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Mapping of Land and Water Structures in The Wogi Irrigation District, Jayawijaya Regency

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Abstract

An irrigation area is a unit of land that receives water from a single irrigation network, consisting of the area to be irrigated and the main structure of the irrigation network. There are various types of irrigation, such as surface irrigation, swamp irrigation, and pump irrigation, which are used to support agriculture. The irrigation areas in Jayawijaya Regency are managed by local farmers, using a rudimentary irrigation system that relies on rivers and rainwater. Considering the potential of existing natural resources, the performance of Jayawijaya Regency's irrigation areas needs to be optimised to increase local rice production to meet the region's food needs and boost farmers' incomes. Geological conditions in an area are the result of changes in rocks due to plate tectonic processes. Plate tectonics is the relative movement between one plate and another. When the plates move, the distance between two locations on different plates gradually changes. Changes in the geological structure are indicated by the distribution of folds and faults around the movement of the plates. This is what happened in Jayawijaya Regency, where its position is on the Indo-Australian Plate, the Eurasian Plate, and the Pacific Plate, causing the distribution of rock types (lithology types or stratigraphic units, whether igneous, sedimentary, or metamorphic rocks) and stratigraphic relationships.

INTRODUCTION

Irrigation areas have now developed into agricultural areas for rice (Arouna et al., 2023; Mallareddy et al., 2023; Samal et al., 2022; Sikka et al., 2022). To meet food self-sufficiency and conserve water resources, as well as to support the community's economy, the Wamena Irrigation Area in the Papua Mountains Province is a potential agricultural area. However, currently, this area is not supported by an adequate irrigation system; it only consists of rain-fed rice fields and non-technical irrigation. To realize technical irrigation, detailed planning is necessary before construction begins so that the network and water supply system can be adapted to existing field conditions.

The urgency of this research is based on several factors. First, food security in Papua Mountains Province depends heavily on local rice production, yet current yields are below potential due to inadequate irrigation (Irwandhi et al., 2024; Situmorang et al., 2024). Second, climate change has increased rainfall variability, making rain-fed agriculture increasingly risky; technical irrigation provides a buffer against dry spells (Abebaw et al., 2025; Kamali et al., 2023). Third, the Indonesian government's infrastructure development program (including the Trans-Papua road and other connectivity projects) creates opportunities for irrigation development that must be planned based on accurate technical data (Jinca et al., 2022; World Bank, 2019). Fourth, without proper irrigation mapping, investment in water structures may be misdirected, resulting in inefficient water distribution, crop failure, and wasted public funds (Kamara et al., 2020; Muller et al., 2025). Fifth, local farmer groups have expressed willingness to manage technical irrigation systems, but lack the engineering support to design and implement such systems (Hirpara et al., 2024; Chandam et al., 2026).

The novelty of this research lies in four main aspects. First, this study provides the first detailed hydrological and hydraulic analysis of the Wogi Irrigation District (Silo Karno Doga network) using standardized methods (Gumbel, Log Pearson III, Nakayasu) with local rainfall data from BMKG Jayawijaya (2013-2023) (Hidayah et al., 2024; Plamonia et al., 2024). Second, this research maps the 46 sub-systems within the Silo Karno Doga network, providing detailed dimensions for primary, secondary, and tertiary channels — the first such detailed inventory for this area (Abhilash et al., 2025; Yu et al., 2025). Third, this study applies the water balance approach to compare Baliem River discharge with irrigation demand, confirming water availability for the entire 1,555.05 Ha service area (Hidayah et al., 2024; Cholik et al., 2025). Fourth, this research provides channel dimension calculations (B, h, m, n, S, Q) as a reference for future technical irrigation development, filling a critical knowledge gap for engineers working in Papua (Cholik et al., 2025; Abhilash et al., 2025; Lapo-Pauta et al., 2024).

Jayawijaya Regency is a regency in the Papua Mountains Province of Indonesia, located in the Central Highlands region. The regency capital is located in Wamena District, within the Baliem Valley. Jayawijaya Regency covers an area of 13,925 square kilometers. It is one of 43 regencies in the Papua Mountains Province. The administrative area of Jayawijaya Regency borders:

- North : Central Mamberamo Regency and Yalimo Regency
- East : Pegunungan Bintang Regency
- South : Yahukimo Regency
- West : Lanny Jaya Regency and Tolikara Regency

In 2010, Jayawijaya Regency had only 11 districts: Wamena, Asolokobal, Walelagama, Hubikosi, Pelebaga, Asologaima, Musatfak, Kurulu, Bolakme, Wollo, and Yalengga. At the end of 2020, these 11 regions expanded into 40 districts, each with 328 villages and four sub-districts. The three most recent expansions were Wesaput, Popugoba, and Wame, based on Law No. 17 of 2011.

This study aims to: (1) map the land and water structures in the Wogi Irrigation District, Jayawijaya Regency; (2) analyze rainfall data to determine design rainfall for various return periods; (3) calculate flood discharge using the Nakayasu unit hydrograph method; (4) conduct water balance analysis to compare water availability with demand; and (5) plan detailed dimensions for irrigation channels in the Silo Karno Doga network. The research objectives are: (a) to process rainfall data (maximum daily and 3-day) from BMKG Jayawijaya (2013-2023); (b) to calculate evapotranspiration using the Penman method; (c) to determine effective rainfall for paddy and secondary crops; (d) to design channel dimensions for the primary, secondary, and tertiary networks; (e) to produce irrigation network maps for the Wogi area. The contribution of this research is both technical—providing engineering data for irrigation design—and policy-oriented—supporting evidence-based infrastructure planning. The primary benefit is to enable the upgrading of the Wogi Irrigation Area from rain-fed to technical irrigation, increasing rice production, improving farmer incomes, and contributing to food security in Papua Mountains Province.

METHOD

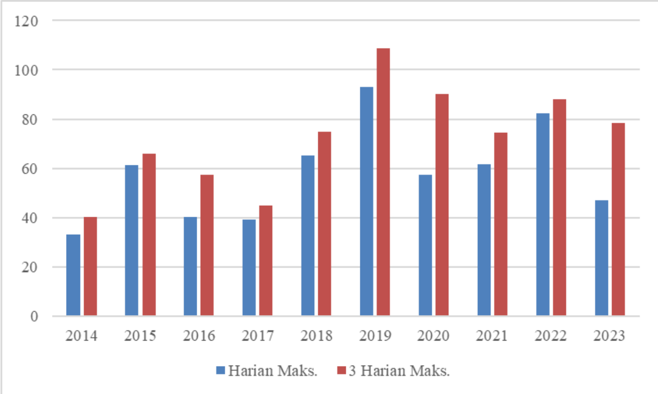
This study employed a quantitative descriptive research method, combining primary data collection (field surveys, measurements) and secondary data analysis (rainfall records, topographic maps, soil data). The research population comprised the entire Wogi Irrigation District in Jayawijaya Regency, including all water structures (dams, primary channels, secondary channels, tertiary channels, culverts, and reservoirs) and irrigated land areas. The data sample included 46 sub-systems within the Silo Karno Doga irrigation network, representing the entire service area of 1,555.05 Ha. The sampling technique was purposive (census approach), including all water structures in the study area due to the limited number and the need for comprehensive mapping. Inclusion criteria: structures currently operational or under construction; exclusion criteria: structures outside the Wogi district boundary. The research instruments included: GPS for coordinate mapping, water level gauges for discharge measurement, soil sampling kits for permeability testing, and standardized data collection forms for channel dimensions and conditions.

