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Optimized Plant Productivity by Evaluating the Performance and Capacity of the Primary Channel at the Irrigation Area (I.A.) Jeuram in Nagan Raya Regency

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ABSTRACT

The development and improvement of irrigation infrastructure serve as the primary source of water supply during the growing season, which can significantly enhance agricultural production. This research aims to evaluate the performance of irrigation systems and the capacity of irrigation channels, this is essential to minimize water loss during the distribution of irrigation water, ensuring that the water needs of rice fields are met and optimizing crop productivity. The research was conducted in Irrigation Area (I.A) Jeuram. This research method is carried out by inventorying the existing conditions of physical and non-physical infrastructure. Then, was evaluates of irrigation area performance, based on the irrigation performance index. The hydraulic analysis to evaluate the channel using HEC-RAS software. The performance of the physical infrastructure of I.A. Jeuram is 26.38% of the optimal condition is 35%. This condition is categorized as moderately to severely damaged. Crop productivity stands is 9.64% of the optimal level of 12.5%. The overall performance index of I.A. Jeuram is 59.32% of its optimal condition, which is 77.5%, indicating that it is in desperate need of attention. While the primary channels can still accommodate the required discharge, its condition is also classified as moderately to severely damaged, compounded by issues of uncontrolled sedimentation. The physical and non-physical infrastructure adversely affects crop productivity and the overall service area of the Jeuram irrigation region. Therefore, it is essential to initiate repairs and ensure regular or periodic operation and maintenance of the irrigation system.

Keywords: crop productivity; HEC-RAS; performance evaluation; irrigation; performance index.

INTRODUCTION

The agricultural sector is the largest consumer of water in the world, consuming on average 70% of all water resources and reaching values close to 95% in some developing countries [1]. Water supply for agricultural needs is facilitated by an irrigation system. The advantage of irrigation systems over rainfed production is that they support farmers during dry seasons, ensuring crop production is not affected and enhancing the quality of agricultural products [2]. Evaluation of the regulation, distribution of water, operation and maintenance of irrigation water networks and irrigation infrastructure planning are the main factors that affect the productivity of agricultural products [3]. The supply and distribution of irrigation water is one of the factors supporting increased plant production. Incorrect management of irrigation networks can result in a decrease in the condition and function of irrigation networks which has a direct impact on agricultural yields [4]. The development and improvement of irrigation infrastructure as the main source of water supply in the growing season can increase development in agriculture to increase production. Construction of buildings and irrigation channels to support the provision of national food is very necessary, the availability of water on the land will be fulfilled even though agricultural land is far from water sources [5].

Limited water availability during the dry season often leaves plant water needs unmet, resulting in decreased agricultural production. Water is a crucial factor influencing growth and enhancing agricultural yields in both quantity and quality. Therefore, it is essential to manage the distribution and allocation of water effectively and efficiently across all channels and irrigation infrastructures to ensure that agricultural water needs in the Jeuram Irrigation Area (I. A.) are adequately met.

The need for water in rice fields during the planting season is a major factor that greatly affects the productivity and quality of agricultural products. The availability of water in rice fields is greatly influenced by the water distribution and distribution system in the irrigation network. A suboptimal irrigation network can affect water loss along the channel and affect the amount of water received by the rice fields. Damage to the irrigation network can be identified by conducting an inventory and evaluation of the existing condition of the irrigation network. The results of the network evaluation need to be followed up with more innovative efforts to solve the problem.

The evaluation of the irrigation network in the Jeuram Irrigation Area (D.I.) must be conducted periodically to ensure that it meets the water requirements of rice fields during the planting season. Currently, the irrigation network is experiencing decreased performance, leading to significant water loss. This issue prevents the irrigation system from adequately serving D.I. Jeuram, which adversely affects agricultural production and quality. The network evaluation results need to be followed up with more innovative efforts to solve the problem. Therefore, research was conducted to evaluate the performance of irrigation channels and capacity to meet the water needs of rice fields, water loss problems, and improvement efforts that will be made to answer the problem of field water needs.

