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REPLANNING OF THE WEDI IRRIGATION NETWORK SYSTEM, KAPAS DISTRICT, BOJONEGORO DISTRICT

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ABSTRACT

Kapas District is located in Bojonegoro Regency with an area of 2,927 ha of rice fields and 2,805 ha of irrigation land. The obstacle faced by farmers is the uneven availability of irrigation water. The irrigation area in Wedi Village is still simple irrigation by pumping river water next to it. This research aims to plan the irrigation network in Wedi, by calculating irrigation water needs and planning the dimensions of the irrigation channels. The algebraic method is used to calculate rainfall and calculate water needs using the Net Field Requirements (NFR) system. Water requirements at the beginning of planting in November I obtained a maximum value of 1.79 lt/s/ha, the alternative for beginning of planting in December I obtained a maximum value of 1.90 lt/s/ha, and the alternative for beginning of planting in December II obtained a value of 1.88 lt/s/ha. Results of overall water balance analysis for each month in 1 year with 3 alternative plantings with surplus results. The channel dimensions obtained are SP 1 = 1.4 m x 1 m, SP 2 = 1.4 m x 1 m, SP 3 = 1.2 m x 1 m, SP 4 = 1.2 m x 1 m, and for secondary channels the results are SS 1 = 0.6 m x 1 m , SS 2 = 0.8 m x 1 m, SS 3 = 0.6 m x 1 m , SS 4 = 0.6 m x 1 m = , SS 5 = 0.6 m x 1 m.

Keyword: *Network Planning, Plant_water_requirements, NFR, channel dimensions.*

1. INTRODUCTION

Bojonegoro Regency is one of the rice centers in East Java [1] which is one of the sub-districts that has great potential for rice development [2] is Kapas District. According to the Food Security and Agriculture Service (2023), the area of rice fields in Kapas District reaches 2,927 ha and irrigated land is 2,805 ha. Even though Kapas District has high agricultural potential, there are still obstacles faced by farmers there in terms of unstable irrigation water availability and uneven water distribution. The irrigation area in Wedi Village still uses a traditional irrigation network system by utilizing the flow from the river next to the agricultural land at the research location by using a diesel pump which is then channeled to the rice fields.

The existing irrigation network system cannot provide an even supply of water throughout the existing agricultural area because water pumps placed in less than optimal locations often result in uneven water distribution throughout the land, especially in higher areas. [3] or far from water sources. This results in some land not getting enough available water supply.

Therefore, it is necessary to re-plan the irrigation network system in a semi-technical and efficient manner to overcome this problem. This planning must involve a thorough analysis of water needs, land topography, and strategic water extraction areas to ensure equitable water distribution. Thus, it is hoped that the new irrigation system can support agricultural activities in a sustainable manner and increase the productivity of agricultural land in the Kapas District area.

This research aims to re-plan the irrigation system in Wedi Village, Kapas District, Bojonegoro Regency. This will be done by calculating the water needs of Wedi Village, Kapas District, Bojonegoro Regency, and also by planning the dimensions of irrigation canals. It is hoped that this research will make a significant contribution to building more effective and efficient irrigation infrastructure. Additionally, it will serve as an example for local governments and related parties as they embark on irrigation projects.

2. LITERATURE REVIEW

Look for information about research subjects related to the problem being discussed. This information comes from a variety of sources, including, but not limited to, reports, reports, and scientific books.

2.1. Area Rainfall Analysis

To calculate rainfall, it is very important to take into account the amount and time of rain [4]. Area rainfall analysis refers to the calculation of average rainfall that occurs in rain catchment areas in a river basin (DAS)[5]. Area average rainfall is calculated based on the rainfall recorded at each rain station in a watershed [6]. This research uses aritmatic/algebraic methods [7] with the rules of using algebra if the area is an area with even rain [8] in the flat area with the following equation:

$$\bar{R} = \frac{1}{n}(R_1 + R_2 + \ldots + R_n) \quad (1)$$

Information :

$\bar{R}$ = Regional average rainfall (mm)
n = Number of rain observation posts
$R_1, R_2, ..., R_n$ = Rainfall at each observation point (mm)
(Lashari, et.al, 2017)

2.2. Mainstay Debit

River discharge that can be relied upon to meet water needs for irrigation in a planned area is called reliable discharge [9][10]. In irrigation planning, the mainstay discharge is a discharge with an 80% probability of occurring, which means that the discharge is expected to be available for 80% of the planned period. Then, the level of debit reliability is calculated based on probability using the Weibull formula [11] as follows:

$$P = \frac{m}{n+1} \times 100\% \quad (2)$$

Information :

P = The probability of occurrence of a set of expected values during the observation period (%)
m = Sequential number of events, in order of variation from large to small
n = Number of data
(Soemarto, 1995) (L. Tria, 2014)

2.3. Effective Rainfall

Effective rainfall for irrigating rice crops is R80, or 70 percent of the mid-monthly average rainfall with a 20 percent chance of non-fulfillment [12] [13]. The mainstay rainfall for DI Wedi is taken from 3 rain stations, namely the Bojonegoro, Kapas and Jati Blimbing rain stations in the form of an equation [14]:

$$Re = 0{,}7 \times \frac{1}{15} R_{80} \quad (3)$$

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$$R_{80} = \frac{n}{5} + 1 \quad (4)$$

Information :

Re = Effective rainfall (mm/day)
R_{80} = Mid-monthly minimum rainfall with a return period of 5 years/mm
N = Number of data
(Department of Public Works, 1986) ,(Aprilia, et.al., 2024)

2.4. Climatology

Climatological calculations are used to calculate the amount of evapotranspiration produced by plants, climatological data is required which includes [15]:

1. Temperature
2. Sunlight
3. Humidity
4. Wind speed
5. Saturation vapor pressure

2.5. Modified Penman Method

According to Penman, a modification of the amount of potential evapotranspiration is formulated as follows [16]:

Eto = c. (W.Rn + (1-W). f (u). (ea – ed) (5)