RESULTS AND DISCUSSIONS

Interpretation of Rainfall Data Processing

In order for rainfall data to be analyzed to produce the required hydrological quantities, the following data processing steps are carried out:

a) Completing missing rainfall data
b) Calculating the average rainfall of an area
c) Calculating semi-monthly rainfall.
d) Calculate the maximum daily and maximum three-day rainfall – annual.



CURAH HUJAN MAKSIMUM HARIAN DAN CURAH HUJAN 3-HARIAN MAKSIMUM										
Tahun	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Harian Maks.	33.2	61.1	40.3	39	65.3	93.2	57.2	61.5	82.4	47
3 Harian Maks.	40.2	65.8	57.4	44.9	75	108.7	90.3	74.6	88	78.5

Figure 1. Maximum Daily Rainfall and Maximum 3-Day Rainfall
(Source: BMKG Jayawijaya, 2024 (processed))

Water Requirements Analysis and Discharge Modulus

Water Needs Analysis

Irrigation water requirements are influenced by several factors, including: hydro-climatological conditions, topographic and geological conditions, types of plants and planting patterns, irrigation network conditions, and socio-cultural factors.

1) Climatological Data

The climatological data used in this planning is from Mattajang Station in Bulukumba Regency. Data for each climatological element—temperature, relative humidity, evaporation, solar radiation, and wind speed—has been separated and processed into monthly and semi-monthly averages. This data is then used to calculate potential evapotranspiration (ET0) .

Eto = c . ET*

ET* = w [(0.75 RS - Rnl) + (1 – w) f(u) (ea-ed)]

Where:

w = a factor related to temperature (t) and the elevation of the area. For areas in Indonesia with elevations between 0 – 500 m, the relationship between t and w can be seen in Table 5.10.

Rs = shortwave radiation in evaporation units (mm/day)
= (0.25 + 0.54 n/N) Ra

Ra = shortwave radiation that meets the outer limits of the atmosphere (Angot number) which is influenced by the latitude of the area.

Rnl = longwave net radiation (mm/day)
= f(t) . f(ed) . f (n/N)
f(t) = temperature function;
f(ed) = vapor pressure function
= 0.34 – 0.044 . √(ed)
f(n/N) = brightness function
= 0.1 + 0.9 n/N
n = actual number of hours of sunshine in 1 day (hours).
N = number of hours possible in 1 day that the sun shines (hours)
f(u) = function of wind speed at a height of 2 m in units (m/s).
= 0.27 (1 + 0.864 u)
u = wind speed (m/s)
(ea-ed) = Difference between saturated vapor pressure and actual vapor pressure
ed = ea x Rh
Rh = Relative humidity (%)
ea = Saturated vapor pressure (mbar)
ed = Actual vapor pressure (mbar)
c = Penman correction number which takes into account the difference in day and night weather conditions.

Consumptive evapotranspiration (Etc) is defined as water loss through soil and plants and can be assumed to be the plant's water requirement or plant evapotranspiration. The amount of Etc is determined as follows:

Etc = ET0 . kc

Where :

ET0 = Reference evapotranspiration
kc = Crop coefficient

Crop coefficients vary according to crop type, time, crop condition and environmental conditions especially local humidity.

Table 1. Plant Coefficient Values Based on Plant Type and Age

Plant Age (months)	Paddy				Secondary crops	
	Common varieties		Superior varieties			
	Nedeco/ Prosida	FAO	Nedeco/ Prosida	FAO	Corn	Peanuts
0.5	1.20	1.10	1.20	1.10	0.58	0.58
1.0	1.20	1.10	1.27	1.10	0.68	0.58
1.5	1.32	1.10	1.33	1.05	1.10	0.76
2.0	1.40	1.10	1.30	1.05	1.21	0.98
2.5	1.35	1.10	1.30	0.95	1.17	1.09
3.0	1.24	1.05	-	-	1.09	1.09
3.5	1.12	0.95	-	-	-	1.09
4.0	-	-	-	-	-	0.63
4.5	-	-	-	-	-	0.63

Percolation is the downward movement of water into the saturated zone within the soil. The percolation rate is influenced by several factors, including soil texture and permeability. The normal percolation rate after flooding ranges from 1–3 mm/day. In this planning, the percolation rate refers to the percolation rate used. namely 2 mm/day.

2) Effective Rainfall (Re)

Effective rainfall is the rainfall that is beneficial during land preparation and plant growth. Effective rainfall for rice plants is taken as 70% of the semi-monthly rainfall with 80%

reliability, mathematically expressed by the equation:
Where:

Re = Effective rainfall (mm/day)
R80 = ½ monthly rainfall with 80% reliability
= Rainfall with ranking (N/5 + 1)

Meanwhile, effective rainfall for secondary crops is taken from Table A.27 KP-01 based on monthly rainfall, monthly plant water requirements and monthly evapotranspiration.

3) Irrigation Efficiency

In this design, water loss is planned as follows:

a. Tertiary channel = 20%, so efficiency = 80%
b. Secondary Channel = 10%, so efficiency = 90%
c. Primary Channel = 10%, so efficiency = 90%

The overall efficiency is calculated as follows: Tertiary network efficiency x Secondary network efficiency x Primary network efficiency, so the overall irrigation efficiency is = 65%.

Dissipation Modulus

The drain module in the irrigation network is analyzed from the maximum 3-day rainfall data as shown in the figure above.

The dissipation modulus is analyzed using the following equation:

Dm = (l/dt.Ha)

Where: D(n)= R(n)T + n(IR – ET – P – □S)
n= Number of consecutive days
D(n) = Surface water flow n days (mm)
R(n)T = Rainfall in n consecutive days with return period T
IR= Irrigation water supply (mm/day)
ET0 = Evapotranspiration (mm/day)
P= Percolation (mm/day)
ΔS = Additional inundation (mm)

In this planning, the R(n)T calculation is based on 3 (three) daily rainfall with a 5-year return period and frequency analysis is carried out using the Gumbel method and the Log Pearson Type III method.

1) Gumbel Method

The Gumbel method is based on the type 1 extreme value distribution proposed by Fisher and Tippett (1928). The probability distribution (P) is expressed by the equation:

$$p = 1 - e^{-e^{-y}} \quad (3.1)$$

or

$$y = -In\,[-In\,(1-p)] \quad (3.2)$$

Where:

p is the probability of equal or greater rainfall or flow and y is the probability distribution function. If this method is used to predict rainfall (or discharge) from n data sets with a return period T, then the equation is:

$$\overline{X}T = X + (0.7797\ y - 0.45)\sigma x \quad (3.3)$$

or

$$\overline{X}T = X + KT\ \sigma x \quad (3.4)$$

Where:

$\overline{X}T$ = Rainfall (or discharge) with a return period of T years
X = Average rainfall (or discharge) from n number of data

$$X = \frac{1}{n}\sum_{i=1}^{n} Xi \qquad i = 1, 2, \ldots, n \quad (3.5)$$

n = Number of years of data

σ_x = Standard deviation

$$x = \frac{\sqrt{(Xi - X)^2}}{n} - 1 \qquad (3.6)$$

Or

$$Sx = \frac{\sqrt{\sum \; Xi^2 - n \, . \, X^2}}{n-1} \qquad (3.7)$$

K_T = Frequency factor, its value depends on the recurrence period T and the amount of data n. For practical use, KT can be calculated using the equation:

$$K_T = \frac{Y_T - Y_n}{S_n} \qquad (3.8)$$

Where:

YT = Reduction that depends on the return period T

Yn = Reduction of the average value, depending on the number of data n

Sn = Standard deviation reduction, depending on the number of data n

The values of YT, Yn and Sn are shown sequentially in Tables 6 to 7.