RESEARCH METHODS

Irrigation networks are channels, buildings, and complementary buildings which are a single unit needed for the provision, maintenance, provision, use, and disposal of irrigation water. Irrigation channels are infrastructure that distributes water from dams, weirs, and reservoirs to agricultural land owned by the community. With this irrigation channel, the water needs of the farmers' fields will be guaranteed [6]. Classification of irrigation networks when viewed from the aspect of their arrangement can be divided into three types, Simple Irrigation Networks, Semi-Technical Irrigation Networks, and Technical Irrigation Networks.

Figure 1. Layout of the research locatio

The research was conducted in the Jeuram Irrigation Area (D.I) located in Nagan Raya Regency. The objects of the research were the main building (bending), primary channels and rice fields that were flowed by the primary channels. The research location can be seen in Figure 1. The research flowchart can be seen Figure 2.

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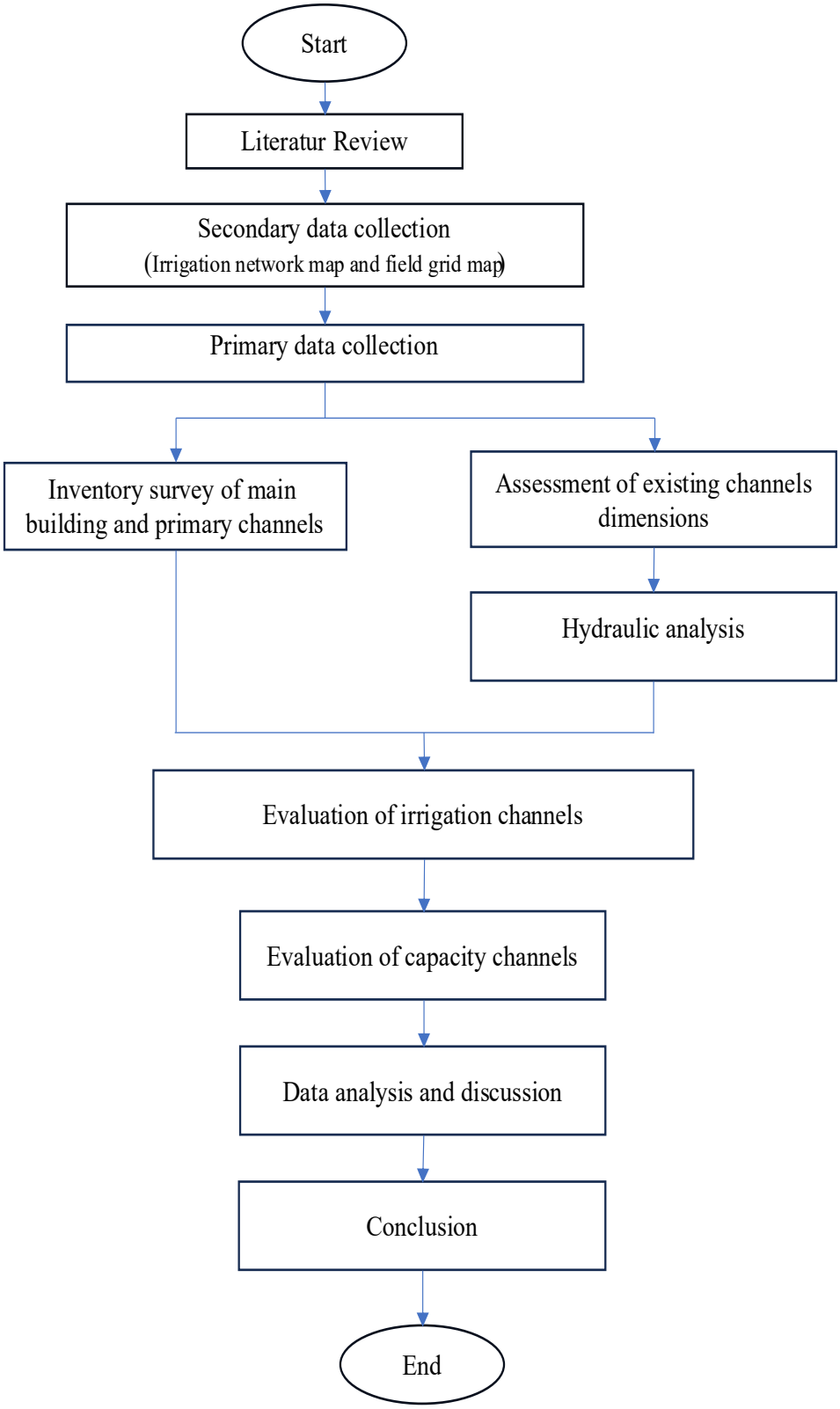

