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Rehabilitation and Development of Irrigation System in Lokoliku Village, West Nusa Tenggara

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***Abstract*— *Water is an important requirement in agricultural activities, especially in rice farming. The effectiveness and efficiency of water distribution greatly determine the success in agricultural activities and indirectly affect the food security in an area. This study aims to develop an irrigation network in Lokoliku Village, South Wewewa District, West Sumba Regency, East Nusa Tenggara. The data included the map of irrigation area, rainfall data, the schematic irrigation channel, and the characteristic data consisting of rain potential, land area, land conditions, and crop types. The hydrological analysis consisted of irrigation water requirements, reliable discharge, water balance, and the irrigation flow system. Based on the results, it is determined that the water demand was 1.4 m3/sec/Ha. The water discharge channeled from the intake based on the requirement in an area was 121.64 Ha is 170,296 m3/sec. In addition, the planned dimensions of the new channel are trapezium-shaped channels with a width of 0.30m (base), a width of 0.90m, a wet channel height of 0.14m, and a embankment height of 0.20m. The results of this study can be used as recommendations for the stakeholders, such as the local agriculture department, the irrigation department or other agencies for developing the irrigation system.*

***Keywords*— *Irrigation system, rice field, water needs.*

I. INTRODUCTION

Agriculture is one of the main sectors in Indonesia, where the biggest commodity is rice. Rice is a plant that in its life requires waterlogging for 3.5 months for ordinary varieties and 2.5 months for superior varieties. To meet water needs, an irrigation network is needed that can distribute water from rivers or water structures continuously and with a certain discharge. However, until now there are still problems in the irrigation network (KP 01). Such as reduced water debit from the intake or take-up building with water discharge reaching the rice fields that are flowed. One of the reasons for this is the irrigation networks that are old and damaged. Therefore in need of rejuvenation or rehabilitation and development of irrigation networks (KP 04).

Irrigation networks play an important role to maintain and channel water from the building up to the land. One of the problems that often occurs is that the existing channels are still natural and not permanent channels, resulting in high levels of infiltration or absorbing water into the ground so that the impact on reducing the amount of water discharge that reaches the land to be drained (KP 02).

Some regions in Indonesia have not used an appropriate irrigation network system and can support water needs in all agricultural land. One of them is in Wewewa Subdistrict, South Sumba Barat Daya, especially in Loko Liku Village, where the irrigation network used is old and many of them are not permanent. Thus, irrigation canals cannot support water needs in all potential agricultural land in the region. Irrigation channel conditions that are not supportive make high sedimentation, thus disrupting water flow. Figure 1 shows the physical condition of the damaged irrigation network (Tertiary Lengthening/transverse) which requires rehabilitation and development to function optimally.

Fig. 1. The condition of irrigation channel in Lokoliku

This problem also has an impact on crop yields. Most rice fields eventually become rain-fed land which can only be cultivated only in the rainy season (KP 05). As for the dry season, this land cannot be used at all. Therefore, rejuvenation and development of irrigation networks are needed so that the land can be utilized maximally.

The purpose of this study is to draw up an irrigation network development plan to determine the water discharge following the needs of irrigation land, as well as determine the dimensions of the right irrigation channel to increase irrigation water needs. In this case, the data that must be known is how much water is needed in each hectare of irrigation area, how much water must be taken from the intake, and what are the dimensions of the channel needed to drain the water.

II. METHOD

The data needed in this study includes a 1: 25,000 scale map of the irrigation area, rainfall data, schematic and upstream Q and downstream Q channel data in Lokoliku, South Wewewa District, Southwest Sumba Regency, and characteristic data consisting of rain potential, land area, land conditions, and crop types. The hydrological analysis consists of calculating irrigation water requirements, reliable discharge, water balance, and irrigation water supply patterns.

