.0	161.7
	2	158.0	160.0	105.0	22,3	239.0	391.0	217.0	191.3	213,3	177.3	94.3	582.0	165.0
Apr	1	774.7	158.0	92.0	495.0	171.3	225,3	480.7	223.7	194.7	271.3	126.0	118.7	56.0
	2	73,7	141.0	241.3	394.0	374.3	264.0	157.7	339.0	332.0	406.3	657.0	292.3	171.0
May	1	385,3	140.3	186.7	131.7	156.7	414,3	226.7	342.3	452.0	168.3	75,7	188.0	223.0
	2	11,3	144.3	188.3	313,3	187.0	275.7	161.0	171.3	233.7	528.0	178.3	246.7	261.3
June	1	121.7	117.0	169.7	160.7	168.0	202.7	247,7	173.3	140.3	176.3	257,7	143.7	212.0
	2	131.3	364.7	169.7	77.0	82.3	39.0	75,7	80.0	249.0	223.7	315,7	310,3	155.0
July	1	140.7	384.3	118.0	184.0	264.7	226.0	84.7	150.7	204.0	218.7	110.7	156.7	126.3
	2	70,3	304.3	71.3	167.3	203.0	111.3	82.3	220.0	132.3	187.7	44,3	172.3	128.7
Aug	1	108.0	159.3	91.3	108.0	144.7	181.0	92.7	280.3	258.3	133.0	23,7	113,3	229.0
	2	226,3	294.3	110.3	185.7	86.3	320.7	42,7	230.3	235.7	477,3	126.7	147,3	201.3
Sept	1	312,3	110.3	75,3	143.3	270.3	204.7	16.0	276,7	197.7	98.0	166.7	371.0	280.7
	2	300.7	384.3	241.7	5.0	333.0	95.0	131.3	191.0	250.3	213,7	55.0	89.3	350.7
Oct	1	191.3	306.3	44,7	260.0	270.3	71.7	78.7	229.0	292.3	397.0	198.7	457.0	170.7
	2	405.0	158.3	417.0	320.0	305,7	241.3	39,3	129.3	97.7	430.3	194.7	253.7	575.0
Nov	1	374.3	126.7	406.3	678.7	569.7	322,3	266.3	421.7	237.0	516.7	83.3	238.7	156.3
	2	321.0	364.3	421.0	255.7	124.0	467,3	370.7	241.7	327,3	332.0	200.3	374.7	128.3
Dec	1	314,3	135.3	150.3	250.7	266.7	88.7	546.0	311.3	160.7	447,3	398.0	177.7	191.0
	2	500.0	86.0	230.0	371.0	69,3	209.7	205,7	84.3	209.7	97.7	327,7	200.7	268.3

3.3. Evapotranspiration

The results of the evapotranspiration calculation can be seen in Table 3.

Table 3. Results evapotranspiration calculation in January-December

Eto	Eto ½ month	Eto	Eto ½ month
mm/hr	mm/hr	mm/hr	mm/hr
5,4	80.5	4,4	65,6
5,9	88.0	4,8	71.6
6,1	90.8	5,6	83.6
6,1	91.4	5,4	80.9
5,6	83.9	6,3	94.7
5,7	85.5	6,1	90.8
5.0	75,1	6.0	89.3
5.0	74.9	6.0	89.5
4,7	70,1	5,6	84.0
4,8	72.0	5,6	83,4
4,6	68.5	5,5	82,2
4,6	69,4	5,5	82.8

3.4. Irrigation Water Needs

a. Land Preparation

The overall land preparation results from January to December as in Table 4.