Figure 2. Flow chart

Collection Data

Data collection is classified from primary data collection and secondary data. Secondary data which includes previous studies, irrigation network maps, maps of rice fields and the organization of P3A/GP3A/IP3A D.I Jeuram. Primary data collection is done by measuring the existing conditions of the main building and irrigation canals and measuring the discharge of each building in the primary channel.

Irrigation Channel Evaluation

Performance assessment based on Minister of Public Regulation [7], Exploitation and maintenance consists of 6 indicators, namely: Physical Infrastructure Aspect, with 45% part weight; Crop Productivity Aspect, with 15% part weight; Supporting Facilities Aspect, with 10% part weight; Issues Organization Aspect with 15% part weight; Documentation Aspect, with 5% part weight; Water User Farmers Association (P3A) Aspect, with 10% part weight [8]. Damage to the irrigation network due to cracked or destroyed channels can cause the volume of water not to be maximized when flowing. The assessment carried out is based on the Overseas Development Administration condition level. The assessment is based on 2 components, namely, channels and regulatory buildings. Based on the assessment channel is divided into 4 conditions, namely good, lightly damaged, moderately damaged, and severely damaged. Based on the regulations building is divided into 3 conditions, namely good, lightly damaged, and heavily damaged [9].

Inventory of irrigation networks is done by direct observation method. Assessment of the condition of buildings or channels inventoried is divided into 4 scales, namely: B (Good), RR (Lightly Damaged), RS (Moderately Damaged), and RB (Severely Damaged) with the following:

1. the building is in good condition if the current condition of the building is between 90% - 100% of its previous condition.
2. A building is in the middleDamaged condition if the current condition of the building is between 80% - <90% of its previous condition.
3. A building is considered to be in Moderate Damage condition if its current state is between 60% and less than 80% of its previous condition.
4. A building is considered to be in a condition of Serious Damage if its current state is less than 60% of its original condition.

An Irrigation Network after completion of construction, there will be a process of damage that is getting longer and longer. Assessment of the condition of the Irrigation Network Physical Infrastructure is divided into two criteria [10] that is:

1. The condition of the irrigation network is assessed by comparing the damage level to its initial state.
2. Physical function of the irrigation network, assessed based on the level of ability to drain water compared to the planned capacity.
3. The physical condition of the irrigation network in this guideline is grouped into 4 (four), that is:
   - ✓ Good criteria B, if damaged level: < 10%; routine maintenance
   - ✓ Minor damage RR, if damaged level: 10% - 20%; periodic maintenance
   - ✓ Moderately damaged RS, if damaged level: 21% - 40%; repair
   - ✓ Severely damaged RB, if damaged level: > 40%; replacement
4. The function of the irrigation network is assessed based on the level of water flow capacity compared to the planned capacity.
   - ✓ Good criteria B, if decreased function: 0% - 20%;
   - ✓ Lack Criteria K, if decreased function: 20% - 40%;
   - ✓ Bad criteria BR, if decreased function: 40% - 80%;
   - ✓ unfunction TB, if decreased function: 80% -100%.