Information:
Eto = Evapotranspiration as reference (mm/day)
W = factors that influence sunlight
C = Weather adjustment factor during day and night
1–W = Weight factor influenced by wind and humidity
Rn = Radiation originating from sunlight (mm/day)
= f(t). f(ed). f(n/N)
f(t) = Temperature function
f(ed) = Vapor pressure function
= 0.34 - 0.44. (ed)
f(u) = Function of wind speed at a height of 2 m (m/s)
= 0.1 + 0.9 n/N
(ea-ed) = Difference between saturated and actual vapor pressure
ed = Actual vapor pressure (mbar)
= ea. RH
RH = Relative air humidity (%)
ea = Saturation vapor pressure (mbar)
(Department of Public Works, 1986), (A.Y. Baskoro.et.al, 2024)

2.6. Irrigation Water Requirements

Irrigation water requirements is a term that refers to the amount of water available and needed to irrigate an area and rice fields [17]. The amount of water needed by an irrigation network system is influenced by variables such as planting patterns and plant types. To determine the amount of water needed for rice field irrigation (NFR), start by calculating water requirements for land preparation (PWR), consumptive use (ETc), seepage and percolation (P), water layer replacement (WLR), effective rainfall (Re), irrigation water withdrawal requirements (DR), and general irrigation efficiency (η).
The following is an estimate of the amount of water needed for irrigation:

$$NFR = \frac{Etc+IR+P+WLR-Re}{EI} \times A \quad (6)$$

Information :
NFR = Water requirement for irrigation in rice fields (lt/sec/ha)
Etc = Use of growth period (mm/day)
IR = Water requirement for irrigation at the rice field level, in mm/day,
WLR = Water layer substitution (mm/day)
P = Percolation (mm/day)
Re = Effective rainfall
EI = Irrigation efficiency (%)
A = Irrigation area (ha)
(Department of Public Works, 1986), (KP-01, 2013), (Fitriansyah, et.al, 2020)

1. **Consumptive Water Needs (Etc)**
By considering the crop coefficient factor (kc), consumptive water requirements for land crops can be defined. The most commonly used equation is:

$$Etc = Eto \times kc \quad (7)$$

Information :
Etc = Consumptive water requirements (mm/day)
Eto = Evapotranspiration (mm/day)
kc = Crop coefficient
(Departemen Pekerjaan Umum, 1986), (KP-01, 2013), (Fitriansyah, et.al, 2020)

2. **Water Requirements for Land Preparation (IR)**

For calculating water requirements during land preparation, the method developed by Van De Goor and Zijltra (Irrigation Planning Standard KP-01, 2013) is used, namely the following equation:

$$IR = M \frac{e^k}{e^{k-1}} \quad (8)$$

Information :
R : Water requirement at rice field level (mm/day)
M : Water needs to replace water loss due to evaporation and percolation in saturated rice fields.
(Department of Public Works, 1986), (KP-01, 2013), (Fitriansyah, et.al, 2020)

2.7. Channel Planning

For a ground channel with a square shape as in the picture with base width = b, water depth = h. Formulas for calculating square channels:

a. Wet Perimeter Area (A)
$$A = (b \times h) \quad (9)$$
b. Wet Section (P)
$$P = (b + 2h) \quad (10)$$
c. Hydraulic Radius (R)
$$R = \frac{A}{P} \quad (11)$$
d. Flow Speed (V)
$$V = \frac{1}{n} \times R^{\frac{2}{3}} \times S^{\frac{1}{2}} \quad (12)$$
e. Flow Discharge (Q)
$$Q = V.\ A \quad (13)$$

(Department of Public Works, 1986)

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3. RESEARCH METHOD

The research location in this research is in Wedi Village, Kapas District, Bojonegoro Regency, East Java. The types of data that will be used in the research include rain data, river discharge data, land area data and climate data to calculate irrigation water needs and dimensions of irrigation canals. needed to meet irrigation water needs in the village. The research location can be seen at (Figure-1).

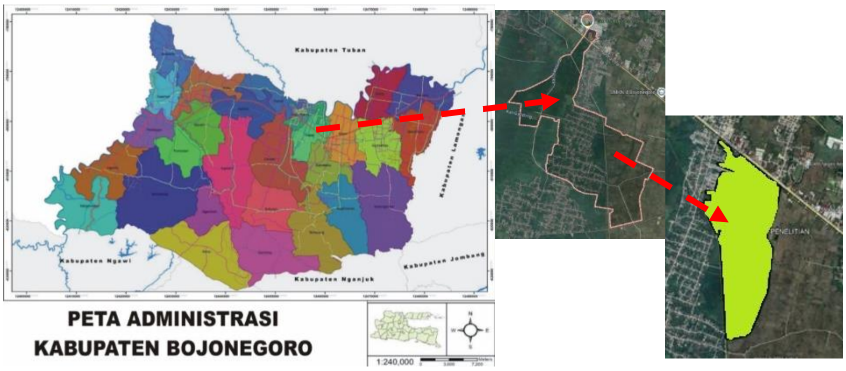

Figure 1 Research Location

3.1. Research Data

Primary and secondary data are collected using quantitative methods for research activities to be carried out.

1. Primary data is collected through direct observation and measurement at the research location.
2. Secondary Data

   Secondary data used in this research includes:
   a. Data on the area of irrigation areas
   b. Rainfall data
   c. Climatological data
   d. Hydrological Data

3.2. Data Analysis and Calculation Process

Researchers conducted a calculation analysis to improve the Wedi Village irrigation network system covering an area of 28 ha, which includes:

1. Data collection

   To collect data, surveys and field identification were carried out in two stages.
   a. Survey the research location to determine the land area and length of irrigation channels required.
   b. Research data is collected, including rainfall data, topographic data, river discharge data, and data on the amount of irrigation water required.
2. Analysis stages
   a. Hydrological Analysis
   b. Climatological Analysis
   c. Irrigation Water Needs
   d. Design of channel dimensions

4. RESULTS OF ANALYSIS AND DISCUSSION

4.1. Hydrological Analysis

1. Mainstay Debit

Discharge data was collected from measurements of the Gandong River discharge from 2000 to 2023. The data was sorted from largest discharge to smallest discharge to determine the probability of 80% or 20% fulfillment. Recap of data is shown in table 1.