Table 4. Land Preparation Water Needs

period		Eto	Eo	P	M	Q	S	K	IR
Jan	1	5.37	5.90	2	7.90	30	250	0.95	12.90
	2	5.87	6.45	2	8.45	30	250	1.01	13.26
Feb	1	6.06	6.66	2	8.66	30	250	1.04	13.40
	2	6.09	6.70	2	8.70	30	250	1.04	13.43
Mar	1	5.59	6.15	2	8.15	30	250	0.98	13.06
	2	5.70	6.27	2	8.27	30	250	0.99	13.14
Apr	1	5.01	5.51	2	7.51	30	250	0.90	12.64
	2	5.00	5.50	2	7.50	30	250	0.90	12.64
May	1	4.68	5.14	2	7.14	30	250	0.86	12.41
	2	4.80	5.28	2	7.28	30	250	0.87	12.50
Jun	1	4.57	5.02	2	7.02	30	250	0.84	12.33
	2	4.62	5.09	2	7.09	30	250	0.85	12.37
Jul	1	4.38	4.81	2	6.81	30	250	0.82	12.20
	2	4.77	5.25	2	7.25	30	250	0.87	12.48
Aug	1	5.57	6.13	2	8.13	30	250	0.98	13.05
	2	5.40	5.94	2	7.94	30	250	0.95	12.92
Sept	1	6.31	6.94	2	8.94	30	250	1.07	13.59
	2	6.05	6.66	2	8.66	30	250	1.04	13.40
Oct	1	5.95	6.55	2	8.55	30	250	1.03	13.32
	2	5.97	6.56	2	8.56	30	250	1.03	13.34
Nov	1	5.60	6.16	2	8.16	30	250	0.98	13.07
	2	5.56	6.12	2	8.12	30	250	0.97	13.04
Dec	1	5.48	6.03	2	8.03	30	250	0.96	12.98
	2	5.52	6.07	2	8.07	30	250	0.97	13.01

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b. Effective Rainfall

The results of effective rainfall from January to December can be seen in Table 5.

Table 5. Effective Rainfall (Rice-Palawija)

Month	Period	R80	Re(mm)	Type
January	1	101.94	4.76	Rice
	2	64,64	3.02	
February	1	97.80	4.56	
	2	120.94	5,64	
March	1	111,11	5,18	
	2	102.90	4.80	
April	1	113,41	5,29	
	2	154.38	7,20	
May	1	138.63	6,47	
	2	157,72	7,36	
June	1	136.66	4.56	
	2	76,74	3.58	
July	1	116.56	5,44	Palawija
	2	71,14	3,32	
August	1	92.40	3.08	
	2	105,61	3.52	
September	1	93.53	3,12	
	2	82.57	2.75	
October	1	77,29	2.58	
	2	123,10	4,10	Rice
November	1	150.49	7.02	
	2	186.15	8.69	
December	1	147,38	6.88	
	2	85,67	4.00	

c. Water Requirement in Intake Building

The intake discharge value (DR) is obtained from the value of clean water demand in paddy fields divided by the irrigation efficiency value. The irrigation efficiency value is 0.65.

$$DR = \frac{4.58}{(0.65\ \times 8.64)} = 0.82\,\frac{lt}{sec}/are$$

d. Total Agricultural Irrigation Water Needs

The need for irrigation water (KAI) for agriculture is determined by the total area of the Kemumu Nokan Water Irrigation Area, which is 1.436,97 are. An example of calculating the total agricultural water demand in January 1 is:

$$KAI = DR \times Area$$
$$= 0.82 \times 1.436{,}97$$
$$= 1.171.35 \text{ liters/sec}$$
$$= 1.17\ m^3/sec$$

The value of agricultural irrigation water needs for the next semi-monthly period as a whole from January to December can be seen in Table 6.

Table 6. Rice-Palawija Pattern Water Needs

Period		NFR (lt/s/Ha)	DR (lt/s/ha)	Area (Ha)	Q85	KAI (lt/s)	KAI (m3/s)
Nov	1	0.70	1.08	1,436.97	17.59	1546.89	1.55
	2	0.50	0.78	1,436.97	17.58	1114,17	1.11
dec	1	0.33	0.51	1,436.97	18.31	729.94	0.73
	2	0.67	1.03	1,436.97	17,25	1477,27	1.48
Jan	1	0.53	0.82	1,436.97	7,63	1171.35	1.17
	2	0.79	1.22	1,436.97	8,20	1750.69	1.75
Feb	1	0.37	0.57	1,436.97	11.63	815.86	0.82
	2	0.00	0.00	1,436.97	15,31	0.00	0.00
Mar	1	0.91	1.40	1,436.97	14,33	2015.70	2.02
	2	0.97	1.48	1,436.97	13,21	2133,41	2,13
Apr	1	0.45	0.70	1,436.97	16.94	1001.56	1.00
	2	0.23	0.35	1,436.97	17,74	509.45	0.51
May	1	0.25	0.38	1,436.97	17,28	547.65	0.55
	2	0.87	1.34	1,436.97	16.63	1931.82	1.93
Jun	1	0.21	0.32	1,436.97	18,17	456,20	0.46
	2	0.00	0.00	1,436.97	14,24	0.00	0.00
Jul	1	0.00	0.00	1,436.97	17,42	0.00	0.00
	2	0.00	0.00	1,436.97	12.89	0.00	0.00
Aug	1	0.26	0.40	1,436.97	14.52	580.65	0.58
	2	0.25	0.38	1,436.97	13,23	548.94	0.55
Sept	1	0.38	0.59	1,436.97	13.84	849.92	0.85
	2	0.35	0.53	1,436.97	13.64	766,73	0.77
Oct	1	0.00	0.00	1,436.97	13.77	0.00	0.00
	2	0.00	0.00	1,436.97	13.91	0.00	0.00

