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Runoff Analysis Based on Rainfall in Gegesik Irrigation Area

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ABSTRACT

The amount of runoff water flow needs to be calculated based on rainfall data in the region. This research aims to analyze rainfall data to obtain the amount of runoff discharge in the Gegesik irrigation area. In this study using a quantitative approach. The research begins with conducting field surveys and collecting data from related agencies. The method used in analyzing rainfall data uses the Thiessen polygon method to obtain regional rainfall and the NFR method to obtain irrigation water requirements. Based on the analysis of rainfall data using the Thiessen polygon method, it can be seen that the average value of rainfall area in 10 years is 42.32 mm. So it can be known that the need for irrigation water with the NFR method occurs in November, which is 12.67 mm/day. After analyzing these results, it can be seen that the existing discharge is 0.77 m3 / s, the flood discharge that occurs is 1.24 m3 / s and the runoff discharge is 0.47 m3 / s. After the embankment elevation of 1 m, it can be seen that the discharge is 0.999 m3 / s, it can be concluded that the discharge capacity after making the embankment can accommodate the runoff discharge. So to reduce water runoff into rice fields from the research that has been done, it can be suggested to change the dimensions of irrigation with the initial height of the embankment of 0.84 m to 1 m and the need for dredging because of the large amount of sediment that settles in irrigation channels that can cause water to run over into the fields.

Introduction

Gegesik is an area located in Cirebon Regency. (Dienaputra et al., 2022)Water resources can be utilized for agricultural purposes. The Gegesik irrigation area in the rainy season often exceeds the need for irrigation water, so the overflowing water from the waste channel exceeds the capacity of the runoff channel. Irrigation water requirements (NFR) also play an important role in determining the dimensions of runoff flow. NFR is expressed in liters/second/ha.

Gegesik's irrigation network is the performance location of UPT PSDA Kumpulkwista, which is located in the Gegesik sub-district, Cirebon Regency, and has an area of 11,638 ha, by Government Regulation No. 25 of 2001 concerning irrigation. The definition of irrigation networks is channels, buildings, and additional structures forming a single unit that regulates irrigation water starting from the supply, collection, distribution, management, use, and disposal. (Wahid & Anwar, 2016)This research aims to determine the need for irrigation water, the amount of discharge that flows into the runoff flow area in the Gegesik irrigation area, and the dimensions of the runoff channel needed in the Gegesik irrigation area.

Surface runoff is all the water that flows over the earth's surface and flows to deeper levels, such as basins, rivers, lakes, reservoirs, and oceans. (Chandra Sari et al., 2017; Harisuseno & Bisri, 2017; KHARJA et al., 2017). The amount and distribution of runoff is the most important cause of erosion and sedimentation. The greater the impact on the surface, the less water the soil can absorb (Bataradewa & Budirianto, 2021; Mahmud et al., 2024).

Surface runoff is when rainwater is not retained in the soil, vegetation, or watershed and flows directly into the river. (Mohammad et al., 2023). Factors causing surface runoff can be divided into two parts: meteorological factors (rainfall intensity, rainfall duration, and rainfall distribution) and watershed characteristics factors (watershed area and shape, topography, and land use) (Mohammad et al., 2023).

Surface runoff still occurs in many urban areas and is caused by drainage channels that cannot absorb water. The function of drainage channels is to channel surface water into infiltration channels or channels that lead to natural rivers and control inundation and flooding, mainly due to increased surface runoff due to development. (Nus.antara, 2020). The leading cause of this disaster is due to human intervention such as: Decreasing land area as a watershed due to irregular destruction of forests, lack of maintenance of flood control and flow control, sedimentation, obstruction of drainage, etc., and environmental pressure to maintain the functions and benefits of water resources decreases its ability. System anomalies and rainfall exceeding normal limits. Flooding is a natural phenomenon caused by heavy rain and the reduced ability of a water body (river or sewer) to absorb and drain water. Flooding is not a problem if it does not disrupt activities or cause losses to human life. However, immediate action must be taken when human lives or property are involved. Therefore, flood management is needed to reduce losses (Nurdiyanto, 2019).