Hydrology Analysis

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Available discharge refers to the volume of water flowing in the river, determined using daily rainfall data [9]. The analysis of the flood design discharge is calculated after obtaining the planned rainfall data for the period T years. The planned flood discharge is an estimate of the extreme condition discharge at a location to analyze the flood that will occur at a location for a predetermined return period [11]. In this research river discharge is obtained from the results of primary data collection which includes river depth, width, and river flow velocity. River discharge is calculated with Equation 1.

$$Q = A \times v \quad (1)$$

here A is the wet cross-sectional area (m^2); V flow velocity (m/s); dan Q discharge (m^3/s).

Evaluation of Capacity Channels

Hydraulics analysis aims to determine the dimensions of the channel based on normal river discharge and flood river discharge. The calculation of the trapezoidal shape channel is calculated with the following equation [12]:

$$A = (b + zy) \times h \quad (2)$$
$$P = \mathrm{b} + 2\mathrm{y}\sqrt{1 + Z^2} \quad (3)$$
$$T = \mathrm{b} + 2\mathrm{y} \quad (4)$$
$$R = \frac{A}{P} \quad (5)$$

Irrigation channel capacity is calculated using the Manning and Continuity formulas [13]:

$$V \, {}^{1}/_{n} \times R^{2/3} \times S^{1/2} \quad (6)$$
$$Q = A \times V \quad (7)$$

Which: A = channels area (m^2); P = wet perimeter (m); R = hydraulic radius (m); T = peak width (m); V = Velocity flow (m/det); Q = discharge (m^3/det); S = sloope

Evaluation of irrigation cross-sectional capacity is done to determine whether or not the primary channel can accommodate discharge as a cause of overflow. if $Q_{plann} > Q_{cap}$ then the channel needs to be redesigned, otherwise if $Q_{plan} < Q_{cap}$ then the channel does not need to be redesigned [14].

The hydraulics analysis was calculated with the Hec-Ras program. Hec-Ras was developed and created by the Hydrologic Engineering Center (HEC) which is part of the Institute for Water Resources (IWR) under the U.S Army Corps of Engineering (USACE). This program is designed to examine water level profiles, channel changes, and hydraulic calculations [15]. The HEC-RAS program in addition to calculating one-dimensional profiles of river water surfaces is also used to simulate non-uniform flow and calculate sediment transport and water quality [16]. The hydraulics analysis approach with the Hec-Ras program is more paretic and economical time in the calculation process [17]. Existing channel measurement data and discharge data were inputted to obtain channel cross-sectional dimensions in the Hec-Ras program. Flow discharge results were used to determine the capacity of irrigation channels using Hec-Ras software. If Qs > Qb then there is no overflow, otherwise if Qs < Qb then overflow occurs, so it is necessary to plan the dimensions of the new channel

The valuation of the irrigation network channels is conducted using hydraulic analysis. This analysis is performed after determining the design of flood discharge and normal discharge. The purpose is to establish the dimensions and shape of the irrigation canal cross-section, ensuring it can accommodate both normal irrigation flow and flood discharge. To assess the irrigation canal's cross-section, it's essential to calculate both normal and flood discharge. The shape of the channel can be either trapezoidal or rectangular, depending on the specific needs and conditions of the open channel. It's important to note that the flow in irrigation channels is typically not uniform. To determine the

capacity of the channel, we first need to measure and calculate the area of the channels as well as the parameters that shape it. The evaluation of the primary channel capacity in the Jeuram irrigation system is conducted using Equations 2 to 7.

RESULT AND DISCUSSION

Inventory and evaluation of physical facilities

The physical infrastructure of irrigation consists of the existing condition of the main building, the carrier channel, the building on the carrier channel, the waster channel, the building on the waster channel, the inspection road, and the office. The results of the evaluation and assessment of the physical condition of D.I Jeuram can be seen in Table 1.

