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Evaluation of the Sragi Secondary Channel of the Kaliwadas Irrigation Area, Pekalongan Regency

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Abstract: The Sragi secondary channel is located in the Kaliwadas irrigation area, Pekalongan Regency has a length of 7,587 m. The position of the channel is in a rice field area which is used to optimize irrigation to support agricultural business productivity. The existing condition of the channel in the form of native soil causes frequent leaks. Technical handling is needed to repair irrigation buildings in the form of a study on the existing condition of the Sragi secondary channel through field surveys and checking physical conditions. Furthermore, identification of the level of damage to irrigation channels is carried out. From the problems that arise at the identification stage, recommendations are then given in the form of proposals for improvements to buildings and irrigation channels. The results of the field survey in the form of network tracing provide data that the level of physical and functional damage to the Sragi secondary channel infrastructure reaches >40%. The condition is categorized as very bad with the classification of severely damaged which requires repair or replacement. Most of the damage in the form of spots or localized occurred on the existing lining of masonry and precast concrete starting from Hm 50+00 to Hm75+68. The recommendations for improvement are in the form of dismantling the existing precast concrete lining according to the point of damage. It is recommended to repair the lining using K-300 precast concrete so that the structure of the irrigation channel is safe against the risk of deformation.

Keywords: *channel; deformation; functional damage; irrigation; walkthrough*

1. Introduction

Irrigation is the effort of providing, regulating, and distributing irrigation water to support various types of agriculture, including surface irrigation, swamp irrigation, groundwater irrigation, pump irrigation, and pond irrigation [1], [2], and [3]. In the case of surface irrigation, such as paddy fields, the availability of irrigation water becomes a benchmark for agricultural productivity. Irrigation is intended to support agricultural productivity and increase agricultural production to achieve national food security and bring benefits to the community [4]. Furthermore, irrigation also provides benefits, especially for farmers and other members of society, through the sustainability of irrigation systems and the success of agricultural development. Effective irrigation system management can support the agricultural development sector by increasing harvest yields [5].

Increasing the age of irrigation channels starting from the time of construction, naturally or as a result of the influence of irresponsible human activities can cause a decrease in the function of these channels. Likewise, irrigation buildings have decreased in function due to increasing age and the influence of human activity [6]. The effect of physical damage to irrigation channels also has an impact on reducing the capacity of irrigation systems [7]. On the other hand, there is a demand for the need for the distribution of water for efficient irrigation needs throughout irrigation plots or networks to irrigate paddy fields, which is very much needed by farmers. Based on PUPR Ministerial Regulation No. 12/PRT/M/2015 concerning the Exploitation and Maintenance of Irrigation Networks, states that evaluation of the performance of irrigation systems is intended to determine the performance conditions of irrigation systems consisting of physical infrastructure, plant productivity, supporting facilities, personnel organization, documentation, and P3A institutional conditions [8]. Improvements to the performance conditions of the irrigation system can indirectly increase the productivity of farmers' crops [9].

Irrigation networks are a unified system consisting of channels, structures, and other complementary buildings intended for the provision, distribution, utilization, delivery, and disposal of irrigation water [10]. Operationally, irrigation networks can be categorized into three categories: primary, secondary, and tertiary irrigation networks. According to [8], the primary irrigation network consists of main structures, primary channels, drainage channels, distribution structures, intake structures, and other complementary buildings. On the other hand, the secondary irrigation network is a part of the irrigation network that includes secondary channels, drainage channels, distribution structures, intake structures, and complementary buildings. The presence of the secondary irrigation network is important to the existence of secondary channels that supply water to tertiary channels and ultimately reach the individual rice fields.

The Sragi secondary channel is a secondary channel built by the Dutch East Indies Government in 1870, in the sub-watershed area (sub-DAS) of Genteng or Layangan River, a tributary of the Comal River. The rice fields on the right side of Layangan River are served through an intake on the right of the Kaliwadas Dam, and the water is channeled to the Kesesi primary channel. The rice fields on the left side of the river are served through an intake on the left to the Wadas Sekargadung primary channel. The secondary rice fields consist of several tertiary plots served by one secondary channel. Meanwhile, a collection of several secondary plots forms a primary plot served by a main channel or primary channel. The success of the irrigation system depends on the availability of water in the secondary channel to be distributed to the tertiary plots [11].