Table 2. Y_T Values for Several Return Periods

Return Period, *T* (years)	Y_T
2	0.3665
5	1.4999
10	2.2502
20	2.9702
25	3.1985
50	3,9019
100	4.6001
200	5.2958

Table 3. Reduction of mean value, Y_n

n	Y_n values									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
10	0.4952	0.4996	0.5035	0.5070	0.5100	0.5125	0.5157	0.5181	0.5202	0.5220
20	0.5236	0.5252	0.5268	0.5283	0.5296	0.5309	0.5320	0.5332	0.5343	0.5353
30	0.5362	0.5371	0.5380	0.5388	0.5396	0.5402	0.5410	0.5418	0.5424	0.5430
40	0.5436	0.5442	0.5448	0.5453	0.5458	0.5463	0.5468	0.5473	0.5477	0.5481
50	0.5485	0.5489	0.5493	0.5497	0.5501	0.5504	0.5508	0.5511	0.5515	0.5518
60	0.5521	0.5524	0.5527	0.5530	0.5533	0.5535	0.5538	0.5540	0.5543	0.5545
70	0.5548	0.5550	0.5552	0.5555	0.5557	0.5559	0.5561	0.5563	0.5565	0.5567
80	0.5568	0.5570	0.5572	0.5574	0.5576	0.5578	0.5580	0.5581	0.5583	0.5585
90	0.5586	0.5587	0.5589	0.5591	0.5592	0.5593	0.5595	0.5596	0.5598	0.5599
100	0.5600									

Table 4. Standard Deviation Reduction, Sn

n	S_n values									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
10	0.9436	0.9697	0.9833	0.9971	1.0095	1.0206	1.0316	1.0411	1.0493	1.0563
20	1.0628	1.0696	1.0754	1.0811	1.0864	1.0915	1.0961	1.1004	1.1047	1.1086
30	1.1124	1.1159	1.1193	1.1226	1.1255	1.1285	1.1313	1.1339	1.1363	1.1388
40	1.1413	1.1436	1.1458	1.1480	1.1499	1.1519	1.1538	1.1557	1.1574	1.1590
50	1.1607	1.1623	1.1638	1.1653	1.1667	1.1681	1.1695	1.1708	1.1721	1.1733
60	1.1747	1.1759	1.1770	1.1782	1.1793	1.1803	1.1814	1.1824	1.1834	1.1844
70	1.1854	1.1863	1.1873	1.1881	1.1890	1.1898	1.1907	1.1915	1.1923	1.1930
80	1.1938	1.1945	1.1953	1.1960	1.1967	1.1973	1.1980	1.1987	1.1994	1.2001
90	1.2007	1.2013	1.2020	1.2026	1.2032	1.2038	1.2044	1.2049	1.2055	1.2060
100	1.2065									

2) Log Pearson Type-III Method

The Log Pearson Type III method is based on the Log Pearson Type III distribution. The equation used is:

$\text{Log } X_T = \log X + K_T S_{\log x}$ (3.9)

$\log X = \frac{1}{n}\sum_{i=1}^{n} Log\ Xii = i = 1, 2, . . ., n$ (3.10)

Where:

KT = Frequency factor, the values of which are shown in Table 5.9 for the corresponding values of G and return period T;

G = *Skewness* coefficient , calculated from the equation

$$G = \frac{n\sum\left(\log X_i - \overline{\log X}\right)^3}{(n-1)(n-2)\left(\sigma_{\log X}\right)^3}$$ (3.12)

Table 5. K Values for the Type III Log Pearson Distribution

Coefficient Skewness *G*	Return Period, *T* (years)					
	2	**5**	**10**	**25**	**50**	**100**
	Opportunity (%)					
	50	20	10	4	2	1
3.0	-0.396	0.420	1,180	2,278	3,152	4,051
2.8	-0.384	0.460	1,210	2,275	3.114	3,973
2.6	-0.368	0.499	1,238	2,267	3,071	3,889
2.4	-0.351	0.537	1,262	2,256	3,023	3,800
2.2	-0.330	0.574	1,284	2,240	2,970	3,705
2.0	-0.307	0.609	1,302	2,219	2,912	3,605
1.8	-0.282	0.643	1,318	2,193	2,848	3,499
1.6	-0.254	0.675	1,329	2,163	2,780	3,388
1.4	-0.225	0.705	1,337	2.128	2,706	3,271
1.2	-0.195	0.732	1,340	2,087	2,626	3,149
1.0	-0.164	0.758	1,340	2,043	2,542	3,022
0.9	-0.148	0.769	1,339	2,018	2,498	2,957
0.8	-0.132	0.780	1,336	1,993	2,453	2,891
0.7	-0.116	0.790	1,333	1,967	2,407	2,824
0.6	-0.099	0.800	1,328	1,939	2,359	2,755
0.5	-0.083	0.808	1,323	1,910	2,311	2,686
0.4	-0.066	0.816	1,317	1,880	2,261	2,615
0.3	-0.050	0.824	1,309	1,849	2,211	2,544
0.2	-0.033	0.830	1,301	1,818	2,159	2,472
0.1	-0.017	0.836	1,292	1,785	2.107	2,400
0.0	0.000	0.842	1,282	1,751	2,054	2,326

Table 6. Calculation of Mean Value and Standard Deviation

No.	Xi	Xi-Xm	(Xi-Xm) ^{2}
1	54.4	-3.3	10.83
2	33.2	-24.5	599.80
3	61.1	3.4	11.62
4	40.3	-17.4	302.44
5	39.0	-18.7	349.35
6	65.3	7.6	57.90
7	93.2	35.5	1260.90
8	57.2	-0.5	0.24
9	61.5	3.8	14.51
10	82.4	24.7	610.54
11	47.0	-10.7	114.30
Amount	634.6		3332.4

No.	Xi	Xi-Xm	$(Xi\text{-}Xm)^2$
Average (Xm)	57.7		
Standard Deviation (Sx)	18.25494		

For n = 11, from the respective Tables it is obtained

Yn = 0.4996 and Sn = 0.9697; and for T = 5 years, YT = 1.4999.

$$K_T = \frac{Y_T - Y_n}{S_n} = \frac{1{,}4999 - 0{,}4996}{0{,}9697} = 1{,}03156$$

$X_T = \bar{X} + K_T \times S_x = 57{,}7 + 1{,}03156 \times 18{,}25494 = 76{,}531\ mm$ or R(n)T = 76.531 mm

Table 7. Calculation of Statistical Parameters Using the Type III Log Pearson Method

No	Year	Rain Data	LogXi	(LogXi - LogX')²	(LogXi - LogX')³
1	2013	54.4	1,736	0.000036	-0.0000002
2	2014	33.2	1,521	0.048610	-0.0107175
3	2015	61.1	1,786	0.001974	0.0000877
4	2016	40.3	1,605	0.018581	-0.0025327
5	2017	39.0	1,591	0.022666	-0.0034123
6	2018	65.3	1,815	0.005373	0.0003938
7	2019	93.2	1,969	0.051893	0.0118212
8	2020	57.2	1,757	0.000249	0.0000039
9	2021	61.5	1,789	0.002233	0.0001056
10	2022	82.4	1,916	0.030384	0.0052964
11	2023	47.0	1,672	0.004833	-0.0003360
Amount (€)		634.6	19,158	0.187	0.001
Average (X')		57,691	1,742	0.017	0.000

Design Rainfall

The process of processing rainfall data starts from processing centralized rainfall data into regional average rainfall and then from the regional average daily rainfall data, the maximum daily rainfall is determined which will be used to analyze the design rainfall.