Although the existence of water sources is renewed through the hydrological cycle, changes in climate and land cover cause changes in the water balance, thus requiring control of water sources as well as adaptation and mitigation efforts in natural resource infrastructure planning. To ensure the sustainability of water sources, it is necessary to study the hydrology of water sources and watersheds, taking into account the problems of the water cycle, hydrological modeling of watersheds, land degradation processes in river sections, the reliability of water sources, and the impact of deteriorating water balance. We investigated water sources. Restoration and adaptation efforts are carried out along with these changes, which are part of watershed management (Wahid & Anwar, 2016). Extreme rainfall and land use change due to urbanization can affect soil properties, mainly through soil and riverbank erosion and the loss of nutrients and pollutants such as nitrogen, phosphorus and potassium to existing agricultural land. Surface runoff and watershed water management severely damage bridges, public infrastructure, flooding and siltation (Mazur, 2018). flooding. Flooding is a natural phenomenon that occurs frequently. Floods cause many losses. Floods can occur due to high rainfall, poor land use, etc. Therefore, the role of flood control is important (Wahid & Anwar, 2016). Irrigation is a water structure in the form of a channel that functions to drain water from the dam to the plot periodically to meet the water needs of plants in the rice field dam. Water is one of the determining factors in the agricultural production process. Therefore, irrigation investment is significant and strategic for agricultural water supply. To meet the water needs of various farm purposes, water (irrigation) must be available in sufficient quantity, time, and quality. If not, plant growth will be inhibited, ultimately affecting agricultural production (A. K. Sari, 2019). Irrigation is an artificial structure intended to supply, regulate, and remove excess water. This research was conducted to determine the amount of irrigation runoff needed, the amount of runoff available on irrigation channels, and the amount of overflow runoff (Gumilar & Permana, 2021).

Research conducted by Rahman & Anwar, (2017) Analysis of the Performance of the Kumpulkwista Irrigation Network in Cirebon Regency. Based on the data analysis, it can be concluded that the performance and function of the irrigation channels are suboptimal, with an average condition of below 55% (functioning poorly), so that they cannot carry out the existing water management/water services. Therefore, normalization efforts are needed (Improvement, Rehabilitation, Maintenance, and Care) of the Irrigation Network (Irrigation Channels and buildings).

The novelty of this study is that in contrast to previous studies that only focused on irrigation water needs or runoff analysis separately, this study combines both aspects to provide a more holistic solution in water resource management in the Gegesik area. In addition, this study examines the irrigation and runoff systems using actual data from the Gegesik area, Cirebon, which is still limited in previous studies. This data will provide an accurate picture of irrigation and runoff problems in the area.

This research aims to determine the irrigation water requirements (Net Irrigation Requirement/NFR) for irrigation systems in the Gegesik area. Its benefits include helping farmers and the community understand irrigation water requirement patterns and the impact of excessive surface flow on agricultural productivity.