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Table 1. Recap of Reliable Debt Calculations (m3/d)

No.	P (%)	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agt	Sep	Okt	Nov	Des
1	4%	3.81	3.61	4.19	3.66	3.13	2.28	2.19	1.24	1.44	2.25	3.45	2.83
2	8%	3.45	3.14	3.61	3.29	2.18	1.49	0.99	0.68	0.50	2.24	3.36	2.77
3	12%	3.24	2.80	3.40	3.20	2.05	1.49	0.92	0.57	0.44	1.01	1.91	2.47
4	16%	2.93	2.74	3.08	2.79	2.01	1.30	0.75	0.52	0.40	0.89	1.76	2.26
5	20%	2.77	2.72	3.00	2.70	1.87	1.12	0.75	0.52	0.37	0.70	1.70	2.13
6	24%	2.63	2.52	2.89	2.53	1.86	1.09	0.73	0.50	0.36	0.56	1.65	2.03
7	28%	2.57	2.45	2.80	2.45	1.51	1.08	0.73	0.50	0.35	0.50	1.33	1.84
8	32%	2.35	2.33	2.80	2.39	1.51	1.04	0.72	0.50	0.35	0.31	1.25	1.82
9	36%	2.28	2.31	2.67	2.17	1.46	1.00	0.70	0.49	0.34	0.28	1.16	1.65
10	40%	2.27	2.22	2.64	2.15	1.35	0.91	0.67	0.43	0.30	0.28	0.99	1.65
11	44%	2.06	2.03	2.57	2.14	1.31	0.88	0.65	0.43	0.30	0.25	0.82	1.62
12	48%	2.00	1.94	2.54	2.08	1.23	0.87	0.61	0.42	0.30	0.25	0.67	1.55
13	52%	1.86	1.92	2.53	1.98	1.11	0.82	0.55	0.37	0.26	0.25	0.67	1.50
14	56%	1.82	1.89	2.36	1.90	1.10	0.81	0.53	0.37	0.26	0.24	0.65	1.33
15	60%	1.75	1.83	1.95	1.84	1.08	0.80	0.53	0.37	0.25	0.21	0.58	1.17
16	64%	1.61	1.73	1.87	1.77	1.04	0.77	0.52	0.36	0.25	0.21	0.45	1.13
17	68%	1.50	1.71	1.87	1.71	1.02	0.76	0.51	0.35	0.23	0.18	0.32	1.08
18	72%	1.46	1.67	1.77	1.68	0.97	0.75	0.48	0.33	0.23	0.18	0.28	0.95
19	76%	1.38	1.65	1.75	1.51	0.96	0.74	0.47	0.33	0.22	0.18	0.17	0.86
20	80%	1.23	1.58	1.63	1.45	0.96	0.73	0.45	0.31	0.22	0.17	0.17	0.85
21	84%	1.11	1.57	1.60	1.37	0.85	0.65	0.44	0.31	0.21	0.16	0.15	0.71
22	88%	1.02	1.55	1.59	1.30	0.82	0.63	0.40	0.27	0.19	0.15	0.13	0.65
23	92%	1.00	1.53	1.43	0.71	0.52	0.33	0.23	0.16	0.11	0.13	0.12	0.23
24	96%	0.53	0.34	1.16	0.68	0.47	0.30	0.21	0.15	0.10	0.07	0.11	0.07
Q50	50.00	1.93	1.93	2.53	2.03	1.17	0.84	0.58	0.40	0.28	0.25	0.67	1.52
Q80	80.00	1.23	1.58	1.63	1.45	0.96	0.73	0.45	0.31	0.22	0.17	0.17	0.85

Source: Analysis Results, 2024

2. Climatology

Air temperature, wind speed, relative humidity, and useful sunshine duration are used in climatological calculations to calculate the amount of plant evapotranspiration. Table 2 shows the results of average potential evapotranspiration calculations for 2018–2023, and an example of a calculation carried out in February is shown here.

Known: February data

Temperature (T) = 27.59 □C
Relative humidity (Rh) = 85.66 %
Wind speed (U) = 24.11 km/hour
Duration of Sunlight (n/N) = 29.51 %

Solution:

f (n/N) = 0.1+0.9 x n/N
= 0.1 + 0.9 x 29.51
= 0.37

Temperature factor, f(T)

$$= \left[\frac{T-T_1}{T_2-T_1}\right] + \left[\frac{f(T)-f(T)_1}{f(T)_2-f(T)_1}\right]$$

$$= \frac{26-28}{27.59-28} = \frac{15.9-16.3}{f(T)_2-16.3}$$

$$= \frac{f(T)_2-16.3}{27.59-28} = \frac{15.9-16.3}{26-28}$$

$$= f(T)_2 - 16.3 = \left(\frac{15.9-16.3}{26-28}\right) \times (27.59 - 28)$$

$$= f(T)_2 - 16.3 = -0.082$$

$$= f(T)_2 = -0.082 + 16.3$$

$$= f(T)_2 = 16.22$$

Preasure factor (W)

$$= \left[\frac{T-T_1}{T_2-T_1}\right] = \left[\frac{W-W_1}{W_2-W_1}\right]$$

$$= \left[\frac{26-28}{27.59-28}\right] = \left[\frac{0.76-0.78}{W_2-0.78}\right]$$

$$= \left[\frac{W_2-0.78}{27.59-28}\right] = \left[\frac{0.76-0.78}{26-28}\right]$$

$= W_2 - 0.78 = \left[\frac{0.76-0.78}{26-28}\right] \times (27.59 - 28)$
$= W_2 - 0.78 = -0.0041$
$= W_2 = 0.78 - 0.0041$
$= W_2 = 0.776$