Using the maximum daily rainfall, a frequency analysis will be conducted to determine the design rainfall for a specific return period. The methods used are the Extreme Value method (Gumbel method) and the Log Pearson Type III method.

Gumbel Method

The Gumbel method is based on the type 1 extreme value distribution proposed by *Fisher* and *Tippett* (1928). The probability distribution (P) is expressed by the equation:

$$p = 1 - e^{-e^{-y}}$$

Or

$$y = -\ln[-\ln(1-p)]$$

Where p is the probability of equal or greater rainfall or flow and y is the probability distribution function.

If this method is used to predict rainfall (or discharge) from n amounts of data with a return period T, then the equation is:

$$X_T = \overline{X} + (0.7797y - 0.45)\sigma_x$$

Or

$$X_T = \overline{X} + K \times Sx$$

Where:

XT = Rainfall (or discharge) with a return period of T years

= Average rainfall (or discharge) from n number of data

$$\overline{X} = \frac{1}{n}\sum_{i=1}^{n} X_i \qquad i = 1, 2, \ldots, n$$

n = Number of years of data

σ_x = Standard deviation

$$S_x = \sqrt{\frac{(x_i - \overline{x})^2}{n-1}}$$

Or

$$S_x = \sqrt{\frac{\sum X_i^2 - n \cdot \overline{X}^2}{n-1}}$$

k = Frequency factor, its value depends on the recurrence period T and the amount of data n. For practical use, KT can be calculated using the equation:

$$K_T = \frac{Y_T - Y_n}{S_n} \qquad (3.13)$$

Where:

YT = Reduction that depends on the return period T

Yn = Reduction of the average value, depending on the number of data n

Sn = Standard deviation reduction, depending on the number of data n

Table 8. Calculation of Probable Rainfall Using the Gumbel Method

No	Year	Rmax (mm)	(X' - X)	(X' - X)²	(X' - X)³
1	2012	54.40	-3,291	10,830	-35,641
2	2013	33.20	-24,491	599,805	-14689.761
3	2014	61.10	3,409	11,622	39,620
4	2015	40.30	-17,391	302,444	-5259.771
5	2016	39.00	-18,691	349,350	-6529.671
6	2017	65.30	7,609	57,898	440,553
7	2018	93.20	35,509	1260,896	44773.254
8	2019	57.20	-0.491	0.241	-0.118
9	2020	61.50	3,809	14,509	55,267
10	2021	82.40	24,709	610,539	15085.868
11	2022	47.00	-10,691	114,296	-1221.923
Amount		635	0.000	3332.429	32657.677
Average		57,691	0.000	302,948	2968,880
Standard Deviation				18,255	
CV				0.316426666	
Cs				0.656136345	
Tsk				0.047702428	

Table 9. Results of Calculation of Possible Rainfall in a Certain Period Using the Gumbel Method

T	X_T
2	71.9710
5	97.9957
10	115.2284
25	136.9983
50	153.1495
100	169.1813

Log Pearson Type III Method

The Log Pearson Type III method in the Log Pearson Type III distribution, uses the following equation:

$$\log X_T = \overline{\log X} + K_T S_{\log x}$$

$$\overline{\log X} = \frac{1}{n}\sum_{i=1}^{n} \log X_i \qquad i = 1, 2, \ldots, n$$

$$S_{\log x} = \sqrt{\frac{\sum\left(\log X_i - \overline{\log X}\right)^2}{n-1}}$$

KT = frequency factor, the value of which is shown in the Table for the corresponding values of G and return period T;
G = skewness coefficient, calculated from the equation:

$$G = \frac{n\sum\left(\log X_i - \overline{\log X}\right)^3}{(n-1)(n-2)\left(\sigma_{\log X}\right)^3}$$

Table 10 Calculation of Statistical Parameters of the Log Pearson Type III Method

No	Year	Pmax (mm)	lnx	(lnX - lnX')²	(lnX - lnX')³
1	2013	54.4	3,996	0.000	0.000
2	2014	33.2	3,503	0.258	-0.131
3	2015	61.1	4.113	0.010	0.001
4	2016	40.3	3,696	0.099	-0.031
5	2017	39.0	3,664	0.120	-0.042
6	2018	65.3	4,179	0.028	0.005
7	2019	93.2	4,535	0.275	0.144
8	2020	57.2	4,047	0.001	0.000
9	2021	61.5	4,119	0.012	0.001
10	2022	82.4	4,412	0.161	0.065
11	2023	47.0	3,850	0.026	-0.004
Amount		635	44,112	0.991	0.009
Average		57,691	4,010	0.090	0.001
Standard Deviation			0.102		
Csy			0.034		

Table 11. Results of Design Rainfall Calculations Using the Log Pearson Type III Method

T	X_T
2	55,192
5	60,110
10	62,914
25	66,062
50	68,188
100	70,164

Table 12. Results of Rainfall Calculations in Certain Periods Using the Gumbel Method and the Type III Log Pearson Method

Return Period	Gumbel method (mm/day)	Pearson III Log Method (mm/day)
2	54,691	55,192
5	70,831	60,110
10	81,518	62,914
25	95,020	66,062
50	105,037	68,188
100	114,980	70,164

Furthermore, the results of the planned rainfall calculations used/selected are the planned rainfall results from the Gumbel method calculations.

Nakayasu Unit Hydrograph

The results of calculations using the above methods can then be compared with the results of calculations using the Unit Hydrograph method. In this study, the Nakayasu Method was used.

The Nakayasu method is based on the unit hydrograph theory and uses effective rainfall (the portion of total rainfall that produces direct runoff). The parameters influencing flood analysis using the Nakayasu method are:

1) Rainfall Intensity

To analyze rainfall intensity, Dr. Mononobe's formula is used, namely:

$Rt = R_{24} / 24 \cdot (24/T)^{2/3}$

Where:

Rt = Average rainfall from the beginning to hour T (mm/hour)

T = Rain time from the beginning to hour T (hours)

R24 = Maximum rainfall in 24 hours (mm/hour)

RT= T . Rt – (T – 1) . (R(T – 1)

Where:

RT = Rainfall intensity at hour T (mm/hour)

R(T-1) = Average rainfall from the beginning until hour (T – 1)

2) Effective Rain

Re = f . RT

Where:

R = Effective rainfall

f = River flow coefficient

RT = Rainfall intensity (mm/hour)

3) Unit Hydrograph (uH)

The Nakayasu unit hydrograph ordinate is calculated as follows:

Hydrograph peak ordinate: $q_p = \frac{AR_0}{3{,}6\left(0{,}3T_p + T_{0,3}\right)}$

with A = Area of rain-fed area (catchment area)

R0 = Unit rainfall (= 1 mm)

Tp = Time from the start of rain until peak discharge occurs (lag time); hours.