Table 1. Assessment of Physical facilities

No.	Assessment Item	Existing Condition (%)	Maximum Condition (%)
A	Physical Facilities		
1	Main Buildings	8,53	13,00
2	Carrier Channels	6,50	10,00
3	Building at Carrier Channels	6,30	9,00
4	Disposal Channels and building	2,10	4,00
5	Access/Inspect Road	1,95	4,00
6	Housing, Office, and warehouse	1,00	5,00

Inventory and evaluation of nonphysical facilities

Non-physical facilities in the Irrigation Area include aspects such as plant productivity, supporting facilities for operations and maintenance, the organizational structure for operations and maintenance personnel, the availability of relevant documentation, and the institutional support for the Water User Farmers Association (P3A). The results of the assessment of these non-physical infrastructure components are presented in Table 2.

Table 2. Assessment of nonphysical facilities

No.	Assessment Item	Existing Condition (%)	Maximum Condition (%)
A	Nonphysical facilities		
1	Plant productivity	9,64	15,00
2	Supporting facilities	3,60	10,00
3	Personal organization	10,80	15,00
4	Documentation	2,90	5,00
5	Water User Farmer Group	6,00	10,00

Plant productivity

Plant productivity encompasses an evaluation of irrigation water requirements, crop yield, and rice productivity. The available discharge is 15,700 liters per day per hectare (lt/dt), while the required discharge is 12,370 lt/dt. Currently, there are still rice fields that are not being properly irrigated due to sedimentation in the irrigation channels and damage to those channels. The total area of the D.I. Jeuram is 5,810 hectares, and the growing season occurs twice a year. The first planting season (MT-1) is 5810 ha and the second planting season (MT-II) is 4,470 ha. The annual crop realization area is 10,550 ha. The percentage of crop realization per year is 70%. Average rice productivity is 6.5 tons/ha with rice productivity in 2023 being 5.8 tons/ha. So the average percentage of rice productivity presentation is 84.65%. Based on these results it is necessary to improve the channel against sedimentation and channel damage to obtain better productivity.

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Evaluation performance of Irrigation Area Jeuram

Based on the results of research and evaluation, D.I Jeuram has a performance index of 59.32% in the category of less and in dire need of attention. The results of the D.I Jeuram performance evaluation can be seen in Table 3.

Table 3. Performance index irrigation area Jeuram

No.	Assessment Item	Existing Condition (%)	Maxsimum Condition (%)	Minimum Condition (%)	Optimum Condition (%)
1.	Physical Infrastructure	26,38	45	25	35
2.	Plant productivity	9,64	15	10	12,5
3.	Supporting facilities	3,6	10	5	7,5
4.	Personal organization	10,8	15	7,5	10
5.	Documentation	2,9	5	2,5	5
6.	Water User Farmer Group	6	10	5	7,5
	Performance	**59,32**	100	55	77,5

Overall, the performance of D.I. Jeuram is at 59.32%, indicating a condition that requires significant attention. This situation adversely affects crop productivity. While the cross-section of the primary channel can still accommodate the water flow needed for irrigation, the condition of the primary channel itself is also classified as having moderate to severe damage, compounded by uncontrolled sedimentation. To improve this situation, it is vital to regularly or periodically repair, operate, and maintain the irrigation system.