Method

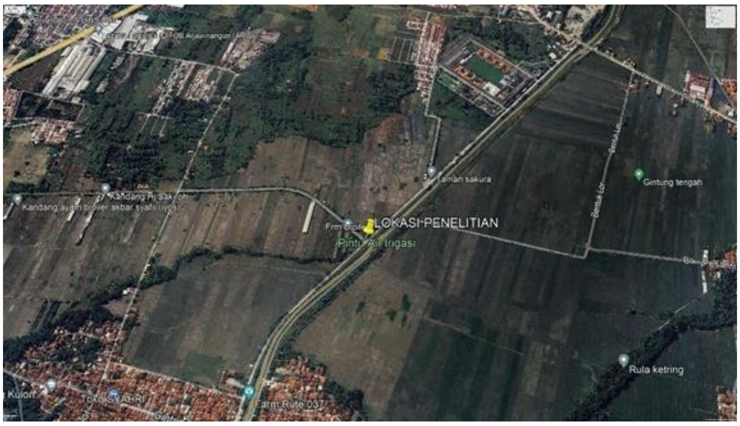


Figure 1: Watershed of the Research Site concerning 3 Rainfall Stations

This research was conducted during the STA Gintung Lor, Cirebon Regency, and West Java runoff, with coordinates 108˚24 45' East 6˚38" 16 LS. The flow that overflows into the rice field area is detrimental to the owner of the rice field. Primary data was obtained through interviews with residents to obtain runoff information and analyze the conditions around the irrigation flow and the embankment at the location of the research site. Secondary data, which was used in the form of irrigation network building schemes, village plot areas, and flow rates, was obtained from the Regional Technical Implementation Unit (UPTD) PUPR Region 1 on Jl—Dusun lima village Gegesik kidul sub-district Gegesik regency Cirebon, West Java. The rainfall data was obtained from the Cirebon Regency Public Works and Spatial Planning Office (PUTR).

This research begins with field observations to obtain flow discharge data. After making observations in the field, the next step is to analyze regional rainfall using the Polygon Thiessen method. This method provides the results of the area of rainfall stations that affect a watershed, so that rainfall between stations is considered linear and represents the region. (Ramadhan & Susetyo, 2021). Next calculate the peak flow discharge.

$$P = \frac{A1.p1 + A2.p2 + A3.p3 + \cdots + An.pn}{A1 + A2 + A3 + \cdots + An} = \sum_{i=1}^{n} \frac{Ai.\,pi}{Ai}$$

P= Regional Rainfall (mm)

A1,A2,A3,...,An = Area of Influence STA 1,2,3,...,n p1,p2,p3,...,pn = Area of Influence STA 1,2,3,...,n

The results of rainfall calculations based on the Thiessen polygon equation are presented in Table 1. The rational method is used to estimate the peak discharge Qp. The equation of the rational method for estimating peak water flow can be calculated using the following equation:

Qp = 0.00278 .C. I. A

Q = Peak Discharge (m^3/second) C= Flow Water Coefficient

I = Rain Intensity (mm/hour)

A = Watershed Area (Km^2) 0.00278 = (Terms)

After calculating the rainfall, the next step is calculating the irrigation water requirement using the NFR method. The field's NFR or irrigation water requirement is used to analyze runoff based on rainfall in the Gegesik irrigation area. The formula used is as follows:

$$NFR = Etc + p + WLR - Re \quad DR = (NFR \times A)/e$$

NFR = net water demand in rice fields (mm/day)
Etc = crop evapotranspiration (mm/day)
P = percolation (mm/day)
Re = effective rainfall (mm/day)
WLR = water layer replacement (mm/day)

To calculate the capacity of the river channel, the Manning formula is used as follows:

$$\boldsymbol{Q = A \times V}$$

Q = Discharge (m3 /det)

A = Cross-Sectional Area (m2) V = Flow Velocity (m/sec)

To calculate the runoff in the Gegesik irrigation area, the following formula is used:

Q = Qmax - Q Capacity

Q = Runoff Discharge (m3 /det)

Results and Discussion

Rainfall Analysis

High-intensity rainfall has a higher infiltration capacity than low-intensity rainfall. Even during heavy rainfall events, the total surface flow generated is more significant, even though the amount of rainfall in both events is the same. However, during heavy rain, the kinetic energy of rainwater can damage the soil surface structure and reduce infiltration. (Farida & Irnawati, 2020),

When the intensity of rainfall in a watershed exceeds the infiltration capacity, water will fill the depressions in the soil surface when the infiltration rate is reached. When the basins are complete, the water flows to the surface. (Ikhwan et al., 2022).

The rainfall data used in this study is rainfall data from STA Walahar, STA Bunder, and STA Arjawinangun in the last 10 years from 2013 - 2022. Where the data is obtained from PUTR Kab. Cirebon, as for the annual average amount of data as follows:

Table 1. Rainfall Data for 10 Years 3 Stations

Tahun	Curah Hujan Stasiun (mm)		
	Walahar	Arjawinangun	Bunder
2013	42.29	36.92	33.92
2014	6.88	58.00	6.33
2015	12.08	46.25	6.71
2016	56.33	48.21	45.33
2017	57.42	33.08	38.92
2018	25.54	25.94	32.00
2019	23.88	25.38	34.13
2020	63.54	53.94	44.33
2021	57.88	53.77	50.33
2022	66.79	55.75	57.58