3.5. Water Balance

The water balance is used to determine the balance between water availability and water demand in the irrigation area as a whole. Water treatment for agricultural irrigation water needs is the main point that must be fulfilled, before adding functional water flow to the PLTMH planning [14].

The water balance in the Water Nokan Kemumu Irrigation Area is obtained based on the reliable discharge value with a probability of 85% (Q_{85}) which is the water availability and irrigation water demand value (KAI).

The water balance for the semi-monthly period of the Kemumu Nokan Water Irrigation Area can be seen in Table 7.

Table 7. Water Balance for the Semi-Monthly Period at Air Nokan Kemumu

Period		Q_{85}	KAI (m^3/sec)	Final discharge	Information
Jan	1	7,63	1.17	6,46	Fulfilled
	2	8,20	1.75	6,45	Fulfilled
Feb	1	11.63	0.82	10.82	Fulfilled
	2	15,31	0.00	15,31	Fulfilled
Mar	1	14,33	2.02	12,32	Fulfilled
	2	13,21	2,13	11.08	Fulfilled
Apr	1	16.94	1.00	15.94	Fulfilled
	2	17,74	0.51	17,23	Fulfilled
May	1	17,28	0.55	16.73	Fulfilled
	2	16.63	1.93	14.70	Fulfilled
June	1	18,17	0.46	17,71	Fulfilled
	2	14,24	0.00	14,24	Fulfilled
July	1	17,42	0.00	17,42	Fulfilled
	2	12.89	0.00	12.89	Fulfilled
Aug	1	14.52	0.58	13.94	Fulfilled
	2	13,23	0.55	12.68	Fulfilled
Sept	1	13.84	0.85	12.99	Fulfilled
	2	13.64	0.77	12.87	Fulfilled
Oct	1	13.77	0.00	13.77	Fulfilled
	2	13.91	0.00	13.91	Fulfilled
Nov	1	17.59	1.55	16.04	Fulfilled
	2	17.58	1.11	16,47	Fulfilled
dec	1	18.31	0.73	17.58	Fulfilled
	2	17,25	1.48	15.77	Fulfilled

From the calculation results it is known that the minimum discharge value (Q_{min}) is 7.63 m^3/s in January, the 1st period, and the maximum irrigation water demand value (KAI_{max}) is 2.13 m^3/s in March, the 2sc period. Discharge data and irrigation water needs then used to determine the optimal final discharge of irrigation, with the following description:

$$Q_{optimal} = 7.63 - 2.13$$
$$Q_{optimal} = 5.5 \text{ m}^3\text{/sec}$$

Determination of the planned Discharge is based on the optimal Discharge value available. The planned Discharge must also be adjusted based on the capacity of the existing primary canal of Water Nokan Kemumu Irrigation. The initial planned discharge for the PLTMH in this study was planned in 4 discharge alternatives for determining the optimal discharge for the power planning and design of the PLTMH building. Alternative 1 is the maximum discharge and the alternative 4 is the minimum discharge. The selected Discharge plan each alternative can be seen in Table 8.

Table 8. Several Alternative Initial Plan Discharge

Alternative	Discharge (m3/sec)
I	5,5
II	5
III	4
IV	3

The water balance in Air Nokan Sub Watershed presented in Figure 2.