The dimensions of the planned channel and building must be able to drain the discharge plan. Plan discharge is the amount of water per unit time planned to flow. To find out the size of the planned discharge, it is first necessary to calculate the water requirements in the fields and the possible water losses. The debit plan calculation formula is as follows:

$Q = q \times A$

$S = 11.5467 \times C\,(Q/V)^{0.5}$

$Qr = Q + S$

$Qr = q \times A$

Where :

q = water requirements per unit area (Lt/second/ha)

A = Area of irrigated area (ha)

S = Loss of water due to seepage (Moritz), in lt/s/km

V = drainage speed in the channel (m/sec)

C = Moritz coefficient, Table-1

Qr = plan discharge (Lt/sec)

Channel dimensions are carried out based on the planned dimensions (Table 1), henceforth the channel base slope is determined based on the planned Q, selectable: b / d, V, and m. Furthermore, the high water flow must be calculated under normal conditions (100% Q plan) and low (70% Q plan). This is so that at maximum flow, the channel can drain water. Likewise, when water is low, canals and buildings still function well. To find out the level of water in the channel, a trial and error method is carried out, as follows:

$A = (b + m)d$

$P = b + 2d\,(1 + m^2)^{0.5}$

$R = A/P$

$V = (R^{2/3} \times S^{1/2}) / n$

$Q = A \times (R^{2/3} \times S^{1/2}) / n$

$A.R^{2/3} = (Q \times n)/S^{1/2}$

Where:

A : Wet cross-sectional area

P : the circumference of a wet cross-section

R : hydraulic lines

Q : channel water discharge

n : Manning roughness coefficient

S : channel base slope

Mi : the slope of the cliff/channel wall

TABLE 1. The channel dimension planned

Q	b/d	V	H:V	F	Embankment
0.00-0.15	1.0	0.25-0.30	1 : 1	0.30	1.50
0.15-0.30	1.0	0.30-0.35	1 : 1	0.30	1.50
0.30-0.40	1.5	0.35-0.40	1 : 1	0.40	1.50
0.40-0.50	1.5	0.40-0.45	1 : 1	0.40	1.50
0.50-0.75	2.0	0.45-0.50	1 : 1	0.50	1.50
0.75-1.50	2.5	0.50-0.55	1 : 1	0.50	1.50
1.50-3.00	2.5	0.55-0.60	1 : 1	0.60	1.50
3.0-04.50	3.0	0.60-0.65	1 : 1,5	0.60	2.00
4.50-6.00	3.5	0.65-0.70	1 : 1,5	0.60	2.00
6.00-7.50	4.0	0.70	1 : 1,5	0.60	2.00
7.50-9.00	4.5	0.70	1 : 1,5	0.60	2.00

III. Result and Discussion

A. Water Needs for Plant

Irrigation water needs are very important to know. Factors that determine the amount of irrigation water needed for plants are land preparation, consumptive use, percolation and seepage, change of water layers, and effective rainfall. Plant water needs are reviewed based on a water balance that considers several parameters, including percolation, land preparation, plant consumptive use, water layer change, and effective rainfall. The calculation results are explained as follows:

TABLE 2. The calculation of Evaporation and Percolation

Eo + P	T 30 Days		T 45 Days	
mm / day	S250 mm	S300 mm	S250 mm	S300 mm
5.0	11.1	12.7	8.4	9.5
5.5	11.4	13.0	8.8	9.8
6.0	11.7	13.3	9.1	10.1
6.5	12.0	13.6	9.4	10.4
7.0	12.3	13.9	9.8	10.8
7.5	12.6	14.2	10.1	11.1
8.0	13.0	14.5	10.5	11.4
8.5	13.3	14.8	10.8	11.8
9.0	13.6	15.2	11.2	12.1
9.5	14.0	15.5	11.6	12.5
10.0	14.3	15.8	12.0	12.9
10.5	14.7	16.2	12.4	13.2
11.0	15.0	16.5	12.8	13.6

B. Water Needs for Rice Field Preparation

Calculation of irrigation needs during land preparation refers to the method developed by Van de Goor and Zijlstra (1986). The results of the calculation of water demand for land preparation can be seen in table 3.

TABLE 3. Water needs for field preparation

Month	ETo	Eo + P	LP (mm)
January	1.79	3.97	8.85
February	1.56	3.72	8.70
March	1.10	3.21	8.40
April	1.65	3.81	8.75
May	1.33	3.46	8.55
June	0.93	3.02	8.29
July	1.76	3.94	8.83
August	1.40	3.54	8.59
September	0.83	2.92	8.23
October	2.58	4.84	9.38
November	1.95	4.15	8.95
December	2.26	4.48	9.16

C. Minimum Discharge

The minimum discharge is the minimum river discharge for the possibility of being fulfilled which can guarantee the continuity of water supply for irrigation purposes. The calculation of the mainstay debit is done by the basic year method, which is to take a debit pattern from a certain year. The probability of occurrence is calculated by the Weibull equation (Subarkah, 1980):

$$P = \frac{m}{n+1}$$

Where :

P: probability (%)

m: debit data serial number

n: the amount of data discharge

By using a basic year, the basic planning year can be obtained, namely in 2008 with a failure rate of 20%.