Source: Calculation Results

Based on the mapping of 3 rainfall stations, the area of influence of rainfall is obtained based on the Thiessen polygon method as follows:

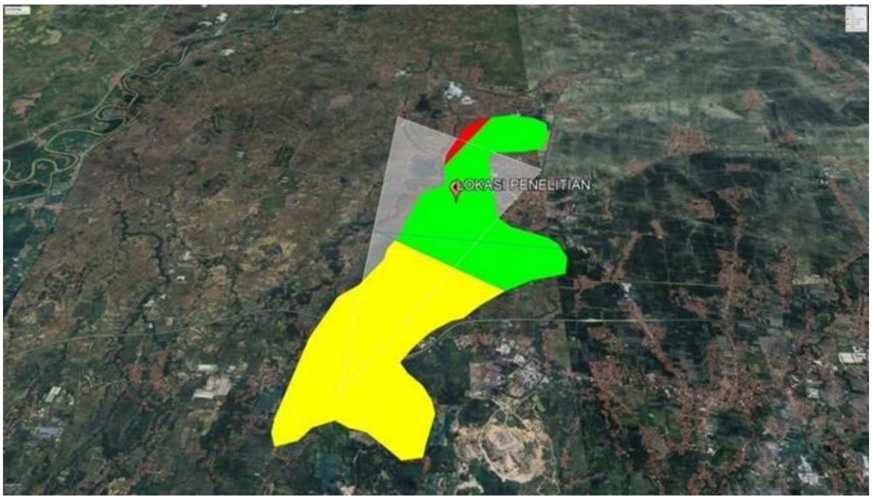


Figure 2: Effect of Polygon on Watershed

Influence of Rainfall Stations on Watersheds

Table 2. Influence of Rainfall

STASIUN	WIDE	PRESENT
WALAHAR	16.	48.476
ARJAWINANGUN	16.5	49.071
BUNDER	0.825	2.454
JUMLAH	33.625	100

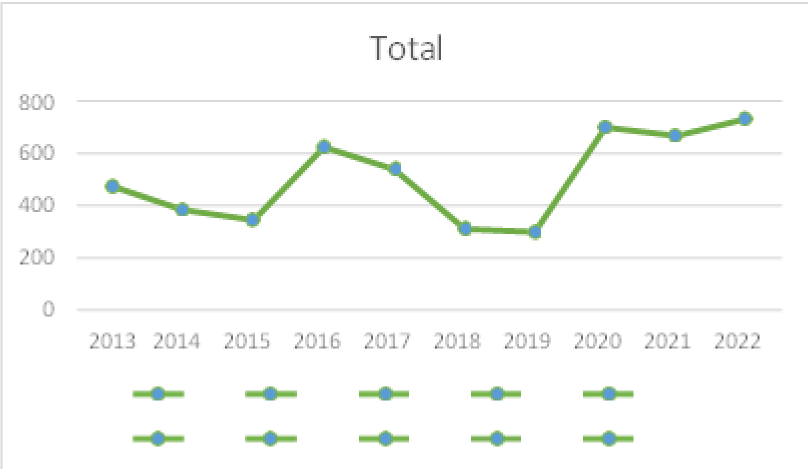
Source: Calculation Results

The results of the calculation of regional rainfall in the watershed can be detailed in the following table:

Table 3. Regional Rainfall 2013-2022

No	Year	Amount	Average
1	2013	473.38	39.45
2	2014	383.39	31.95
3	2015	344.61	28.72
4	2016	624.92	52.08
5	2017	540.27	45.02
6	2018	310.73	25.89
7	2019	298.35	24.86
8	2020	700.29	58.36
9	2021	668.11	55.68
10	2022	733.77	61.15