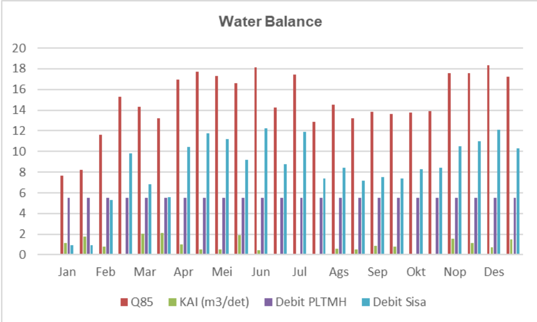

Figure 2. Water Balance in Air Nokan River

Figure 2 demonstrates the availability of water for watering irrigation and rotating turbines in sufficient condition. in the wet months when the rainfall is high there is an excess of water. but in dry months the availability of water is relatively low.

a. Intake Door Capacity

The intake gate is analysed to determine the size of the door capacity and the ability of the door to pass irrigation water optimally. Irrigation water discharge will experience an increase due to the new design discharge for PLTMH operations. The overall flow rate for irrigation will be greater in value than the discharge for normal irrigation operations. So that the door capacity analysis is carried out with free flow [15,16].

The capacity of the intake gate is adjusted to the water level upstream of the door and the door opening. The value of the overall door capacity calculation results carried out in the same way can be seen in Table 9.

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Table 9. Irrigation Intake Door Capacity Existing

No.	MA elevation	h1 (m)	Door Aperture (m)										
			0.2	0.4	0.6	0.8	1	1,2	1,4	1,6	1,8	2	2,2
1	+352	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	+352.2	0.2	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
3	+352.4	0.4	1.21	2,42	2,42	2,42	2,42	2,42	2,42	2,42	2,42	2,42	2,42
4	+352.6	0.6	1.48	2.96	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45
5	+352.8	0.8	1.71	3,42	5,13	6.85	6.85	6.85	6.85	6.85	6.85	6.85	6.85
6	+353	1	1.91	3.83	5,74	7.65	9.57	9.57	9.57	9.57	9.57	9.57	9.57
7	+353.2	1,2	2,10	4,19	6,29	8,38	10.48	12.58	12.58	12.58	12.58	12.58	12.58
8	+353.4	1,4	2,26	4.53	6,79	9.06	11.32	13.58	15.85	15.85	15.85	15.85	15.85
9	+353.6	1,6	2,42	4.84	7,26	9,68	12,10	14.52	16.94	19.36	19.36	19.36	19.36
10	+353.8	1,8	2.57	5,13	7,70	10,27	12.84	15,40	17.97	20.54	23,11	23,11	23,11
11	+354	2	2.71	5,41	8,12	10.82	13.53	16,24	18.94	21.65	24,36	27.06	27.06
12	+354.2	2,2	2.84	5,68	8.51	11.35	14,19	17.03	19.87	22.71	25,54	28,38	31,22

The Kemumu Irrigation intake gate can channel the required discharge for agricultural irrigation water and the maximum planned discharge for PLTMH is 7.13 m3/sec, with an opening height of 0.6 meters at a water level elevation of +353.6 meters above sea level.

b. Primary Channel Capacity

Analysis of the existing primary canal of Kemumu Irrigation was carried out to determine the capacity limit of the canal in flowing water, especially the canal's ability to carry flow discharge with changes caused by the addition of discharge for PLTMH operations.

Primary channel capacity values for each water level are calculated according to the wet cross-sectional area of the channel. The channel capacity values for each water level can be seen in Table 10.

Table 10. Existing Primary Channel Capacity

H	M	A	P	R	I	v	Q
(m)	(m)	(m^2)	(m)	(m)	m	(m/s)	(m^3/s)
0.1	0.114	0.429	4,481	0.096	0.00064	0.212	0.091
0.2	0.229	0.865	4,690	0.184	0.00064	0.329	0.284
0.3	0.343	1.315	4,914	0.268	0.00064	0.421	0.554
0.4	0.457	1,785	5,160	0.346	0.00064	0.500	0.892
0.5	0.571	2,283	5,432	0.420	0.00064	0.569	1,299
0.6	0.686	2,815	5,735	0.491	0.00064	0.631	1,776
0.7	0.800	3,388	6,073	0.558	0.00064	0.687	2,328
0.8	0.914	4,009	6,448	0.622	0.00064	0.739	2,961
0.9	1.029	4,685	6,862	0.683	0.00064	0.786	3,683
1	1.143	5,423	7,317	0.741	0.00064	0.830	4,503
1,1	1.257	6,229	7,814	0.797	0.00064	0.872	5,430
1,2	1,371	7,111	8,354	0.851	0.00064	0.911	6,476
1,3	1,486	8,075	8,936	0.904	0.00064	0.948	7,652
1,4	1,600	9,128	9,563	0.955	0.00064	0.983	8,972
1.5	1,714	10.277	10.234	1.004	0.00064	1.017	10,449
1,6	1,829	11,529	10,949	1.053	0.00064	1,049	12,098
1,7	1,943	12,891	11,709	1.101	0.00064	1,081	13,935
1,8	2,057	14,369	12,514	1.148	0.00064	1.112	15,975
1,9	2,171	15,971	13,364	1.195	0.00064	1.142	18.235
2	2,286	17,703	14,260	1,241	0.00064	1.171	20,733
2,1	2,400	19,572	15,200	1,288	0.00064	1,200	23,486