Watershed Area: 121.64 ha

Soil moisture: 200 mm

Infiltration coefficient (I): 0.5 mm / day.
Recession coefficient (K): 0.5 mm / day.

Furthermore, the results of the mainstay discharge calculation are shown as follows:

TABLE 4. Minimum discharge

5		UNIT	MONTH												Detail
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
I.	DATA														
	1. Average Monthly Rainfall	mm	145.63	144.58	182.53	154.07	136.84	124.91	175.78	111.89	174.69	133.13	181.22	170.12	Data
	2. Average Rainy Day (n)	day	10.30	8.60	9.20	8.60	7.80	6.50	6.00	3.40	4.80	6.50	8.00	9.90	Data
II.	EVAPOTRANSPIRATION	mm/month	55.44	45.28	34.10	49.49	41.23	27.76	54.65	43.30	24.95	80.06	58.60	70.00	Data
III.	EVAPOTRANSPIRATION LIMIT														
	3. Exposed surface (m)	%	30.00	30.00	30.00	30.00	30.00	30.00	40.00	40.00	50.00	50.00	40.00	30.00	Data
	4. E/Et = (m/20)(18-n)	%	11.55	14.10	13.20	14.10	15.30	17.25	24.00	29.20	33.00	28.75	20.00	12.15	
	5. E = Et (m/20)(18-n)	mm	6.40	6.38	4.50	6.98	6.31	4.79	13.12	12.64	8.24	23.02	11.72	8.50	II x 4
	6. EL = Et – E	mm	49.03	38.89	29.60	42.51	34.92	22.97	41.53	30.66	16.72	57.04	46.88	61.49	II - 5
IV.	WATER BALANCE														
	7. Water Surplus (R - EL)	mm	96.60	105.69	152.93	111.56	101.92	101.94	134.25	81.23	157.97	76.09	134.34	108.63	1 - 4
V.	RUN OFF & WATER STORAGE														
	8. Infiltration	mm	38.64	42.27	61.17	44.62	40.77	40.78	53.70	32.49	63.19	30.43	53.74	43.45	0.4 x 7
	9. 0.5 (1+K) I	mm	30.91	33.82	48.94	35.70	32.61	32.62	42.96	25.99	50.55	24.35	42.99	34.76	K = 0.60
	10. K x Vn – 1	mm	0.00	18.55	31.42	48.21	50.35	49.78	49.44	55.44	48.86	59.65	50.40	56.03	
	11. Vn	mm	30.91	52.37	80.36	83.91	82.96	82.40	92.40	81.43	99.41	83.99	93.39	90.79	9 + 10
	12. K – Vn – 1 Continuation	mm	54.48	51.23	51.03	59.98	57.41	54.01	51.98	56.96	49.77	60.19	50.73	56.23	
	13. Vn	mm	85.39	85.05	99.97	95.68	90.02	86.63	94.94	82.96	100.32	84.54	93.71	90.99	9 + 12
	14. K x Vn – 1 Continuation	mm	54.59	51.30	51.07	60.01	57.42	54.02	51.99	56.97	49.78	60.20	50.73	56.23	
	15. Vn	mm	85.50	85.12	100.01	95.70	90.04	86.64	94.94	82.96	100.32	84.54	93.72	90.99	9 + 14
	16. Vn' = Vn – (Vn - 1)	mm	-5.49	-0.38	14.89	-4.31	-5.67	-3.39	8.30	-11.98	17.37	-15.78	9.17	-2.73	0.00
	17. Base Flow = 1 – Vn	mm	44.12	42.66	46.28	48.93	46.44	44.17	45.40	44.48	45.82	46.22	44.56	46.18	
	18. Direct Run-Off	mm	57.96	63.41	91.76	66.93	61.15	61.16	80.55	48.74	94.78	45.65	80.60	65.18	0.6 x 7
	19. Monthly Runoff	mm	102.08	106.07	138.04	115.86	107.58	105.33	125.94	93.21	140.60	91.87	125.17	111.35	17 + 8
	20. Debit, Q = Run-Off x A x 10^6 : Month x 24 x 3600 x 1000	m^3/sec	5.04	5.80	6.81	5.91	5.31	5.37	6.22	4.60	7.17	4.54	6.38	5.50	A= 132.22 km^2

D. Water Balance

To find out whether there is sufficient or less discharge, a comparison is made between the need for irrigation water and the available discharge. The calculation results are presented in Table 5.