Saturated vapor pressure of water (ea) $= \left[\frac{T-T_1}{T_2-T_1}\right] = \left[\frac{ea-ea_1}{ea_2-ea_1}\right]$
$= \left[\frac{26-28}{27.59-28}\right] = \left[\frac{33.6-37.8}{ea_2-37.8}\right]$
$= \left[\frac{ea_2-37.8}{27.59-28}\right] = \left[\frac{33.6-37.8}{26-28}\right]$
$= ea_2 - 37.8 = \left[\frac{33.6-37.8}{26-28}\right] \times (27.59 - 28)$
$= ea_2 - 37.8 = -0.861$
$= ea_2 = 37.8 - 0.861$
$= ea_2 = 36.94$

Wind speed factor, f(U) = 0.27 x (1+U/100)
= 0.27 x (1 + 24.11/100)
= 0.34
ed = ea x Rh
= 36.94 x 85.66
= 31.64 mbar
d = ea-ed
= 36.94 – 31.64
= 5.30 mbar
f(ed) $= 0.34 - 0.044 \times ed^{0.5}$
$= 0.34 - 0.44 \times 31.64^{0.5}$
= 0.092

Angot number, Ra obtained from the Extra Terrestial Radiation (Ra) table by interpolation :

$Ra = \left[\frac{LT-LT_1}{LT_2-LT_1}\right] = \left[\frac{Ra-Ra_1}{Ra_2-Ra_1}\right]$
$= \left[\frac{6-8}{6.39-8}\right] = \left[\frac{16-16.1}{Ra_2-16.1}\right]$
$= \left[\frac{Ra_2-16.1}{6.39-8}\right] = \left[\frac{16-16.1}{6-8}\right]$
$= Ra_2 - 16.1 = \left[\frac{16-16.1}{6-8}\right] \times (6.39 - 8)$
$= Ra_2 - 16.1 = -0.0805$
= 16.02 mm/hr

Solar radiation (Rs) = (0.25+0.5 x n/N) Ra
= (0.25 + 0.5 x 29.51) x 16.02
= 6.369 mm/hr

Shortwave radiation (Rn_s) = (1-0.25) x Rs
= (1-0.25) x 6.369
= 4.78 mm/hr

Long wave radiation (Rn_1) = f (T) x f (ed) x f (n/N)
= 16.22 x 0.092 x 0.37
= 0.55

Net Radiation (Rn) $= Rn_s - Rn_1$
= 4.78 - 0.55
= 4.23

Correction Factor c = 1.1

Potential evapotranspiration (Eto)

Eto $= c. (w [0.75 (Rs-Rn_1) + (1-W) f (u) d])$
= 1.1 x (0.776 [(0.75 x (6.369 – 0.55) + (1-0.776) x 0.34 x 5.30])
= 4.05 mm

Tabel 2. Climatological Data and Calculation of Potential Evaporation for Each Month of the Year 2018 - 2023

Num.	Description	Symbol	Unit	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agt	Sept	Okt	Nov	Des
1	Temperature	T	° C	27.70	27.59	27.88	23.54	28.36	27.87	27.37	27.41	28.09	23.91	28.93	28.35
2	Relative humidity	RH	%	84.68	85.66	84.71	69.22	80.11	78.47	74.59	73.19	70.62	60.25	75.79	80.17
3	Wind velocity	u	km/hour	23.25	24.11	19.06	14.18	19.06	17.28	17.92	19.99	19.28	17.34	19.86	19.63
4	Duration of sunlight	n/N	%	28.87	29.51	44.71	49.90	54.94	52.70	59.47	69.36	61.18	54.95	48.29	38.56
5	f (n/N)			0.36	0.37	0.50	0.55	0.59	0.57	0.64	0.72	0.65	0.59	0.53	0.45
6	Temperature factor	f(T)		16.24	16.22	16.28	15.31	16.37	16.27	16.17	16.18	16.32	15.38	16.49	16.37
7	Pressure factor	W		0.777	0.776	0.779	0.800	0.782	0.779	0.774	0.774	0.780	0.752	0.785	0.782
8	Weighting Factor	(1-W)		0.223	0.224	0.221	0.200	0.218	0.221	0.226	0.226	0.220	0.248	0.215	0.218
9	Saturated vapor pressure of water	ea	mbar	37.17	36.94	37.55	29.02	38.63	37.53	36.48	36.56	38.01	29.65	39.94	38.61
10	Wind speed factor	f(U)		0.33	0.34	0.32	0.31	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
11	Water vapor pressure	ed	mbar	31.48	31.64	31.81	20.09	30.95	29.45	27.21	26.76	26.84	17.86	30.27	30.95
12	d = (ea-ed)			5.69	5.30	5.74	8.93	7.68	8.08	9.27	9.80	11.17	11.79	9.67	7.66
13	f (ed) = 0,34 - 0,044 . ed^0.5			0.093	0.092	0.092	0.143	0.095	0.101	0.110	0.112	0.112	0.154	0.098	0.095
14	Angot numbers	Ra	mm/dy	15.92	16.02	15.58	14.64	13.34	12.72	13.02	13.94	14.98	15.72	15.84	15.76
15	Solar radiation	Rs	mm/dy	6.278	6.369	7.378	7.313	6.999	6.533	7.126	8.320	8.327	8.249	7.784	7.221
16	Shortwave radiation	Rn_s	mm/dy	4.71	4.78	5.53	5.48	5.25	4.90	5.34	6.24	6.25	6.19	5.84	5.42
17	Long wave radiation	Rn_1	mm/dy	0.54	0.55	0.75	1.20	0.93	0.95	1.13	1.32	1.19	1.41	0.86	0.70
18	Net Radiation	Rn	mm/dy	4.16	4.23	4.78	4.28	4.32	3.95	4.21	4.92	5.06	4.78	4.97	4.72
19	Correction factor	c		1.1	1.1	1	0.9	0.9	0.9	0.9	1	1.1	1.1	1.1	1.1
20	Potential Evapotranspiration	Eto	mm/hr	4.02	4.05	4.13	3.58	3.53	3.28	3.53	4.53	5.21	4.97	5.04	4.65

Source: Analysis Results, 2024

4.2. Water Requirements for Irrigation

1. Average Rain

To prepare and process rain data, data from 3 rain stations near the research location for the last 24 years, namely Bojonegoro, Kapas and Jatiblimbing stations, were used. Calculations use algebraic methods because the research location has flat topography.