Source: Calculation Results



Fugure 2. Calculation Result

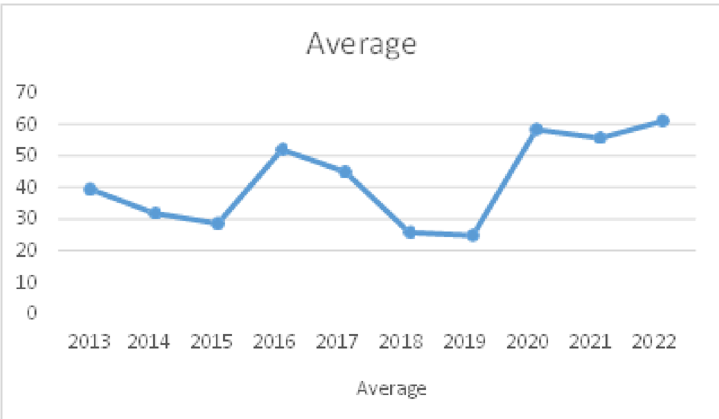


Figure 3. Average

Irrigation water discharge is the amount of water flowing per unit of time expressed in m3

/second or liter/second. To meet the needs of irrigation water, a probability of a reliable discharge must be made, which shows that the availability of irrigation water can match or exceed the irrigation water needs. Debit mainstay (Dependent flow) is the minimum discharge of the river at a certain level of opportunity that can be utilized for water supply. Calculate the mainstay discharge to find the amount of discharge available for irrigation water needs with a calculated risk of failure (Saragi et al., 2023).

After obtaining the results of regional rainfall calculations using the Thiessen polygon method, channel dimension calculations are carried out by comparing the width of the channel base (b) and the depth of the wet channel (h), which is associated with channel capacity. How to determine channel dimensions using the continuity equation. (Dwiputri, 2018). Then the next step is to calculate the water flow discharge using the rational method, so that the results of the flow discharge calculation are as follows:

Table 4. Calculation Result of Water Flow Discharge

No	Year	Average
1	2013	112.45
2	2014	126.79
3	2015	117.95
4	2016	99.98
5	2017	153.16
6	2018	59.09
7	2019	78.08
8	2020	97.58
9	2021	76.46
10	2022	161.93
Jumlah		1083.47
Rata-Rata		108.35

Source: Calculation Results

Analysis of Water Requirements for Irrigation using the NFR method
Effective Rainfall

Water requirements for irrigation are analyzed based on effective rainfall (Re). To calculate the effective rainfall for rice, use the following formula:

For paddy Re = 70% × R80 / 30

On January 1 for rice Effective Rainfall Re (1) = 70% × R80 / 15

= 70 % × 0.12 / 15

= 0.01 mm/day

Other calculations can be presented in Table 5.

Table 5. Effective Rainfall on Rice

Month	Re (mm/day)
Januari	1.33
Februari	0.80
Maret	1.03
April	0.46
Mei	0.31
Juni	0.01
Juli	0.00
Agustus	0.00
September	0.01
Oktober	0.00
November	0.16
Desember	0.03
jumlah	4.14
Rata-rata	0.35

Source: Calculation Results

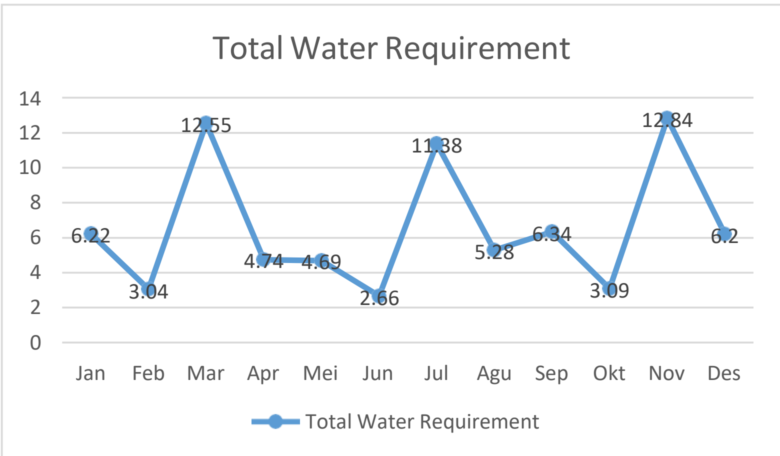


Figure 4. Total Water Demand

Water Requirements for Land Preparation for Rice

a. Land preparation for rice starts in July with:
   Eto = 3.19 mm/day
   Percolation = 1 - 3 mm/day
   Percolation taken = 2 mm/day
   Land preparation time (T) = 30 days
   Saturation (S) = 250 mm
b. Analysis of replacement water demand: Evaporation and percolation
   $M = (1.1 \times ETO) + P$