Evaluation of Channels Irrigation

Evaluation of the channel capacity of irrigation channels is carried out to determine the ability of the channel to drain irrigation water to reach the community's fields. Analysis of channel evaluation is done by numeric modeling with HEC-RAS 5.0 software. The input data used are the existing dimensions of the channel and the discharge at each building in the primary channel. The results of the primary channel evaluation can be seen in Figure 4 to 8

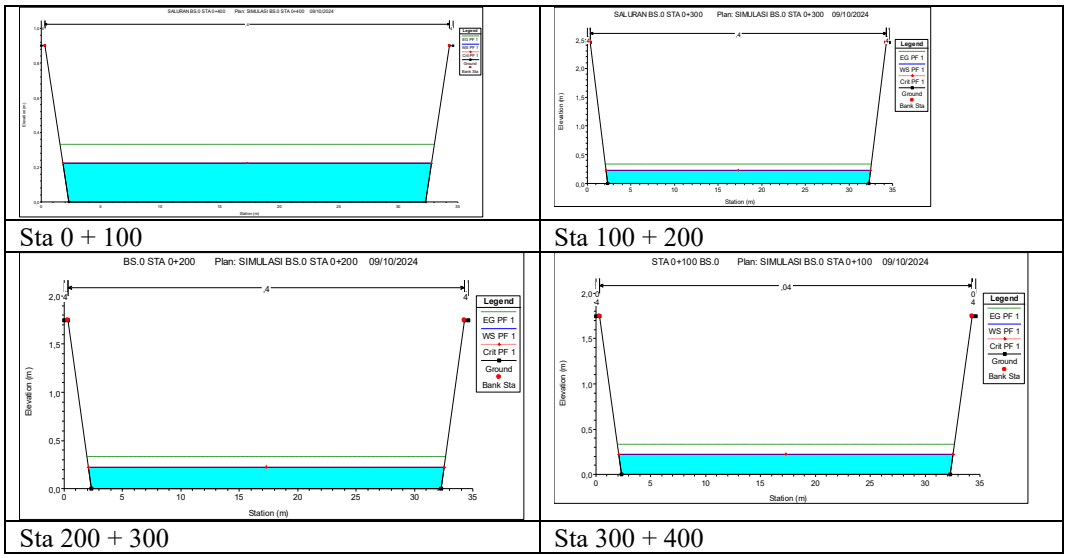
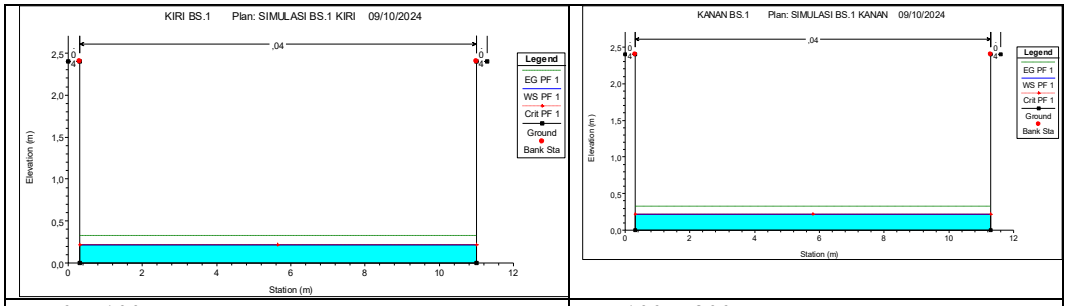
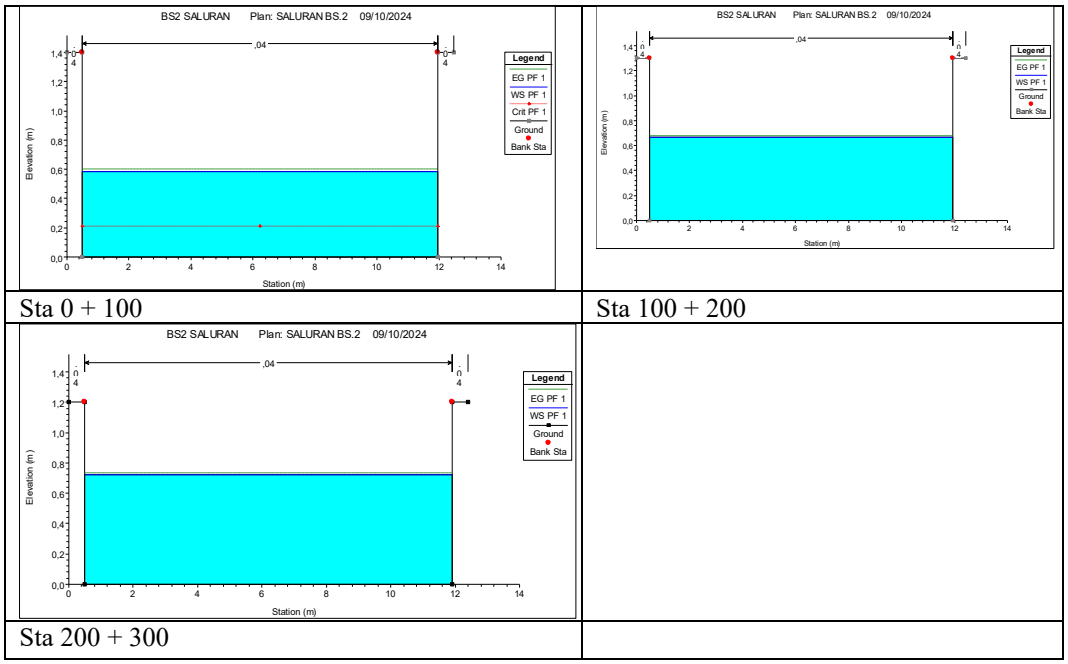