During the fiscal years 1972 to 1974, rehabilitation activities were carried out in the Kaliwadas irrigation area covering 7,223 hectares by Prosida. The optimization involved raising the elevation of the dam's crest to +32.921 meters, extending the Olak Pond to +22.740 meters, adding an Endsill Flip Bucket to +23.440 meters, and changing the intake system from the left side to the right side by using a culvert in the body of the dam with an inlet on the left side of the flushing gate, directing the water flow to the Wadas Sekargadung primary channel. Implementation of rehabilitation activities on irrigation networks through the maintenance of buildings and irrigation canals is intended to meet the needs of irrigation water [12]. In the fiscal year 1990, as part of the operational and maintenance (O & M) activities of the Central Java irrigation project, an intake was constructed on the left side of the Kaliwadas Dam to support the irrigation services of the Wadas Sekargadung primary channel, diverting water from the culvert intake on the right side of the dam. The O & M activities mentioned above are ongoing and self-sustained irrigation management tasks to support the irrigation channel services [13].

Evaluation of the performance of irrigation systems which include buildings and irrigation channels is needed as a reference in improving irrigation systems [14]. The problems faced in the Sragi secondary channel are the condition of the existing channel which has decreased its function and hampered water service in the channel. Based on the results of literature studies and several previous studies in [6], [7], [8], [9], [12], and [14], a study is needed in the form of an analysis of irrigation structures on the existing conditions of physical damage to building and channels infrastructure. irrigation based on PUPR ministerial regulation No. 12/PRT/M/2015 concerning the exploitation and maintenance of irrigation networks. After knowing the problems that occur in the Sragi secondary channel, recommendations for repairing irrigation structures can then be given to restore the function and service of water.

2. Methods

The research is conducted through several stages starting from literature review, data collection and evaluation, identification of the level of damage to irrigation channels, and providing recommendations for the occurring damages. The data used in this study includes both primary and secondary data. The primary data consists of field survey results and identification of the physical condition of irrigation structures, while the secondary data collected includes the irrigation network scheme. The research location is at the secondary channel of Sragi, Kaliwadas Irrigation Area, Pekalongan Regency, as shown in Figure 1. The field survey was conducted on October 14, 2021, using the network tracing method (walkthrough) through direct observation. The purpose of this activity was to obtain information about the existing condition of the irrigation network and identify the damages that occurred in the secondary channel of Sragi. The existing condition referred to the physical condition of the irrigation infrastructure, while the damages to the irrigation channel were related to the physical damage to the infrastructure. The next step involved identifying the level of physical damage to the irrigation network infrastructure by the Regulation of the Minister of Public Works and Housing No. 12/PRT/M/2015 concerning the Exploitation and Maintenance of Irrigation Networks [8]. The final part of this research consists of the results, discussions, conclusions, and recommendations, which include proposed repairs for the buildings and irrigation channels that have been damaged.

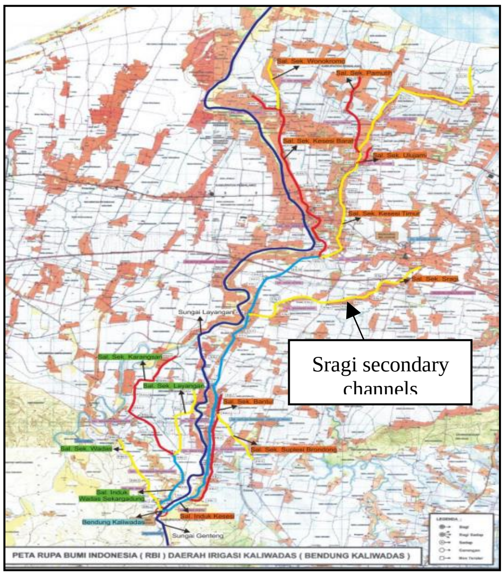

Fig. 1. Research Location

2.1. Functional Performance and Irrigation Network Infrastructure

Operational and maintenance (O & M) activities for inventorying irrigation networks that are required are collecting data on the existing conditions of irrigation networks in the form of physical damage levels and their impact on water service areas. Irrigation services from upstream to downstream areas require proper physical infrastructure for irrigation buildings. These facilities and infrastructure can be in the form of weirs, dams, primary channels, secondary channels, tertiary channels, sluice buildings, spillways, measuring structures, and others. Damage to one or several irrigation structures can affect the performance of the irrigation system, thereby reducing the effectiveness and efficiency of irrigation [15].