= (1.1× 5.28)+ 2

= 7.81 mm/harI

c. Analysis of K value

$$K = \frac{M \times T}{S}$$

$$= \frac{7.81 \times 30}{250}$$

$$= 3.6$$

d. Analysis of paddy field water demand

IR = M × ek / (ek - 1)

= 7.81 × e3,6 / (e3,6 × 1)

= 30.84 mm/day

e. Irrigation water requirement for land preparation

NFR = IR - Re

= 30.84-0.2

= 30.68 mm/day

Further calculations can be seen in Table 6

The amount of water required for irrigation, or irrigation water, is the amount of water needed for irrigation, taking into account the amount of water provided by nature from rainfall and the contribution of groundwater, to meet the needs of evapotranspiration, water loss, and crop water requirements. Is the amount of water required? Plant growth is severely limited by the availability of water in the soil. Lack of water disrupts plant physiological activities and cessation of plant growth (S. Sari, 2012). Water requirements are utilized in knowing the planting pattern and determining the efficiency of the channel, so that the water requirement for each irrigation network is determined based on the following table:

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Table 6: Irrigation Water Requirement

Month	NFR (mm/day)
November	12.68
Desember	6.17
Januari	0.00
Februari	0.00
Maret	0.00
April	0.00
Mei	0.00
Juni	2.65
Juli	11.37
Agustus	5.28
September	6.34
Oktober	3.08
Jumlah	47.58
Rta-rata	3.96

Source: Calculation Results

Flow Capacity

Channel dimensions are the size of the primary, secondary, and tertiary networks, which are used to determine efficiency, water demand, discharge, wet cross-sectional area, channel water level, channel base width, channel plan water level, channel base plan, plan wet circumference, and channel base slope (Suharto, 2020).

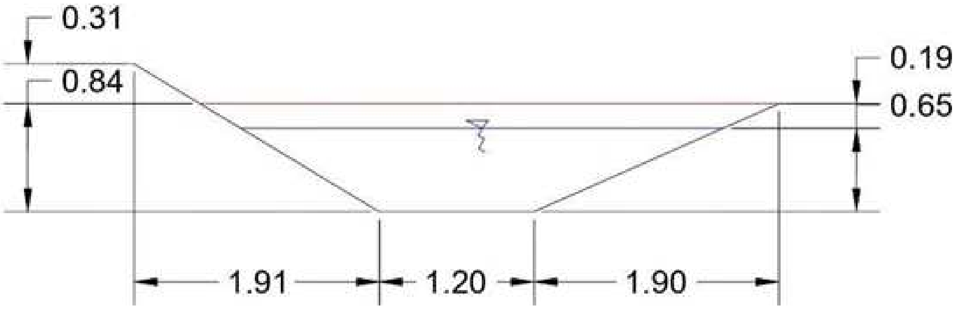

Figure 5. Channel Dimensions

Channel capacity is calculated based on the condition of the channel cross-section at the designated cross-section location. It represents each catchment area at each point (Rinaldy Saputro, 2021).