T0.3 = Time from the peak discharge until the discharge reaches 30% (= 0.3) of the peak discharge

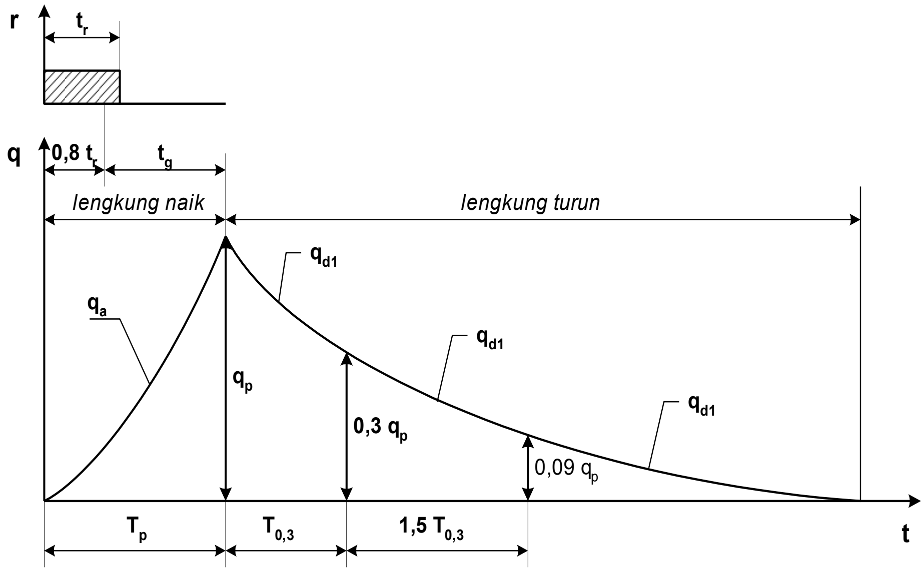


Figure 3. Nakayasu Synthetic Unit Hydrograph

Lag time Tp is calculated using the equation: $T_p = 0{,}8t_r + tg$

with tr = effective rainfall duration (taken from 0.5 tg to tg)

tg = time of concentration, depending on the length of the main river;

Calculated as follows:

If L ≤ 15 km, then $t_g = 0{,}21L^{0{,}7}$

If L > 15 km, then ; $t_g = 0{,}4 + 0{,}058L$

L in km and tg in hours.

T0.3 is calculated using the equation: $T_{0,3} = \alpha \cdot t_g$

With

α = 2.0 for normal drainage areas,

α = 1.5 for drainage areas where the hydrograph's rising curve is slower and the descending curve is faster.

α = 3.0 for drainage areas where the hydrograph's rising curve is faster and the descending curve is slower.

Ordinate on an ascending curve (t < Tp): $q_a = q_p \times \left(\frac{t}{T_p} \right)^{2,4}$

Coordinate on a descending curve (t > Tp):

for $T_p < t < T_{0.3}$: $q_{d1} = q_p \times 0{,}3^{(t-T_p)/T_{0,3}}$

for $T_{0.3} < t < 2.5\ T_{0.3}$: $q_{d2} = q_p \times 0{,}3^{(t-T_p+0{,}5T_{0,3})/(1{,}5T_{0,3})}$

for $t > 2.5\ T_{0.3}$: $q_{d2} = q_p \times 0{,}3^{(t-T_p+1{,}5T_{0,3})/(2T_{0,3})}$

Flood discharge due to rain intensity of 1 mm/hour, calculated using the equation: $Q(t,I) = q(t,1) \times I$

For rain with a duration of more than 1 hour, with respective intensities of I1, I2, I3, . . ., In; the total discharge is calculated using the superposition method as follows:

$Q(t) = q(t,1) \times I_1 + q(t-1,1) \times I_2 + q(t-2,1) \times I_3 + \cdots + q(t-(n-1),1) \times I_n$

The results of flood discharge calculations using the Nakayasu unit hydrograph method for the Wamena dam location are shown in Table 13 and Figure 4.

Table 13. Results of Flood Discharge Calculations Using the Nakayasu Unit Hydrograph Method

No	Return Period (Year)	Method HSS Nakayasu (m^3/sec)
1	2	860,343
2	5	937,018
3	10	980,722
4	25	1029,801
5	50	1062,937
6	100	1093,739

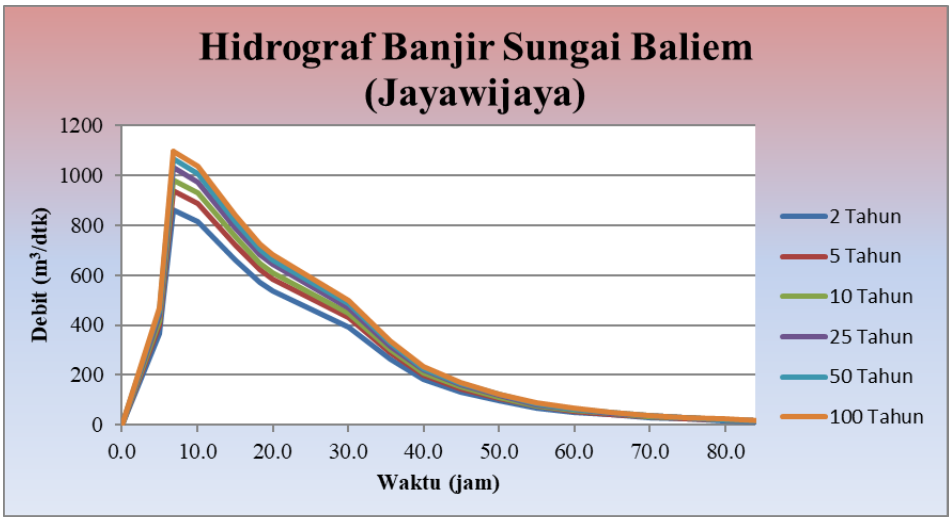


Figure 4. Flood Hydrograph for Baliem River

Water Balance Analysis (Water Balance)

Analysis Approach

The water balance analysis in this study aims to compare water availability in the Baliem River with water demand in the Silo Karno Doga Irrigation Network. A water availability analysis has been conducted. The result is a monthly annual discharge with a reliability of 80% with the Silo Karno Doga network (1555.06 Ha) . Figure 5 below shows the Silo Karno Doga Irrigation Network scheme.