The calculation results show that the maximum capacity of the kemumu irrigation primary canal is 23.486 m^3/sec. Required Discharge of 7.13 $m^{3/}$s can be fulfilled with a minimum water level of 1.3 m and a speed value of 0.948 m/s.

3.7 Water Power Capacity

a. Head

The head is determined by taking into account the height from the starting point of water taking at the head pond to the end point at the powerhouse (H_{bruto}). The effective fall height value is influenced by the amount of energy loss (H_{tosses}). Initial planning will assume a large value of energy loss, namely 10% of the gross height. Based on the topographic map of the research location, the value of the difference in height is obtained, so the amount of energy loss is calculated as follows:

Elv. Tranquilizer tank plan : + 363 mswl
Elv. Plan turbine : + 359.5 mswl
Initial plan height (*H*) : 3.5 m
If H_{losses} 0.35 m so that the head is 3.15 m.

b. Generated Power

The amount of power is determined by the planned discharge of the PLTMH (*Q*) and the known effective fall height (H_{eff}). If Q = 5.5 m^3/sec and H_{eff} = 3.15 m so the generated power for the Kemumu PLTMH alternative I as follows [12]:

$$P = \rho \times g \times Q \times H_{eff} = 169.96\ kW$$

The resulting power results based on the next alternative discharge plan as a whole can be seen in Table 11.

Table 11. Power Generated Alternative Discharge Plans

Alternative	Discharge (m^3/sec)	Head (m)	Power (watt)	Power (kW)
I	5,5	3,15	169,958.2	169.96
II	5	3,15	154,507.5	154.51
III	4	3,15	123,606.0	123,61
IV	3	3,15	92,704.5	92.70

The maximum design discharge is obtained in alternative I which is 5.5 m^3/sec which can produce a power potential of 169.96 kW. The resulting value has met the power criteria in the PLTMH planning by taking into account the planning location and the source of hydropower which is based on irrigation canals. So that it is used in the design of the next PLTMH building.

3.8 Planning of Several Components of the PLTMH Building

a. Intake gate

The intake gate is planned to be one door with the amount of discharge adjusted according to the height of the door opening. The capacity of the intake gate must be at least 120% of the requirement (dimensional requirement) to increase flexibility and as an effort to meet higher requirements during the life of the project. Technical planning for the intake of PLTMH, namely:

Discharge (Q) : 120%×5.5 m3/s = 6.6 m3/s
Door width (b) : 2 m
Aperture threshold height (a) : 1.5 m
Discharge Coefficient (μ) : 0.8
Gravity Speed : 9.81 m/s [2]

Then the door capacity is calculated by Eq. 9 and is affected by the value of high energy loss (z) as follows [9]:

$$Q = \mu b a \sqrt{2 \cdot g \cdot z}$$

$$6.6 = 0.8 \cdot (2) \cdot (1,5)\sqrt{2 \cdot 9,81 \cdot z}$$

$$\sqrt{z} = \frac{6,6}{10,63}$$

$$\sqrt{z} = 0.62$$

$$z = 0.384 \text{ m}$$

Based on the trial-and-error results, it was found that the high energy loss required for the MHP intake gate was 0.384 m.

b. Sedimentation Tub

The design of the settling basin is carried out by analysing the length of the settling path and the critical speed of falling granules.