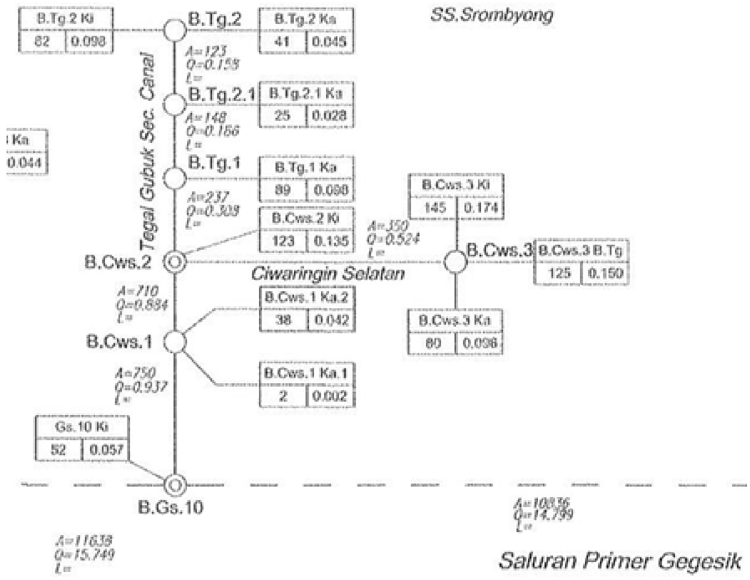

Figure 6. Network Schematic

From Figure 4 it can be seen that the water demand that must be flowed to fulfill the capacity of the design embankment has a discharge of 15,749 m3 /s, which results in the overflow of water from the right embankment to the rice fields. To find out the capacity of the river in existing conditions, the formula below:

$$Q = A \times V$$

Then the data obtained from the field are:

b= 1.2 m
h= 0.84 m
Talud= 1:1.5 with m = 1.5
V= 0.37 m/set

a. A= (b + (m × h) × h
= (1.2 + (1.5 x 0.84)) x 0.84
= 2.07 m2

b. Q = A × V
= 2.07 x 0.37
= 0.77 $m3/s$

Maximum Discharge Calculation

V = 0.37

c. A = (b + m × h) × h
= (1.2 + (1.5 x 1.15)) x 1.15
= 3.36 m^2

d. Q = A . V

= 3.36 x 0.37
= 1.24 $m/s3$

Minimum Discharge Calculation

V= 0.37 m/set

e. A = (b + m . h) . h
= (1.2 + (1.5 x 0.65)) x 0.65
= 1.41

f. Q = A . V
= 1.41 x 0.37
= 0.52 $m/s3$

Runoff Discharge Calculation

g. Q = Q max - Q capacity
= 1.27 - 0.77
= 0.47 $m/s3$

Capacity Handling Channel Dimensions

The data obtained in the field are:

B = 1.2
h = 1
Talud = 1:1.5 with m = 1.5

The cross-sectional channel shape used is trapezoidal.

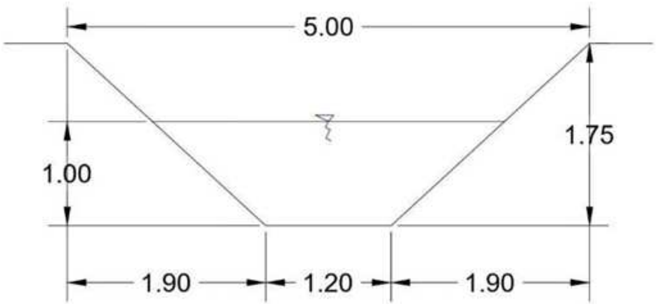

Figure 7. Channel Cross-Section

Q= A × V

a. A = (b + m × h) × h
= (1.2 + (1.5 x 1)) x 1
= 2.7 m^2

b. Q = A × V
= 2.7 x 0.37
= 0.999 $m/s3$

Conclusion

The following conclusions can be drawn from the research results and calculations that have been carried out: Based on the analysis of regional rainfall from three rainfall observation stations using the Thiessen polygon method, the average value of regional rain in 10 years is 42.32 mm. Irrigation water demand in the study area occurs in November at 12.67 mm/day based on NFR calculations. With the known discharge capacity of 0.77 m3 /s and the maximum discharge of 1.24 m3 /s, it can be known that the runoff discharge is 0.47 m3 /s, it can be concluded that the discharge capacity after making the embankment can accommodate the runoff discharge. So to reduce water runoff into rice fields from the research that has been done, it can be suggested changes in the dimensions of irrigation with the initial height of the embankment of 0.84 m to 1 m and the need for dredging because of the amount of sediment that settles in irrigation channels that can cause water to runoff into the fields.

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