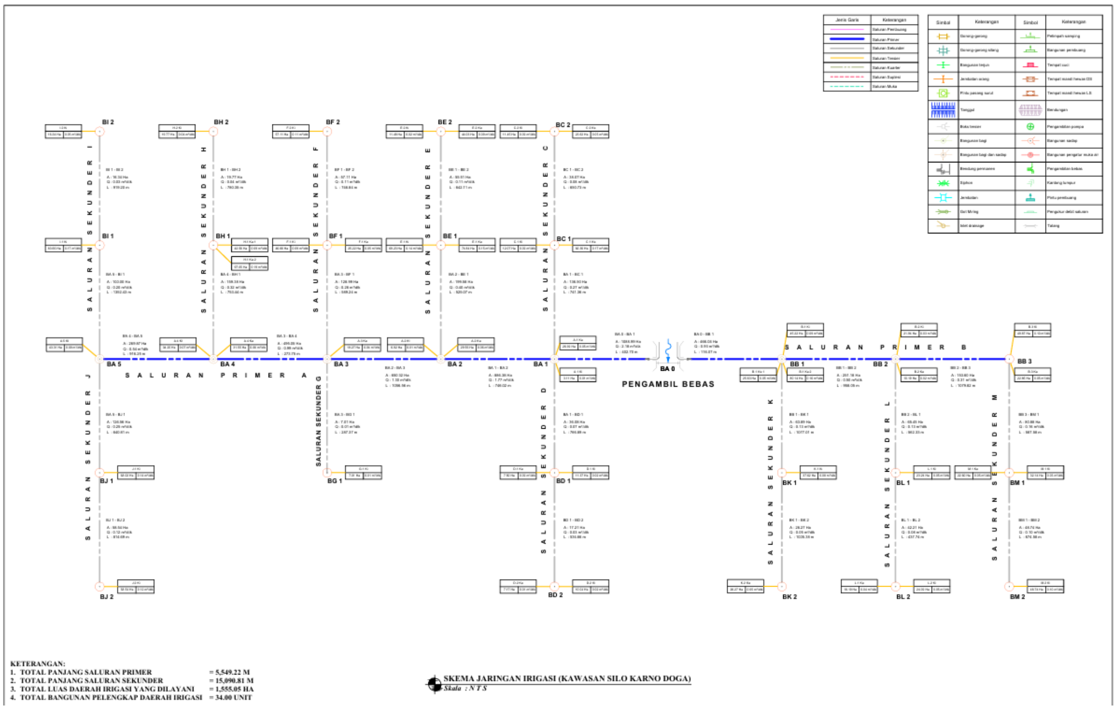


Figure 5. Silo Karno Doga Irrigation Network Scheme

The Wamena Irrigation Network System can be divided into 46 sub-systems, namely:

1. Subsystem 1: Silo Karno Doga Irrigation Network.
   - Irrigation area : 26.92 Ha
   - Water source : Free intake
   - Tapping (A.1 Ka) : Silo Karno Doga Dam
2. Subsystem 2: Silo Karno Doga Irrigation Network.
   - Irrigation area : 3.11 Ha
   - Water source : Free intake
   - Tapping (A.1 Ki) : Silo Karno Doga Dam
3. Subsystem 3: Silo Karno Doga Irrigation Network.
   - Irrigation area : 29.56 Ha
   - Water source : Free intake
   - Tapping (A.2 Ka) : Silo Karno Doga Dam
4. Subsystem 4: Silo Karno Doga Irrigation Network.
   - Irrigation area : 6.29 Ha
   - Water source : Free intake
   - Tapping (A.2 Ki) : Silo Karno Doga Dam
5. Subsystem 5: Silo Karno Doga Irrigation Network.
   - Irrigation area : 19.27 Ha
   - Water source : Free intake
   - Tapping (A.3 Ka) : Silo Karno Doga Dam
6. Subsystem 6: Silo Karno Doga Irrigation Network.
   - Irrigation area : 31.55 Ha
   - Water source : Free intake
   - Tapping (A.4 Ka) : Silo Karno Doga Dam
7. Subsystem 7: Silo Karno Doga Irrigation Network.
   - Irrigation area : 34.25 Ha

- Water source : Free intake
- Tapping (A.4 Ki) : Silo Karno Doga Dam

8. Subsystem 8: Silo Karno Doga Irrigation Network.
   - Irrigation area : 43.31 Ha
   - Water source : Free intake
   - Tapping (A.5 Ki) : Silo Karno Doga Dam
9. Subsystem 9: Silo Karno Doga Irrigation Network.
   - Irrigation area : 25.63 Ha
   - Water source : Free intake
   - Tapping (B.1 Ka 1) : Silo Karno Doga Dam
10. Subsystem 10: Silo Karno Doga Irrigation Network.
    - Irrigation area : 34.25 Ha
    - Water source : Free intake
    - Tapping (B.1 Ka 2) : Silo Karno Doga Dam
11. Subsystem 11: Silo Karno Doga Irrigation Network.
    - Irrigation area : 45.22 Ha
    - Water source : Free intake
    - Tapping (B.1 Ki) : Silo Karno Doga Dam
12. Subsystem 12: Silo Karno Doga Irrigation Network.
    - Irrigation area : 10.19 Ha
    - Water source : Free intake
    - Tapping (B.2 Ka) : Silo Karno Doga Dam
13. Subsystem 13: Silo Karno Doga Irrigation Network.
    - Irrigation area : 24.94 Ha
    - Water source : Free intake
    - Tapping (B.2 Ki) : Silo Karno Doga Dam
14. Subsystem 14: Silo Karno Doga Irrigation Network.
    - Irrigation area : 22.85 Ha
    - Water source : Free intake
    - Tapping (B.3 Ka) : Silo Karno Doga Dam
15. Subsystem 15: Silo Karno Doga Irrigation Network.
    - Irrigation area : 49.87 Ha
    - Water source : Free intake
    - Tapping (B.3 Ki) : Silo Karno Doga Dam

Detailed Planning of Irrigation Channels

1) Channel Dimensions

Table 14. Planning of Water Structures on Main Channels in the Silo Karno Doga Irrigation Area

REKAP DIMENSI BANGUNAN GORONG - GORONG								
No.	Uraian	Kode Skema	Dimensi					
			Tubuh Gorong - Gorong			Saluran Primer/Sekunder		
			Lebar	Panjang	Tinggi	Lebar Atas	Lebar Bawah	Tinggi
			(B)	(L)	(H2)	(BSP_{Atas})	(BSP_{Bawah})	(H)
			M^1	M^1	M^1	M^1	M^1	M^1
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1.	**Kawasan Silo Karno Doga**							
a.	Saluran Kiri	BB 3a	1.50	7.00	1.50	3.10	1.10	1.20
		BB 3b	1.50	7.00	1.50	3.10	1.10	1.20
b.	Saluran Kanan	BC 1a	1.50	6.00	1.50	2.20	1.20	1.10
		BE 1a	1.50	6.00	1.50	2.30	1.30	1.30
		BA 3a	2.00	6.00	2.00	3.90	1.90	1.80

Table 15. Summary of Dimensional Planning in the Silo Karno Doga Irrigation Area

Nama Kawasan : Silo Karno Doga
Nama Saluran : Saluran Primer A

No.	Segmen Saluran	Luas Lahan (Ha)	Q (m^3/dtk)	L (m)	h (m)	B (m)	A (m^2)	P (m)	R (m)	V (m/dtk)	W (m)	H (m)	$Q_{kontrol}$ (m^3/dtk)
1.	BA 0 - BA 1	1,088.99	2.178	402.70	1.463	2.194	3.349	6.331	0.845	0.407	0.500	1.963	2.178
2.	BA 1 - BA 2	886.38	1.773	746.02	1.354	2.031	4.384	5.861	0.782	0.387	0.500	1.854	1.773
3.	BA 2 - BA 3	650.32	1.301	1,056.56	1.206	1.808	3.634	5.218	0.696	0.358	0.500	1.706	1.301
4.	BA 3 - BA 4	495.05	0.990	273.75	1.088	1.633	2.961	4.711	0.629	0.334	0.500	1.588	0.990
5.	BA 4 - BA 5	269.87	0.540	916.25	0.867	1.300	1.879	3.752	0.501	0.287	0.500	1.367	0.540