The settling tank design is determined by the following calculation [14]:

Design discharge (Q) : 5.5 m^3/sec
Qs: 120% × 5.5 m^3/s : 6.6 m^3/s
Building height (h) : 2 m
Temperature (t) : 20°

Sediment diameter (d) : 0.5 mm (Dia the maximum
permitted for PLTA low pressure)
Coarse sand vs : 1.5 m/s

Critical flow (Fr) : 1
Settling speed (w) : 0.07 m/s
K channel : 40
critical speed: a= 44 (for 0.1mm < d < 1mm)

$v = 44\sqrt{0{,}5}$ = 31.11 cm/sec = 0.31 m/sec

Calculation of granular descent time with Eq. 10 [14]:

$$T = \frac{h}{w}$$
$$= \frac{2}{0{,}07}$$
$$= 28.57 \text{ seconds}$$

Length of settling tank Eq. 11 [14]:

$$L = v \times Q$$
$$= 0.31 \times 28.57$$
$$= 8.9 \text{ m}$$

Width of settling tank [14]:

$$Q = b \cdot h \cdot v$$
$$b = \frac{Q}{h \cdot v}$$
$$b = \frac{5{,}5}{2 \cdot 0{,}31} = 8.9 \text{ m}$$

Tilt during draining Equality [14]:

$$Icr = \frac{Vcr^2}{(R^{\frac{2}{3}} \cdot K)^2}$$
$$Fr = \frac{Vcr}{\sqrt{gd}}$$
$$1 = \frac{Vcr^2}{\sqrt{9{,}81 \cdot d}}$$
$$12 = \frac{(\frac{Qs}{b \cdot d})^2}{9{,}81 \cdot d}$$
$$12 = \frac{(\frac{6{,}6}{8{,}9 \cdot d})^2}{9{,}81 \cdot d}$$
$$1^2 = \frac{(0{,}75/d)^2}{9{,}81 \cdot d}$$
$$12 = 0.057/d^3$$
$$d = 0.385 \approx 0.4\text{m}$$
$$Vcr = 0.75/d = 0.75/0.4$$
$$= 1.87 \text{ m/s} > 0.31 \text{ m/s (Safe)}$$

$$R = \frac{(b \cdot d)}{b + 2d} = \frac{(8{,}9 \cdot 0{,}4)}{8{,}9 + 2\,(0{,}4)} = 0.36 \text{ m}$$

So that,

$$Icr = \frac{1{,}87^2}{(0{,}36^{\frac{2}{3}} \cdot 40)^2}$$
$$Icr = 0.0085 \approx 0.01$$
$$hs = 0.01 \text{ x } (2 \text{ x } 8.9) = 0.18 \text{ m}$$

The calculation results show that the dimensions of the settling basin are 8.9 m long and 8.9 m wide.

c. Waterway

The water way is planned according to the planned discharge of the MHP with a square cross section. Calculation of the water way using the Manning formula. Calculation of water way channel design with the following steps are described [14]:

Value n : 0.017;
Slope : 0.0004
Design discharge (Q) : 5.5 m^3/sec
Channel width (b) : 3.5 m
Guard height (W) : 0.40 m
Speed (v) : 1 m/s

Calculation of water depth with Eq. 14 :

$$Q = A \times v$$
$$Q = (b \times h) \times v$$
$$5.5 = (3.5 \times h) \times 1$$
$$h = 1.58 \text{ m} \approx 1.6\text{m}$$

Calculation of water way length with Equation:

$$V = \frac{1}{n} \cdot (\frac{A}{P})^{\frac{2}{3}} \cdot S^{\frac{1}{2}}$$
$$1 = \frac{1}{0{,}017} \cdot (\frac{3{,}5 \cdot 1{,}6}{P})^{\frac{2}{3}} \cdot 0{,}0004^{\frac{1}{2}}$$
$$1 = \frac{0{,}042}{0{,}017 P^{\frac{2}{3}}}$$
$$P^{2/3} = 3.76$$
$$P = 7.31 \text{ m} \approx 7.4 \text{ m}$$

The results of the calculation of the carrier canal design with a design width of 2 m, namely the water depth (h) is 1.6 m with a guard height of 0.40 m and a channel length of 7.4 m. The total height of the carrier channel is 2 m.

d. Head Pond (Forebay)

A head pond is placed at the end of the carrier channel before the flow directly enters the turbine. The head pond is the initial reference point for determining the effective fall height for the design of the penstock pipe and the position of the turbine for the PLTMH.