Figure 4. Result simulation channel BS.0- BS.1



Sta 0 + 100	Sta 100 + 200

Figure 5. Result simulation BS. 1 – BS.2



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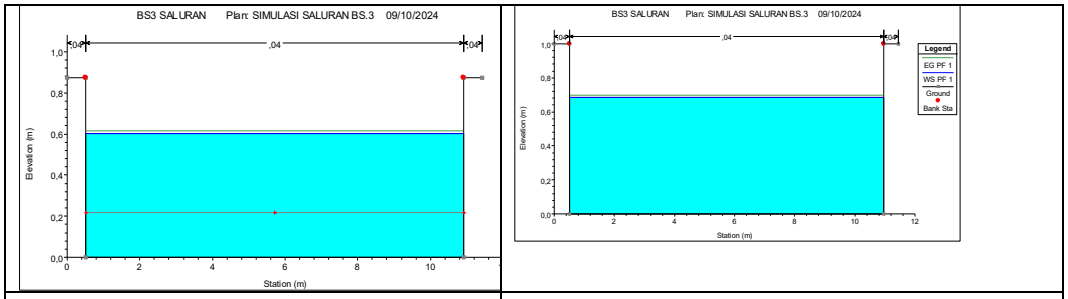
Sta 200 + 300	

Figure 6. Result simulation BS.2 – BS.3



Sta 0 + 100	Sta 100 + 200

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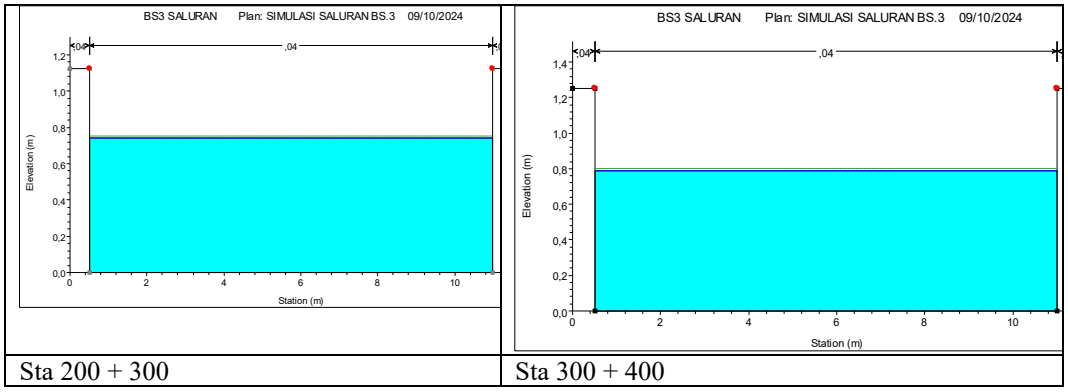