Nama Kawasan : Silo Karno Doga
Nama Saluran : Saluran Primer B

No.	Segmen Saluran	Luas Lahan (Ha)	Q (m^3/dtk)	L (m)	h (m)	B (m)	A (m^2)	P (m)	R (m)	V (m/dtk)	W (m)	H (m)	$Q_{kontrol}$ (m^3/dtk)
1.	BA 0 - BB 1	466.06	0.932	116.07	1.064	1.596	2.830	4.605	0.615	0.329	0.500	1.564	0.932
2.	BB 1 - BB 2	251.18	0.502	958.05	0.844	1.266	1.780	3.653	0.487	0.282	0.500	1.344	0.502
3.	BB 2 - BB 3	153.60	0.307	1,079.82	0.702	1.053	1.231	3.037	0.405	0.250	0.400	1.102	0.307

Nama Kawasan : Silo Karno Doga
Nama Saluran : Saluran Sekunder C

No.	Segmen Saluran	Luas Lahan (Ha)	Q (m^3/dtk)	L (m)	h (m)	B (m)	A (m^2)	P (m)	R (m)	V (m/dtk)	W (m)	H (m)	$Q_{kontrol}$ (m^3/dtk)
1.	BA 1 - BC 1	136.50	0.273	741.36	0.744	1.116	1.107	2.779	0.398	0.247	0.300	1.044	0.273
2.	BC 1 - BC 2	38.07	0.076	650.73	0.461	0.691	0.425	1.722	0.247	0.179	0.300	0.761	0.076

Nama Kawasan : Silo Karno Doga
Nama Saluran : Saluran Sekunder D

No.	Segmen Saluran	Luas Lahan (Ha)	Q (m^3/dtk)	L (m)	h (m)	B (m)	A (m^2)	P (m)	R (m)	V (m/dtk)	W (m)	H (m)	$Q_{kontrol}$ (m^3/dtk)
1.	BA 1 - BD 1	36.08	0.072	766.89	0.452	0.678	0.408	1.688	0.242	0.177	0.300	0.752	0.072
2.	BD 1 - BD 2	17.21	0.034	534.66	0.342	0.513	0.234	1.278	0.183	0.147	0.300	0.642	0.034

Nama Kawasan : Silo Karno Doga
Nama Saluran : Saluran Sekunder E

No.	Segmen Saluran	Luas Lahan (Ha)	Q (m^3/dtk)	L (m)	h (m)	B (m)	A (m^2)	P (m)	R (m)	V (m/dtk)	W (m)	H (m)	$Q_{kontrol}$ (m^3/dtk)
1.	BA 2 - BE 1	199.58	0.399	525.07	0.858	1.287	1.472	3.205	0.459	0.271	0.400	1.258	0.399
2.	BE 1 - BE 2	55.51	0.111	642.11	0.531	0.796	0.564	1.983	0.284	0.197	0.300	0.831	0.111

Nama Kawasan : Silo Karno Doga
Nama Saluran : Saluran Sekunder F

No.	Segmen Saluran	Luas Lahan (Ha)	Q (m^3/dtk)	L (m)	h (m)	B (m)	A (m^2)	P (m)	R (m)	V (m/dtk)	W (m)	H (m)	$Q_{kontrol}$ (m^3/dtk)
1.	BA 3 - BF 1	128.99	0.258	589.24	0.728	1.092	1.061	2.721	0.390	0.243	0.300	1.028	0.258
2.	BF 1 - BF 2	57.11	0.114	746.84	0.537	0.805	0.576	2.005	0.287	0.198	0.300	0.837	0.114

Nama Kawasan : Silo Karno Doga
Nama Saluran : Saluran Sekunder G

No.	Segmen Saluran	Luas Lahan (Ha)	Q (m^3/dtk)	L (m)	h (m)	B (m)	A (m^2)	P (m)	R (m)	V (m/dtk)	W (m)	H (m)	$Q_{kontrol}$ (m^3/dtk)
1.	BA 3 - BG 1	7.01	0.014	287.37	0.244	0.367	0.119	0.913	0.131	0.117	0.300	0.544	0.014

Nama Kawasan : Silo Karno Doga
Nama Saluran : Saluran Sekunder H

No.	Segmen Saluran	Luas Lahan (Ha)	Q (m^3/dtk)	L (m)	h (m)	B (m)	A (m^2)	P (m)	R (m)	V (m/dtk)	W (m)	H (m)	$Q_{kontrol}$ (m^3/dtk)
1.	BA 4 - BH 1	159.58	0.319	753.44	0.788	1.183	1.243	2.946	0.422	0.256	0.400	1.188	0.319
2.	BH 1 - BH 2	19.77	0.040	780.35	0.360	0.541	0.260	1.347	0.193	0.152	0.300	0.660	0.040

Nama Kawasan : Silo Karno Doga
Nama Saluran : Saluran Sekunder I

No.	Segmen Saluran	Luas Lahan (Ha)	Q (m^3/dtk)	L (m)	h (m)	B (m)	A (m^2)	P (m)	R (m)	V (m/dtk)	W (m)	H (m)	$Q_{kontrol}$ (m^3/dtk)
1.	BA 5 - BI 1	100.00	0.200	1,352.43	0.662	0.993	0.877	2.473	0.354	0.228	0.300	0.962	0.200
2.	BI 1 - BI 2	16.34	0.033	919.20	0.336	0.503	0.225	1.254	0.180	0.145	0.300	0.636	0.033

Nama Kawasan : Silo Karno Doga
Nama Saluran : Saluran Sekunder J

No.	Segmen Saluran	Luas Lahan (Ha)	Q (m^3/dtk)	L (m)	h (m)	B (m)	A (m^2)	P (m)	R (m)	V (m/dtk)	W (m)	H (m)	$Q_{kontrol}$ (m^3/dtk)
1.	BA 5 - BJ 1	126.56	0.253	640.81	0.723	1.085	1.046	2.702	0.387	0.242	0.300	1.023	0.253
2.	BJ 1 - BJ 2	58.54	0.117	814.69	0.542	0.812	0.587	2.023	0.290	0.200	0.300	0.842	0.117

Nama Kawasan : Silo Karno Doga
Nama Saluran : Saluran Sekunder K

No.	Segmen Saluran	Luas Lahan (Ha)	Q (m^3/dtk)	L (m)	h (m)	B (m)	A (m^2)	P (m)	R (m)	V (m/dtk)	W (m)	H (m)	$Q_{kontrol}$ (m^3/dtk)
1.	BB 1 - BK 1	63.89	0.128	1,077.01	0.560	0.839	0.626	2.091	0.300	0.204	0.300	0.860	0.128
2.	BK 1 - BK 2	26.27	0.053	1,005.38	0.401	0.602	0.322	1.498	0.215	0.163	0.300	0.701	0.053

Nama Kawasan : Silo Karno Doga
Nama Saluran : Saluran Sekunder L

No.	Segmen Saluran	Luas Lahan (Ha)	Q (m^3/dtk)	L (m)	h (m)	B (m)	A (m^2)	P (m)	R (m)	V (m/dtk)	W (m)	H (m)	$Q_{kontrol}$ (m^3/dtk)
1.	BB 2 - BL 1	65.45	0.131	562.33	0.565	0.847	0.638	2.110	0.302	0.205	0.300	0.865	0.131
2.	BL 1 - BL 2	42.21	0.084	437.74	0.479	0.719	0.459	1.790	0.256	0.184	0.300	0.779	0.084