Table 3. Average Rainfall

Year	Jan		Peb		Mar		Apr		May		June	
	1	2	1	2	1	2	1	2	1	2	1	2
2000	194.00	240.67	118.33	81.67	120.00	117.33	224.67	133.00	67.33	72.67	29.00	33.33
2001	67.67	186.67	64.83	108.83	247.83	105.50	74.50	66.50	2.00	0.00	69.50	7.33
2002	60.00	177.67	126.67	108.33	74.33	70.33	49.67	16.67	35.00	8.00	0.00	0.00
2003	70.67	100.00	217.67	48.67	147.67	40.00	39.33	17.67	37.00	27.67	0.33	0.00
2004	187.33	275.67	108.67	114.33	352.00	94.00	131.00	15.00	35.00	60.67	12.67	0.00
2005	139.67	185.33	104.67	100.00	144.33	102.33	225.00	23.00	62.33	1.00	10.00	34.67
2006	89.83	65.00	121.33	189.00	46.00	174.50	95.00	34.33	176.67	53.67	3.00	0.00
2007	36.00	89.00	96.67	173.33	64.67	170.33	121.67	76.33	8.00	32.67	50.33	36.00
2008	113.00	160.00	99.33	110.00	198.00	111.33	84.33	74.33	37.33	71.67	22.00	0.00
2009	159.33	112.67	86.33	193.00	197.00	79.33	69.67	144.33	51.33	151.00	30.67	0.00
2010	200.33	190.17	220.67	147.00	211.00	171.00	215.33	117.67	110.67	147.00	89.00	56.33
2011	66.33	77.33	107.33	60.67	125.67	199.00	111.67	72.33	168.67	53.67	7.67	13.33
2012	165.00	114.67	200.33	112.00	166.00	129.00	52.00	33.33	82.33	3.33	54.00	6.33
2013	219.67	205.00	62.33	108.33	273.33	71.67	186.33	80.67	27.33	52.33	91.67	22.67
2014	168.33	21.00	55.00	144.00	284.67	82.33	172.00	175.67	16.67	31.33	4.00	56.67
2015	89.33	204.33	266.67	140.00	39.33	65.67	130.00	96.67	21.67	1.00	47.67	0.00
2016	75.33	160.67	146.33	145.33	117.33	73.00	133.67	50.67	36.00	56.67	34.33	76.33
2017	90.33	263.33	75.67	142.67	118.00	92.33	89.00	60.00	48.67	55.33	92.00	11.00
2018	130.00	107.33	97.67	226.67	195.00	92.00	42.33	39.67	0.00	56.67	0.67	21.67
2019	106.33	93.00	62.67	2.33	241.67	209.00	162.33	54.67	46.67	4.33	0.00	0.00
2020	143.00	146.67	164.67	187.00	189.00	96.67	237.67	9.67	76.00	22.00	0.67	0.33
2021	132.00	281.33	42.00	77.00	240.00	62.67	144.33	11.00	16.33	7.00	67.67	98.33
2022	106.00	107.67	168.00	141.33	263.67	123.33	117.67	75.67	70.00	131.33	34.67	79.67
2023	84.67	248.00	119.67	111.33	90.67	111.33	256.67	28.67	52.00	0.00	29.00	0.00
2000	0.00	2.33	0.00	0.00	14.67	105.33	128.33	96.33	155.33	325.00	71.83	81.17
2001	62.00	19.00	0.00	0.00	44.00	12.33	76.67	132.00	37.83	160.33	41.83	158.00
2002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.33	91.67	167.33	94.67
2003	0.00	0.00	0.00	0.00	17.00	10.00	148.33	86.00	80.67	228.00	125.67	126.67
2004	24.67	2.00	0.00	0.00	2.00	2.00	0.00	12.33	9.00	77.67	98.33	101.67
2005	1.67	5.00	31.00	2.00	2.33	18.00	5.33	28.33	30.67	149.00	173.33	156.67
2006	0.00	0.00	0.00	0.00	1.33	0.00	0.00	9.67	49.00	45.33	86.33	148.33

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Year	Jan		Peb		Mar		Apr		May		June	
	1	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
2007	18.67	4.00	0.00	11.33	0.00	0.00	36.00	28.00	143.67	33.67	203.00	232.33
2008	2.67	0.00	15.67	48.00	2.00	8.33	105.00	23.00	112.00	97.33	81.00	179.00
2009	5.00	0.00	1.67	14.67	0.00	0.00	9.67	29.00	26.00	127.67	42.00	151.33
2010	86.33	93.00	7.67	95.67	147.67	72.00	157.67	160.33	91.67	52.33	170.67	210.33
2011	11.67	0.00	0.00	0.00	39.67	8.33	10.67	72.00	149.67	169.00	132.67	178.33
2012	0.00	0.00	0.00	0.00	0.00	0.00	32.33	22.33	73.33	150.67	114.00	163.33
2013	105.00	8.67	0.00	0.00	4.33	0.00	14.00	55.00	53.67	121.00	220.67	75.67
2014	7.67	0.00	0.00	0.00	0.00	0.00	3.33	18.67	29.00	54.00	142.67	265.33
2015	0.00	0.00	0.00	0.00	0.00	0.00	6.33	0.00	47.00	19.67	106.00	72.00
2016	7.00	9.67	74.67	0.00	10.00	44.67	140.00	31.33	120.00	194.00	146.67	39.33
2017	0.00	33.00	0.00	0.00	0.00	73.00	32.33	107.67	141.67	206.00	198.00	56.00
2018	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	38.33	25.00	35.00	34.67
2019	3.00	0.00	0.00	0.00	0.00	0.00	0.00	2.33	58.67	4.00	30.00	178.67
2020	37.33	19.00	23.67	14.00	0.00	22.00	65.00	92.67	99.67	177.00	134.67	208.67
2021	10.67	0.67	18.33	5.00	33.33	111.00	1.67	35.00	125.00	140.67	144.00	177.33
2022	32.67	1.67	56.33	5.67	36.67	22.33	127.67	243.33	248.00	196.67	68.33	99.67
2023	35.67	0.00	3.00	0.00	1.07	0.00	0.00	3.33	37.87	105.27	93.37	32.47

Source: Analysis Results, 2024

After obtaining the average rainfall, the following table 4 is a calculation of effective rainfall for rice and secondary crops.