The capacity of the head pond is planned to be 10 times the planned discharge value (10Q) with dimensions smaller than the settling basin to maintain the stability of the operational discharge continues to be fulfilled [17]. The plan dimensions of the tranquilizer tub with a square shape are as follows:

Volumes (V) : $10 \times 5.5\ m^3/s = 55\ m^3$
The width of the head pond (b): 5 m
Headboard length (L): 7 m
Determine the depth of the head bath with Equation [12]:

$V = b \times L \times h$

$55 = 5 \times 7 \times h$

$h = \frac{55}{5 \times 7}$

$h = 1.6m$

Water flow velocity with new equation:

$Q = v \times A$

$Q = v\,(b \times h)$

$5{,}5 = v\,(5 \times 1{,}6)$

$v = \frac{5{,}5}{5 \times 1{,}6}$

$v = 0.69\ m/s$

Planning for a head pond with the dimensions of a depth (h) of 1.6 m, a width of 5 m and a length of 7 m with a flow rate of 0.59 m/s.

4. Conclusion

The results and discussions regarding the availability of water for irrigation and PLTMH on the Air Nokan River in North Bengkulu can be concluded that the water discharge in the study location can meet the monthly demand for water for irrigation and for electricity generation. Based on the amount of water availability, the optimal final discharge value for power generation is 5.5 m3/second/ The generated electric power is planning for several civilian buildings for power generation is carried out based on the maximum debit and has obtained the dimensions of intake gates, calm tanks, water-carrying canals, and safe head ponds.

References

[1] Thin, KK et al (2020. February), Estimation of Run of River Hydropower Potential in the Myitnge River Basin. Journal of Disaster Research Vol. 15 No. 3. Pp267-275.

[2] Poapa, et al (2017, April), Planning for PLTMH using Irrigation Channels, Journal of Focus Electroda, Vol. 2. No.04 page 1-7.

[3] National Standardization Agency (NCA). Commissioning Guidelines for Micro Hydro Power Plants (PLTMH) with a capacity of up to 100 kW. SNI-8277-2016. Jakarta. 2016.

[4] National Standardization Agency (NCA). Classification of Hydro Power Plants. SNI-8396-2017. Jakarta. 2017.

[5] National Development Planning Agency, Directorate of Water and Irrigation. Book 2 Identification of Water Resources Management Problems in Java Island. Jakarta. 2006.

[6] Ministry of Energy and Mineral Resources, Directorate General of Electricity Utilization of Energy. Technical Guidelines for Standardization of Equipment and Components for Micro Hydro Power Plants (PLTMH). Jakarta. 2008.

[7] Ministry of Energy and Mineral Resources, Directorate General of Electricity Utilization of Energy. A Brief Guide to the Development of Micro Hydro Power Plants (PLTMH). Jakarta. 2011.

[8] Directorate General of Water Resources, Ministry of Public Works. Planning of Irrigation Network Kp-01. Jakarta. 2013.

[9] Directorate General of Water Resources, Ministry of Public Works. Planning of Kp-04 Irrigation Network. Jakarta. 2013.

[10] Mulyono, D. An Analysis of the Rainfall Characteristics in South Garut Regency. Construction Journal. 2014. 12(1), 1-9.

[11] Ningsih, DHU Thiessen Polygon Method for Forecasting Rainfall Distribution for Certain Periods in Areas Without Rainfall Data. Dynamic Journal. 2012. 17(2), 154-163.

[12] Patty, OF Hydropower. Erlangga Publisher, Jakarta. 1995.

[13] Praditya, RW Calculation of the Irrigation Water Needs in the Swamp Muara Asa Irrigation Area, West Kutai Regency, East Kalimantan Province. Student Curve. 2018. 1(1), 873-888.

[14] Center for Education and Training of Water Resources and Construction, Ministry of Public Works and Public Housing. Main Building Planning Module (Weir). Jakarta. 2016.

[15] Sahrani, N., & Hotter, R. (2018, Agus). Rainfall Analysis in Identifying the Potential of Batang Lumpo for PLTMH. UNES Journal of Scientific Research. 2018. 3(2), 119-127.

[16] Soemarto, Engineering Hydrology (in CD). National Business, Surabaya. 1987.

[17] Triatmodjo, B. Applied Hydrology. Beta Offset, Yogyakarta. 2008.

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