TABLE 5. Water balance

Month		Water Discharge (m3/sec)	Water Demand (m3/sec)	Water Balance (m3/sec)
Jan	1	5.04	0.00	5.04
	2	5.04	2.14	2.90
Feb	1	5.80	0.85	4.95
	2	5.80	3.08	2.72
Mar	1	5.81	0.19	6.62
	2	5.81	0.65	6.16
Apr	1	5.91	0.00	5.91
	2	5.91	-0.40	6.31
May	1	5.31	1.25	4.06
	2	5.31	0.25	5.06
Jun	1	5.37	0.32	5.06
	2	5.37	0.39	4.99
Jul	1	6.22	0.75	5.46
	2	6.22	0.61	5.61
Aug	1	4.60	0.27	4.33
	2	4.60	0.10	4.51
Sep	1	7.17	0.00	7.17
	2	7.17	3.59	3.58
Oct	1	4.54	3.08	1.46
	2	4.54	0.00	4.54
Nov	1	6.38	0.00	6.38
	2	6.38	0.00	6.38
Dec	1	5.50	0.00	5.50
	2	5.50	0.00	5.50

Furthermore, water requirements are divided with efficiency, where the primary Ef is 85% determined, secondary Ef 80% and tertiary Ef 80%.

TABLE 6. Water needs divided with the efficiency factor

Month		Water Discharge (m3/sec)	Water Demand/Ef0.54 (m3/sec)	Water Balance (m3/sec)
Jan	1	5.04	0.00	5.04
	2	5.04	3.96	1.08
Feb	1	5.80	1.57	4.22
	2	5.80	5.70	0.10
Mar	1	5.81	0.36	6.45
	2	5.81	1.20	5.61
Apr	1	5.91	0.00	5.91
	2	5.91	-0.73	6.64
May	1	5.31	2.31	3.00
	2	5.31	0.47	4.84
Jun	1	5.37	0.59	4.79
	2	5.37	0.72	4.66
Jul	1	6.22	1.40	4.82
	2	6.22	1.13	5.09
Aug	1	4.60	0.50	4.10
	2	4.60	0.18	4.42
Sep	1	7.17	0.00	7.17
	2	7.17	6.65	0.52
Oct	1	4.54	5.70	-1.16
	2	4.54	0.00	4.54
Nov	1	6.38	0.00	6.38
	2	6.38	0.00	6.38
Dec	1	5.50	0.00	5.50
	2	5.50	0.00	5.50

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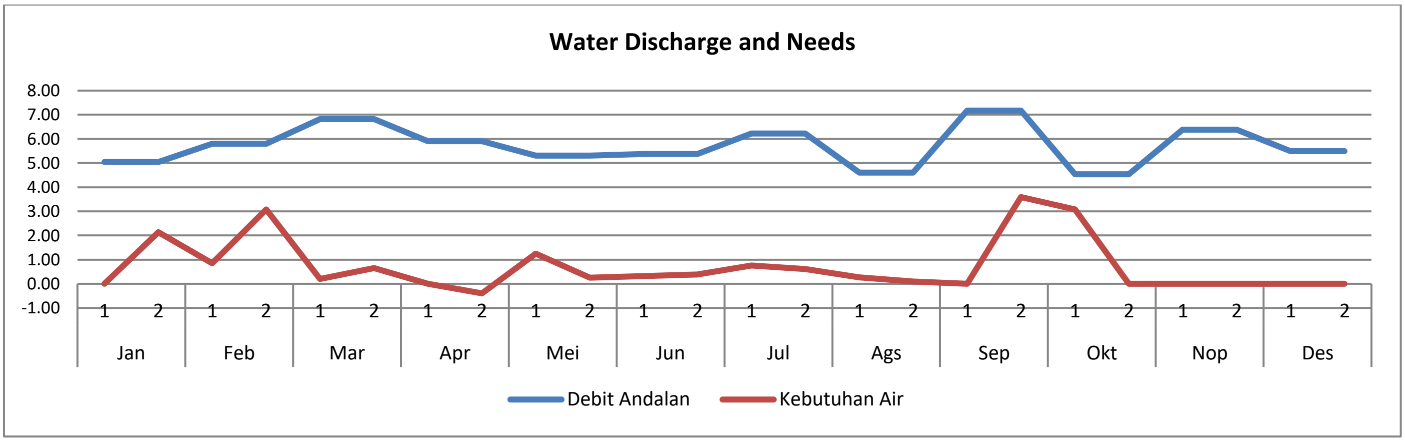