Table 4. Effective Rainfall

Month	Period	R80	R50	Reff (mm/day)	
				Paddy	Secondary crops
Jan	1	70.67	5.12	3.30	0.24
	2	93.00	7.01	4.07	0.31
Peb	1	64.83	5.40	3.24	0.27
	2	81.67	5.66	4.08	0.28
Mar	1	90.67	8.28	4.23	0.39
	2	71.67	4.35	3.14	0.19
Apr	1	69.67	5.87	3.25	0.27
	2	17.67	2.68	12.37	1.87
May	1	16.67	1.96	0.78	0.09
	2	3.33	1.86	0.15	0.08
June	1	0.67	1.35	0.03	0.06
	2	0.00	0.43	0.00	0.30
July	1	0.00	0.28	0.00	0.01
	2	0.00	0.01	0.00	0.00
Augt	1	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00
Sep	1	0.00	0.08	0.00	0.00
	2	0.00	0.24	0.00	0.17
Okt	1	0.00	0.58	0.00	0.03
	2	3.33	1.25	0.15	0.05
Nop	1	37.83	3.08	1.77	0.14
	2	45.33	5.80	2.12	0.27
Des	1	68.33	5.59	3.19	0.26
	2	72.00	6.56	3.15	0.29

Source: Analysis Results, 2024

After obtaining effective rainfall, it is then used to calculate total irrigation water requirements which include water requirements during land preparation, water layer replacement requirements and plant water requirements in rice fields which can be seen in table 5 below.

Table 5. Results of calculating plant water needs

			November		Desember		January		February		March		April		May	
			15	15	15	16	15	16	14	14	15	16	15	15	15	16
Evapotranspiration, Eto	mm		5.04	5.04	4.65	4.65	4.02	4.02	4.05	4.05	4.13	4.13	3.58	3.58	3.53	3.53
Coef. Plants, Kc (FAO IDP No. 24)																
		1		LP	LP	1.10	1.10	1.10	1.10	1.05	0.95		LP	LP	1.10	1.10

			November		Desember		January		February		March		April		May	
			15	15	15	16	15	16	14	14	15	16	15	15	15	16
		2	0.60		LP	LP	1.10	1.10	1.10	1.10	1.05	0.95		LP	LP	1.10
		3	0.96	0.60		LP	LP	1.10	1.10	1.10	1.10	1.05	0.95		LP	LP
ETc/day	mm	1				5.12	4.43	4.43	4.45	4.25	3.93				3.88	3.88
	mm	2	3.02				4.43	4.43	4.45	4.45	4.34	3.93				3.88
	mm	3	4.83	3.02				4.43	4.45	4.45	4.55	4.34	3.40			
ET c 1/2 month	mm	1				81.88	66.39	70.82	62.32	59.48	58.90				58.19	62.07
	mm	2	45.32				66.39	70.82	62.32	62.32	65.10	62.82				62.07
	mm	3	72.52	45.32				70.82	62.32	62.32	68.20	69.44	51.02			
Land Preparation	mm	1		213.59	209.66								198.92	198.92		
(KP-01)	mm	2			209.66	223.64								198.92	198.39	
	mm	3				223.64	203.32								198.39	211.62
Percolation	mm	1				32.00	30.00	32.00	28.00	28.00	30.00				30.00	32.00
	2															
	mm/day	2					30.00	32.00	28.00	28.00	30.00	32.00				32.00
	mm	3						32.00	28.00	28.00	30.00	32.00	30.00			
Water Layer Replacement	mm	1					50.00		50.00							50.00
(WLR), (KP-01)	mm	2						50.00		50.00						
	mm	3							50.00		50.00					
Plant water needs																
	mm	1		213.59	209.66	113.88	146.39	102.82	140.32	87.48	88.90		198.92	198.92	88.19	144.07
	mm	2	45.32		209.66	223.64	96.39	152.82	90.32	140.32	95.10	94.82		198.92	198.39	94.07
	mm	3	72.52	45.32		223.64	203.32	102.82	140.32	90.32	148.20	101.44	81.02		198.39	211.62
Effective Rainfall (Reff)	mm															
(mainstay 80%)	mm	1		31.73	47.83	50.40	49.47	65.10	45.38	57.17	63.47		48.77	12.37	11.67	2.33
	mm	2	46.20		47.83	50.40	49.47	65.10	45.38	57.17	63.47	50.17		12.37	11.67	2.33
	mm	3	46.20	87.03		50.40	49.47	65.10	45.38	57.17	63.47	50.17	48.77		11.67	2.33
Water needs in rice fields																
	mm	1		181.85	161.83	63.48	96.92	37.72	94.93	30.32	25.43		150.15	186.55	76.53	141.74
	mm	2	0.00		161.83	173.24	46.92	87.72	44.93	83.15	31.63	44.66		186.55	186.73	91.74
	mm	3	26.32	0.00		173.24	153.86	37.72	94.93	33.15	84.73	51.27	32.25		186.73	209.29
Water needs in rice fields	l/s/ha	1		1.40	1.25	0.46	0.75	0.27	0.78	0.25	0.20		1.16	1.44	0.59	1.03
(NFR)	l/s/ha	2	0.00		1.25	1.25	0.36	0.63	0.37	0.69	0.24	0.32		1.44	1.44	0.66
	l/s/ha	3	0.20	0.00		1.25	1.19	0.27	0.78	0.27	0.65	0.37	0.25		1.44	1.51
Total mean	l/s/ha		0.07	0.47	0.83	0.99	0.77	0.39	0.65	0.40	0.36	0.23	0.47	0.96	1.16	1.07
Total water requirement in collection	l/s/ha		0.10	0.72	1.28	1.53	1.18	0.61	1.00	0.62	0.56	0.36	0.72	1.48	1.79	1.65
	107.26 l/dt		11.20	77.42	137.79	163.62	126.74	65.12	107.10	66.88	60.37	38.29	77.66	158.84	191.57	176.72
	m3/s		0.01	0.08	0.14	0.16	0.13	0.07	0.11	0.07	0.06	0.04	0.08	0.16	0.19	0.18