Irrigation network maintenance activities are in the form of maintenance, repair, and prevention as well as security for irrigation networks. Irrigation network inspection is part of the maintenance of irrigation networks in the form of routine inspection activities carried out by irrigation workers every certain period, for example, once every 10 or 15 days to know the physical condition of irrigation networks [16]. The physical condition of an irrigation network includes the number, dimensions, type, and physical condition of an irrigation network. As [8], the physical condition of the irrigation network infrastructure can be classified as shown in Table 1. The criteria for the physical condition of irrigation network infrastructure can be seen in Table 2.

Table 1. Classification of the physical condition of irrigation networks

No	Irrigation Network Damage Level	Classification	Description
1	<10 %	Good condition	Routine maintenance
2	10-20 %	Slightly damaged condition	Periodic maintenance
3	20-40 %	Moderately damaged condition	Periodic repair and maintenance
4	>40 %	Heavily damaged condition	Major repair or replacement

Table 2. Physical infrastructure condition of irrigation network

No	Physical Infrastructure Condition	Description
1	Damage level <10 %	Very good
2	Damage level 10-20 %	Good
3	Damage level 20-40 %	Poor
4	Damage level >40 %	Very poor

The assessment of the physical condition of infrastructure can be calculated following the following equation [17].

$$Is = \frac{Sf}{St}\ x\ weight \quad (1)$$

$$Ib = \frac{Bf}{Bt}\ x\ weight \quad (2)$$

with Is, Sf, St, Ib, Bf, Bt are irrigation channels indicators, the length of properly functioning channels, the total length of channels, building indicators, the number of properly functioning buildings, and the total number of buildings, respectively.

The weight criteria used to determine the indicators of the physical condition of the irrigation network are shown in Table 3 [16].

Table 3. Weights of indicators for the physical condition of the irrigation network

No	Indicators	Weight (%)
1	Primary buildings	28.89
2	Conveyance channel	22.22
3	Buildings on the conveyance channel	20.00
4	Drainage channel and its buildings	8.89
5	Entrance/ inspection road	8.89
6	Office	11.11

The functional condition of the irrigation network infrastructure is related to the physical condition of the irrigation network. If the physical condition of the infrastructure is good, it is usually proportional to the functional condition of the irrigation network. The assessment of the functional condition of the irrigation network infrastructure can be calculated using the equation below, with damage criteria presented in Table 4 [17].

$$Is = \frac{Sf}{St}\ x\ 100\% \tag{3}$$

$$Ib = \frac{Bf}{Bt}\ x\ 100\% \tag{4}$$

Table 4. Functional infrastructure condition of irrigation network

No	Functional Infrastructure Condition	Description
1	Damage level <10 %	Very good
2	Damage level 10-20 %	Good
3	Damage level 20-40 %	Poor
4	Damage level >40 %	Very poor

3. Result and Discussion

3.1. Problem in Sceondary Channel of Sragi

The results of the walkthrough, related to the existing condition of the channels, can be summarized as the following problems in the secondary channel of Sragi:

1) From Hm 50+00 to 75+68, the lining on both the right and left sides mainly consists of old precast concrete, which has experienced localized damage in the form of spots or patches.
2) The old precast concrete measures 40cm x 80cm x 0.6cm and is installed with a foundation made of stone masonry and a top cap made of brick masonry (rolag).
3) The inside of the precast concrete lacks lean concrete (B0), resulting in direct contact with the ground. Considering the structural condition mentioned above, it is susceptible to deformations (changes in the arrangement of precast concrete).
4) In the field, it was observed that the lining, which mainly consists of precast concrete, has suffered various damages, including cracks, shifts, subsidence, fractures, and others.

The results of the field survey for several points of the channel that have experienced damage can be seen in Table 5. Documentation of the existing condition of the secondary channel of Sragi can be seen in Figure 2 to Figure 5.