Fig. 2. Water discharge and needs for the irrigation

TABLE 7. Alternative water needs

PERIOD		ETO (mm/day)	P	R Effective for rice	WLR	C1	C2	C3	C	Etc (mm/day)	NFR (mm/day)	DR(l/sec/ha)
1		2	3	4	6	7	8	9	10	11	12	13=12/(ex8.64)
Sep	1	0.83	1	0.35		LP	LP	LP	LP	8.23	7.88	1.40
	2	0.83	1	0.86		1.10	LP	LP	LP	8.23	7.37	1.31
Oct	1	2.58	1	2.46		1.10	1.10	LP	LP	9.38	6.91	1.23
	2	2.58	1	1.08	1.10	1.05	1.10	1.10	1.08	2.80	3.82	0.68
Nov	1	1.95	1	3.23	1.10	1.05	1.05	1.10	1.07	2.08	0.96	0.00
	2	1.95	1	4.31	2.20	0.95	1.05	1.05	1.02	1.99	0.88	0.16
Dec	1	2.26	1	6.34	1.10	0.00	0.95	1.05	0.67	1.51	-2.74	0.00
	2	2.26	1	4.11	1.10		0.00	0.95	0.32	0.72	-1.30	-0.23
Jan	1	1.79	1	1.90				0.00	0.00	0.00	0.00	0.00
	2	1.79	1	4.15		LP	LP	LP	LP	8.85	4.70	0.84
Feb	1	1.56	1	6.83		1.10	LP	LP	LP	8.70	1.87	0.33
	2	1.56	1	1.94		1.10	1.10	LP	LP	8.70	6.75	1.20
Mar	1	1.10	1	2.87	1.10	1.05	1.10	1.10	1.08	1.19	0.43	0.08
	2	1.10	1	1.85	1.10	1.05	1.05	1.10	1.07	1.17	1.43	0.25
Apr	1	1.65	1	5.74	1.10	1.05	1.05	1.05	1.05	1.73	-1.91	0.00
	2	1.65	1	4.07	1.10	0.00	0.95	1.05	0.67	1.10	-0.87	-0.15
May	1	1.33	1	2.65	1.10	0.50	0.00	0.95	0.48	0.64	2.74	0.49
	2	1.33	1	0.22		0.75	0.50	0.00	0.42	0.55	0.55	0.10
Jun	1	0.93	1	0.39		1.00	0.75	0.50	0.75	0.69	0.69	0.12
	2	0.93	1	1.30		1.00	1.00	0.75	0.92	0.85	0.85	0.15
Jul	1	1.76	1	0.96		0.82	1.00	1.00	0.94	1.66	1.66	0.30
	2	1.76	1	2.27		0.45	0.82	1.00	0.76	1.33	1.33	0.24
Aug	1	1.40	1	0.55			0.45	0.82	0.42	0.59	0.59	0.11
	2	1.40	1	3.31				0.45	0.15	0.21	0.21	0.04
						Maximum water demand for planting season I						1.40
						Maximum water demand for planting season II						1.20

E. The dimension of Irrigation Channel

The final result of determining channel dimensions is as follows:

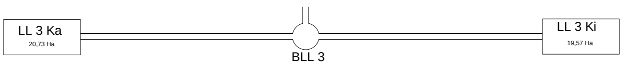

Fig. 3. Transversal scheme of the irrigation channel

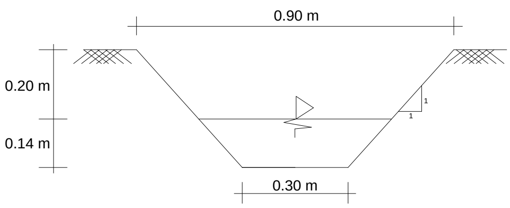

Fig. 4. Cross-section A-A

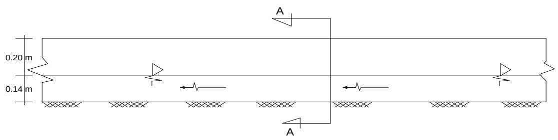

Fig. 5. Transversal scheme of the irrigation channel

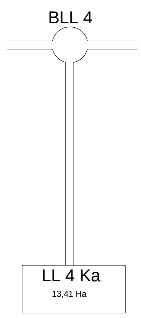

Fig. 6. Cross-section

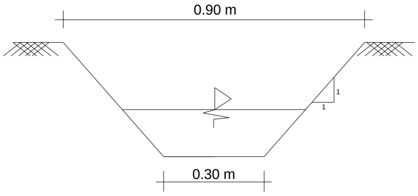

Fig. 7. Cross-section A-A

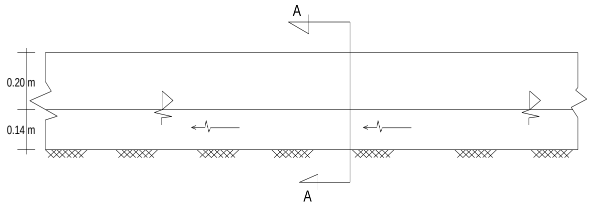

Fig. 8. Transversal section of irrigation network

F. Water Distribution System

The irrigation system was created to optimize the use of water for rice farming in the fields. Today, various irrigation systems have been developed to increase the sustainability of water productivity. The survey results in Lokoliku Village, Wewewa Subdistrict, Southwest Sumba Regency show that the elevation of the land is good support for graffiti water distribution, so it is highly recommended to implement a continuous flow system (Continous Flow System). Continuous Flow System is a system of continuous water drainage through quaternary distribution channels to rice fields in all irrigation areas. In this system, water is distributed through tapping gates in rice fields.

Furthermore, in a rice field plot, water flows from the first plot that receives water to subsequent plots until the whole plot is flooded. If the water has exceeded the plot capacity, it will then flow into the drainage system. Thus, the amount of water that must be flowed from the Quaternary channel to the rice field plot is the sum of evapotranspiration, percolation, seepage and excess water discharged through the drain. In terms of equity and efficient use of water, continuous water supply has the potential to dispose of water or is inefficient. The advantages and disadvantages of continuous water supply are described as follows. The Continuous Flow System has several advantages, including labor efficiency because water management is very simple, standing water in the rice fields remains high so that the growth of weeds can be hampered, the water supply in the rice fields remains sufficient even if there is a problem in the water source, the addition of substances The nutrients from irrigation water into the rice fields are continuous, and the dimensions of the quaternary and sub-terrain channels are quite small. The Continuous Flow System also has several disadvantages, including water waste in the upstream / near the tapping gate, while in remote areas (downstream) it is unlikely to receive water. In addition, it cannot use rainwater because the rice fields are full of water. The rice field area has the potential to experience flooding if high rainfall.

Based on these considerations, and in terms of sedimentation problems that occur in the field, the implementation of the Continuous Flow System must be initiated by improving existing water channels so that the water supply can meet the needs in all fields. From the results of the analysis and processing of available water discharge data that exceeds the crop water requirements, it is necessary to do maintenance by re-evaluating the problem and implementing a good management system so that the water needs in the irrigation area can be met. The result is maximally satisfying the food needs of the surrounding community.

IV. CONCLUSION

The conclusions of this study are:

1. The water demand for each hectare area was 1.4 m^3/sec/Ha.
2. The total of waterdischarge required for watering the whole area was 121.64 Ha is 170,296 m3/sec.
3. The planned and suggested new channel dimensions were trapezium-shaped channels with a bottom width of 0.30 m, top width of 0.90 m, the height of the wet channel 0.14 m, and a height of 0.20 m for the embankment.

Generally, the results of the analysis show that the water availability was enough to support the water needs, thus it needs to be supported by an adequate irrigation system. The results of this study can be used as recommendations for the stakeholders, such as the local agriculture department, the irrigation department or other agencies for developing the irrigation system to support the argiculture in the area.

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