Table 5. Results of calculating plant water needs(continued)

			June		July		August		September		Okcober	
			15	15	15	16	15	16	15	15	15	16
Evapotranspirasi, Eto	mm		3.28	3.28	3.53	3.53	4.53	4.53	5.21	5.21	4.97	4.97
Coef. Plants, Kc (FAO IDP No. 24)												
		1	1.10	1.10	1.05	0.95	0.50	0.75	1.01	1.05	0.96	0.60
		2	1.10	1.10	1.10	1.05	0.95	0.50	0.75	1.01	1.05	0.96
		3	1.10	1.10	1.10	1.10	1.05	0.95	0.50	0.75	1.01	1.05
ETc/day	mm	1	3.61	3.61	3.71	3.36	2.26	3.40	5.26	5.47	4.77	2.98
	mm	2	3.61	3.61	3.89	3.71	4.30	2.26	3.91	5.26	5.22	4.77
	mm	3	3.61	3.61	3.89	3.89	4.75	4.30	2.60	3.91	5.02	5.22
ET c 1/2 month	mm	1	54.13	54.13	55.64	53.70	33.96	54.33	78.91	82.03	71.58	47.72
	mm	2	54.13	54.13	58.29	59.35	64.52	36.22	58.59	78.91	78.29	76.36
	mm	3	54.13	54.13	58.29	62.18	71.31	68.82	39.06	58.59	75.31	83.51

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			June		July		August		September		Okcober	
			15	15	15	16	15	16	15	15	15	16
Land Preparation	mm	1										
(KP-01)	mm	2										
	mm	3										
Percolation	mm	1	30.00	30.00	30.00	32.00						
	2 mm/hari	2	30.00	30.00	30.00	32.00	30.00					
	mm	3	30.00	30.00	30.00	32.00	30.00	32.00				
Water Layer Replacement	mm	1		50.00								
(WLR), (KP-01)	mm	2	50.00		50.00							
	mm	3		50.00		50.00						
Plant water needs												
	mm	1	84.13	134.13	85.64	85.70	33.96	54.33	78.91	82.03	71.58	47.72
	mm	2	134.13	84.13	138.29	91.35	94.52	36.22	58.59	78.91	78.29	76.36
	mm	3	84.13	134.13	88.29	144.18	101.31	100.82	39.06	58.59	75.31	83.51
Effective Rainfall (Reff)	mm											
(mainstay 80%)	mm	1	0.47	0.00	0.00	0.00	0.00	0.00	1.17	3.62	8.63	20.07
	mm	2	0.47	0.00	0.00	0.00	0.00	0.00	1.17	3.62	8.63	20.07
	mm	3	0.47	0.00	0.00	0.00	0.00	0.00	1.17	3.62	8.63	20.07
Water needs in rice fields												
	mm	1	83.67	134.13	85.64	85.70	33.96	54.33	77.74	78.42	62.95	27.66
	mm	2	133.67	84.13	138.29	91.35	94.52	36.22	57.43	75.29	69.66	56.29
	mm	3	83.67	134.13	88.29	144.18	101.31	100.82	37.90	54.98	66.68	63.45
Water needs in rice fields												
	l/dt/ha	1	0.65	1.03	0.66	0.62	0.26	0.39	0.60	0.61	0.49	0.20
(NFR)	l/dt/ha	2	1.03	0.65	1.07	0.66	0.73	0.26	0.44	0.58	0.54	0.41
	l/dt/ha	3	0.65	1.03	0.68	1.04	0.78	0.73	0.29	0.42	0.51	0.46
Total mean	l/dt/ha		0.77	0.91	0.80	0.77	0.59	0.46	0.45	0.54	0.51	0.36
Total water requirement in collection	l/dt/ha		1.19	1.40	1.24	1.20	0.91	0.71	0.69	0.83	0.79	0.55
	107.26 l/dt		128.15	150.03	132.92	128.21	97.83	76.38	73.68	88.84	84.84	58.83
	m3/s		0.13	0.15	0.13	0.13	0.10	0.08	0.07	0.09	0.08	0.06

Source: Analysis Results, 2024

4.3. Irrigation Channel Planning

To flow irrigation water, square cross-section channels are used in the planning of this carrier channel. The two categories of carrier channels are primary and secondary channels. An example of calculating primary channel discharge in one of D.I Wedi's plots is below. Table 6 below shows the overall planned discharge results for each channel on D.I Wedi.