Table 5. The existing condition of secondary channel of Sragi

No	Location	Length (m)	Existing condition
1	Hm 50+00 to 50+75	75	The right side lining is made of precast concrete measuring 40cm x 80cm x 0.6m with localized damages.
2	Hm 50+00 to 52+82	282	The right side lining is made of stone masonry with localized damages.
3	Hm 57+57 to 60+50	293	Both the right and left side linings are made of precast concrete measuring 40cm x 80cm x 0.6cm with localized damages.
4	Hm 62+00 to 64+20	220	The left side parapet made of stone masonry is still in good condition. From Hm 63+35 to 63+50 (15 m), the parapet made of stone masonry is damaged.

No	Location	Length (m)	Existing condition
5	Hm 64+20 to 65+31	111	Both the right and left side linings made of precast concrete have localized damages.
6	Hm 66+25 to 67+97	172	The right side lining made of precast concrete is still in good condition. The left side lining made of precast concrete has localized damages.
7	Hm 71+00 to 75+68	468	Both the right and left side linings of the existing precast concrete are still good.

Fig. 2. Existing Condition Hm 00+00

Fig. 3. Existing Condition Hm 50+00

Fig. 4. Existing Condition Hm 58+00

Fig. 5. Existing Condition Hm 71+00

3.2. Identification of Damages in the Secondary Channel of Sragi

From the issues present in the secondary channel of Sragi, the identification of the level of physical damage and the condition of the irrigation network infrastructure can be conducted by referring to the Regulation of the Minister of Public Works and Housing No. 12 of 2015 concerning the Exploitation and Maintenance of Irrigation Networks [8]. Based on the results of the walkthrough, the data on the condition of the irrigation buildings are presented in Table 6.

Table 6. The condition of the irrigation buildings in the secondary channel of Sragi

No	Type of Irrigation Buildings	Quantity	Average Physical Condition of Infrastructure (%)	
			Infrastructure	Function
1	Intake structure	13	50	50
2	Drop structure	7	50	60
3	Complementary structure	26	50	50
4	Water gate	25	35	35

Based on the criteria for the physical condition of the irrigation network infrastructure, as referenced in [8] in Table 1 and Table 2, the average level of damage to the irrigation structures in the secondary channel of Sragi reaches >40%, as shown in Table 6. The physical condition of the irrigation structures is categorized as very poor with a classification of heavy damage. Therefore, repair or replacement of the physical infrastructure at specific points experiencing damages is required.

The assessment of the physical condition of the irrigation structures can be calculated using the irrigation building indicators shown in Table 7.

Table 7. The assessment of the physical infrastructure condition of irrigation buildings

Criteria	Total of Properly Functioning Buildings	Total Number of Buildings	Weight (%)	Building Indicators (%)
Physical condition of irrigation infrastructure buildings	41	71	20	11.55

Based on the calculation of the irrigation building indicators, which is 11.55%, the value of the index for the physical condition of irrigation infrastructure buildings in the secondary channel of Sragi, which is considered to be in good condition, is 57.75%. On the other hand, the physical infrastructure in a damaged state, requiring repair or replacement, accounts for 42.25%. The results of the network tracing in the secondary channel of Sragi provide data on the level of damage to the irrigation channel infrastructure at several points. The damages to the physical infrastructure have an impact on the functional condition of the irrigation channel. This is reflected in the decrease in the performance of the irrigation system in terms of the effectiveness and efficiency of the irrigation channel [15]. The field survey results for the physical condition and function of the irrigation channel in the secondary channel of Sragi are shown in Table 8.

Table 8. The physical condition and function of the secondary channel of Sragi

No	Type of Irrigation Buildings	Location	Length (m)	% Average Physical Condition	
				Infrastructure	Function
1	BKi.5-BSg.1	Hm 10+00	1.000	45	50
2	BSg.1-BSg.2	Hm 13+73	373	50	50
3	BSg.2-BSg.3	Hm 28+47	1.474	45	50
4	BSg.3-BSg.4	Hm 29+92	145	40	45
5	BSg.4-BSg.5	Hm 37+15	723	50	45
6	BSg.5-BSg.5a	Hm 40+27	312	55	50
7	BSg.5a-BSg.6	Hm 46+87	660	50	50
8	BSg.6-BSg.7	Hm 49+84	297	45	50
9	BSg.7-BSg.8	Hm 53+76	392	60	55
10	BSg.8-BSg.9	Hm 57+50	374	50	50
11	BSg.9-BSg.10	Hm 63+50	600	60	55
12	BSg.10-BSg.11	Hm 71+59	809	55	50
13	BSg.11-BSg.12	Hm 75+87	428	45	50