Nama Kawasan : Silo Karno Doga
Nama Saluran : Saluran Sekunder M

No.	Segmen Saluran	Luas Lahan (Ha)	Q (m^3/dtk)	L (m)	h (m)	B (m)	A (m^2)	P (m)	R (m)	V (m/dtk)	W (m)	H (m)	$Q_{kontrol}$ (m^3/dtk)
1.	BB 3 - BM 1	80.88	0.162	587.58	0.611	0.917	0.748	2.284	0.327	0.216	0.300	0.911	0.162
2.	BM 1 - BM 2	48.74	0.097	674.58	0.506	0.758	0.511	1.889	0.271	0.191	0.300	0.806	0.097

Dimensions of the Primary Channel of Silo Karno Doga

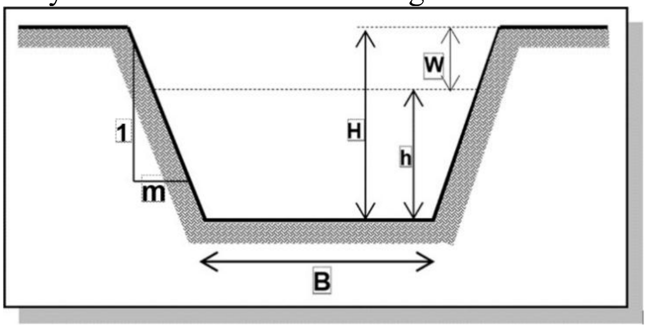


Figure 6. Irrigation Channel

Provision:

1. S = 0.00006
2. n = 0.017
3. m = 1,000
4. B = 1,500
5. A = 2,500
6. P = 4.328
7. R = 0.578
8. Q = 0.790

Information:

Q = Planned Discharge (m3/sec)
L = Channel Length (m)
S = Channel Base Slope
m = Comparison of Internal Angles of the Channel
n = Channel Wall Roughness Coefficient Value
h = Water Height in the Channel

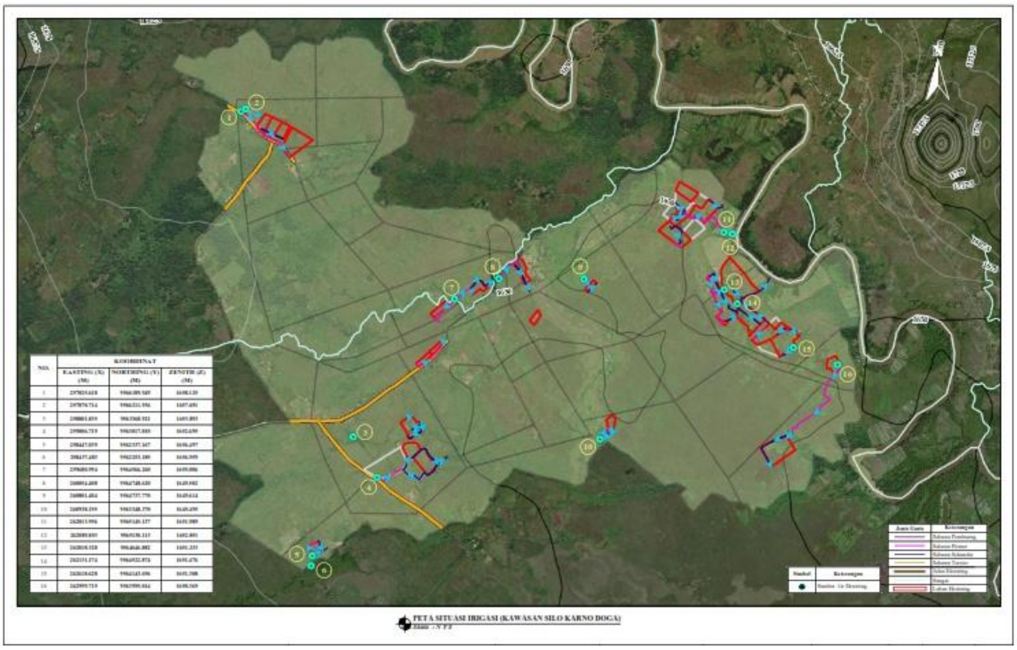


Figure 7. Irrigation Situation Map in the Silo Karno Doga Area

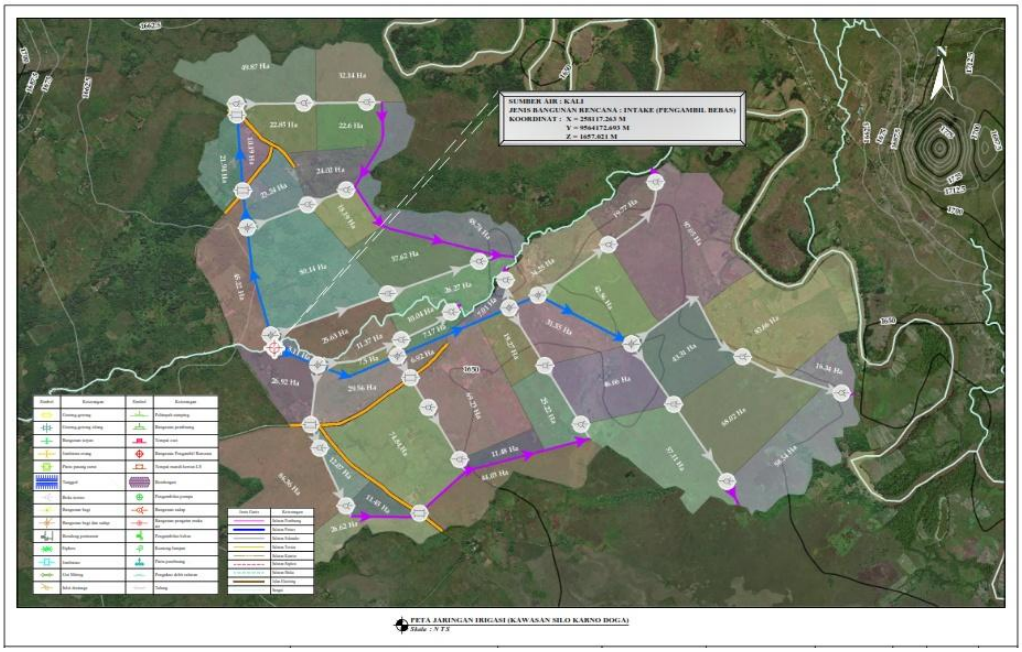


Figure 8. Irrigation Network Map in the Silo Karno Doga Area

CONCLUSION

From the results of the author's analysis of Land Mapping and Water Structures in the Wogi Irrigation Area, Jayawijaya Regency, regarding central government policies as below. 1) Despite having great agricultural potential, it currently relies solely on rain-fed systems and non-technical irrigation, which are vulnerable to seasonal fluctuations and climate change. 2) Irrigation channel optimization analysis is conducted to maximize agricultural profits and optimize water distribution effectively. Damage and blockages in irrigation channels can lead to uneven water distribution, so routine maintenance is essential. 3) In this study, there are several conclusions that can be drawn, in the Silo Karno Doga area with an irrigation area served of 1,555.05 Ha which is located in Jayawijaya Regency, there are water structures (dams, irrigation channels, reservoirs and culverts). 4) The impact of the existence of these water structures is both positive (increased community welfare) and negative (changes to the ecosystem). Mapping of land and building water needs (for agriculture, housing, or industry) is sufficient and how it is utilized.

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