Plot area (Block VI) = 40.38 ha
Max NFR planting pattern December I = 1.23 lt/dt/ha (maximum NFR)
Planned debt on plot VI = (Plot Area x NFR)/Irrigation Efficiency
= (40.38 x 1.79)/0.9
= 80.31 l/sec = 0.0803 m3/s

Table 6. Results of Channel Capacity Calculations on D.I Wedi

NO	CANAL	SECTION	AREA (ha)	NFR Maks (l/s/ha)	e	Plan Discharge Q (l/s)	Plan Debit Q (m3/s)
1	Primary	SP 1	107.26	1.23	0.9	146.59	0.1466
2	Secondary	SS1	1.03	1.23	0.9	1.41	0.0014
3	Primary	SP 2	106.23	1.23	0.9	145.18	0.1452
4	Secondary	SS 2	23.40	1.23	0.9	31.98	0.0320
5	Secondary	SS 3	11.25	1.23	0.9	15.38	0.0154
6	Primary	SP 3	71.58	1.23	0.9	97.83	0.0978
7	Secondary	SS 4	15.60	1.23	0.9	21.32	0.0213
8	Secondary	SS 5	15.60	1.23	0.9	21.32	0.0213
9	Primary	SP 4	40.38	1.23	0.9	55.19	0.0552

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Source: Analysis Results, 2024

After getting the planned discharge for each channel, you can continue to calculate the planned square channel dimensions for each section using trial and error until the channel discharge exceeds the planned discharge. The following is an example of calculating the dimensions of primary channel 2 which can be seen below:

- Known:
  - Channel bottom width (b) = 1.4 m (trial and error)
  - Water level (h) = 1 m
  - Channel bottom slope (S) = 0.001 m
  - Manning coefficient (n) = 0.015
- Solution:
  - Wet cross-sectional area (A)
    A = b x h
    = 1.4 x 1
    = 1.4 m2
  - Channel wet circumference (P)
    P = b + 2 x h
    = 1.4 + 2 x 1
    = 3.40 m
  - Hydraulic radius (R)
    R = A/P
    = 1.4/3.40
    = 0.412 m
  - Flow velocity (V)
    $V = \frac{1}{n} \times R^{\frac{2}{3}} \times S^{\frac{1}{2}}$
    $= \frac{1}{0.015} \times 0.412^{\frac{2}{3}} \times 0.001^{\frac{1}{2}}$
    $= 0.119\ m/s^2$
  - Guard Height (w)
    W = 1/3 x h
    = 1/3 x 1
    = 0.33 m
  - Debit (Q)
    Q = V. A
    = 0.119 x 1.4
    $= 0.1168\ m^3/dt > Q_{plan}$
    Q = 0.1168 > 0.1452 (OK)

The overall calculation can be seen in table 7 and the channel image can be seen in figure 2 below:

Table 7. Calculation Results of Box Channel Dimensions

NO	CANAL	SECTION	b	h	A (m^2)	P (m)	R	S	n	V	w	Plan Discharge Q (l/s)	Plan Debit Q (m3/s)
1	Primary	SP 1	1.4	1.00	1.40	3.40	0.412	0.001	0.015	0.119	0.333	0.1668	0.1466
2	Secondary	SS1	0.6	1.00	0.60	2.60	0.231	0.001	0.015	0.037	0.333	0.0225	0.0014

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3	Primary	SP 2	1.4	1.00	1.40	3.40	0.412	0.001	0.015	0.119	0.333	0.1668	0.1452
4	Secondary	SS 2	0.8	1.00	0.80	2.80	0.286	0.001	0.015	0.057	0.333	0.0459	0.0320
5	Secondary	SS 3	0.6	1.00	0.60	2.60	0.231	0.001	0.015	0.037	0.333	0.0225	0.0154
6	Primary	SP 3	1.2	1.00	1.20	3.20	0.375	0.001	0.015	0.099	0.333	0.1186	0.0978
7	Secondary	SS 4	0.6	1.00	0.6	2.60	0.231	0.001	0.015	0.037	0.333	0.0225	0.0213
8	Secondary	SS 5	0.6	1.00	0.6	2.60	0.231	0.001	0.015	0.037	0.333	0.0225	0.0213
9	Primary	SP 4	1.00	1.00	1	3.00	0.333	0.001	0.015	0.078	0.333	0.0781	0.0552

Source: Analysis Results, 2024

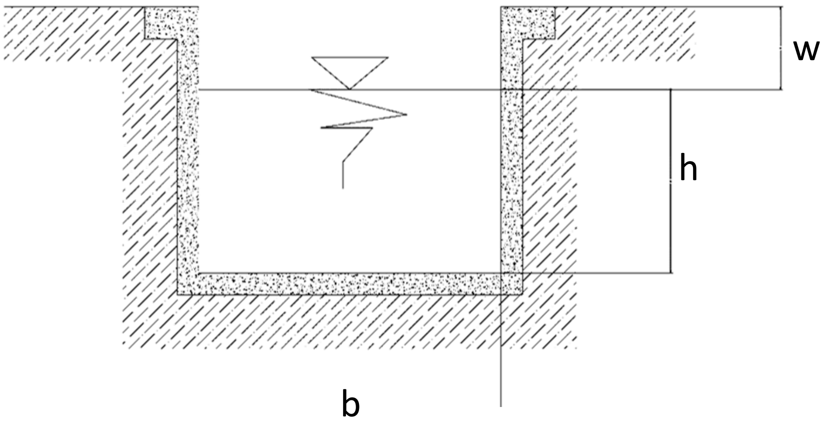

Figure 2. Box Channal Design

5. CONCLUSION

Based on the results of research in the Wedi Village irrigation area, it can be concluded that:

1. Irrigation water requirements for the November I planting pattern obtained a maximum value of 1.79 lt/sec/ha, for the December I planting pattern the maximum value was obtained at 1.90 lt/sec/ha, and for the December II planting pattern the value was 1.88 lt/ha. dt/ha.
2. Water balance analysis in the Wedi irrigation area obtained overall results for each month in 1 year with 3 forms of cropping patterns with surplus results without any water shortage at all.
3. Channel dimension results obtained SP 1 = 1.4 m x 1 m, SP 2 = 1.4 m x 1 m, SP 3 = 1.2 m x 1 m, SP 4 = 1.2 m x 1 m, and for secondary channels obtained results SS 1 = 0.6 m x 1 m, SS 2 = 0.8 m x 1 m, SS 3 = 0.6 m x 1 m, SS 4 = 0.6 m x 1 m = , SS 5 = 0.6 m x 1 m.

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