Figure 5. Result simulation BS.3-BS.4

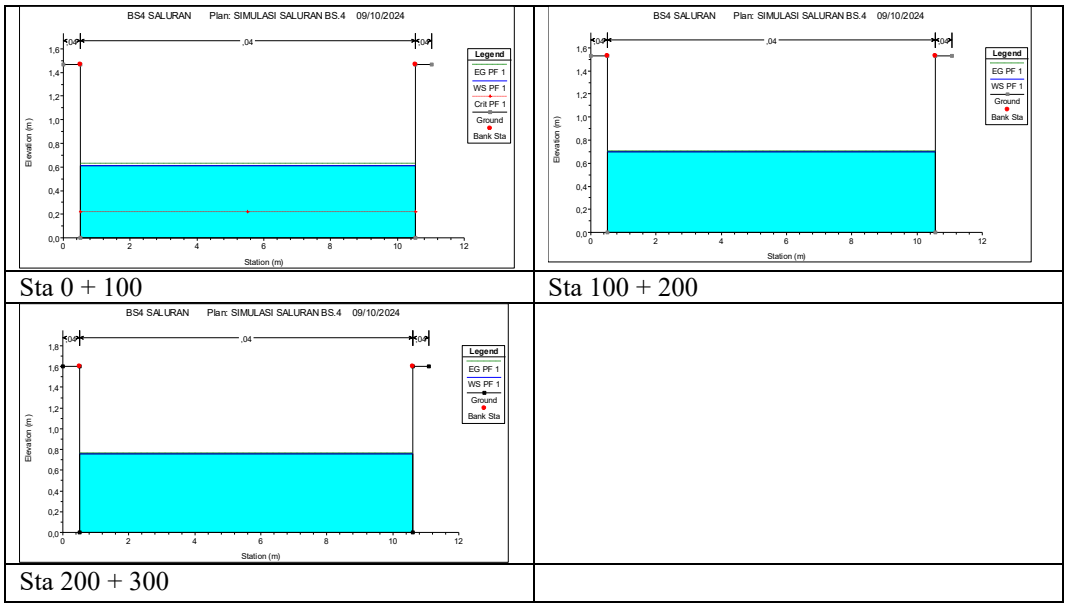

Figure 6. Result simulation BS.2 – BS.3

Based on the results of the channel evaluation, the D.I Jeuram primary channel can still accommodate the current water flow. However, the channel has changed from a trapezoidal shape to a square shape. Additionally, there is uncontrolled sedimentation occurring in the area. To address these issues, it is essential to repair the channel and remove the sediment, as this deterioration is leading to an increase in the area of rice fields that cannot be irrigated and is reducing the effective service area of D.I Jeuram.

CONCLUSION

The performance condition of the physical infrastructure of D.I Jeuram is currently at 26.38% of the optimal condition limit of 35%. This places it in the category of moderate to severe damage, leading to a decline in the functionality of the irrigation channels. It is essential to undertake repairs on the main building of the weir, as well as the carrier and waste channels, including the structures associated with them. The deterioration of the physical infrastructure directly impacts crop productivity, which is currently at only 9.64% of the optimal level of 12.5%. Improving water availability during the planting period is crucial for enhancing crop productivity. To optimize crop yields, both physical and non-physical infrastructure improvements are necessary. Overall, the performance of D.I. Jeram is at 59.32%, indicating a condition that requires significant attention. This situation adversely affects crop productivity. While the cross-section of the primary channel can still accommodate the water flow needed for irrigation, the condition of the primary channel

itself is also classified as having moderate to severe damage, compounded by uncontrolled sedimentation. To improve this situation, it is vital to regularly or periodically repair, operate, and maintain the irrigation system.

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