As per the criteria for physical damage to irrigation networks in [8], it is obtained that the average level of physical damage to the infrastructure in the secondary channel of Sragi is 50%. This means that more than 40% of the irrigation channel is experiencing physical infrastructure damage. The assessment of the physical condition of the irrigation channel infrastructure is obtained from the values of the irrigation channel indicators, as shown in Table 9.

Table 9. The assessment of the physical infrastructure condition of the irrigation channel

Criteria	Length of Properly Functioning Channel (m)	Total Length of Channels (m)	Weight (%)	Irrigation Channels Indicators (%)
The physical condition of irrigation channel infrastructure	3,881	7,587	22.22	11.37

The calculation of the irrigation channel indicator in Table 9 shows a value of 11.37%, which is subsequently used to determine the index of the physical condition of the irrigation channel infrastructure. It is found that the physical condition index of the irrigation channel infrastructure is 51.15%, indicating that it is in good condition. The remaining 48.85% falls into the criteria of the irrigation channel infrastructure being in a deteriorated state and need of repair or replacement.

Based on the results of the calculation of the level of physical damage to the infrastructure of buildings and irrigation channels in the Sragi secondary channel, it is known that the level of physical infrastructure damage is >40%. Therefore, it is proposed to carry out repairs or replacements at the points that have suffered damage, by the criteria for the level of physical infrastructure damage [8]. The repairs can be carried out selectively to be more cost-effective. The priority for repairs starts with the irrigation channels, irrigation structures, and other supporting buildings.

3.3. Recomendation of the Secondary Channel of Sragi

The recommendations provided consist of proposed repairs or technical interventions based on the level of physical infrastructure damage. Different levels of physical infrastructure damage are taken into consideration, whether they are spot repairs or comprehensive ones. Recommendation are provided according to the specific locations that have experienced physical and functional damage to the infrastructure. Meanwhile, in some areas where the existing condition is still functioning well, it is recommended to maintain it. The repair recommendations are presented in Table 10.

Table 10. Recommendations for Improvements to the Sragi secondary channel

No	Location	Length (m)	Existing Condition	Recommendation for Improvements
1	Hm 50+00 s.d 50+75	75	Left-side stone masonry lining is damaged	Repairs with precast concrete K-300
2	Hm 50+00 s.d 52+82	282	Right-side stone masonry lining is damaged in spots	Replace damaged old stone masonry with a stone masonry 1 : 4

No	Location	Length (m)	Existing Condition	Recommendation for Improvements
3	Hm 50+75 s.d 52+00	125	Left-side stone masonry lining is damaged in spots	Replace damaged old stone masonry with a stone masonry 1 : 4
4	Hm 52+00 s.d 52+82	82	Left-side stone masonry lining is damaged	Repairs with precast concrete K-300
5	Hm 57+57 s.d 60+50	293	Left and right precast concrete lining are damaged	Repairs with precast concrete K-300
6	Hm 62+00 s.d 64+20	220	The left-side lining consists of a parapet with old stone masonry in good condition	Maintain the old stone masonry parapet
7	Hm 63+35 s.d 63+50	15	The left-side lining consists of a parapet with old stone masonry damaged	Repair the stone masonry parapet 1 : 4
8	Hm 64+20 s.d 65+31	111	Both left and right precast concrete linings are damage	Repairs with precast concrete K-300
9	Hm 66+25 s.d 67+97	172	The right-side precast concrete lining is still in good condition	Maintain the old precast concrete
10	Hm 66+25 s.d 67+97	172	The left-side precast concrete lining is damage	Repairs with precast concrete K-300
11	Hm 71+00 s.d 75+68	468	Both left and right precast concrete linings are still in good condition	Maintain the old precast concrete

Based on Table 10, it is known that the majority of the physical damage that has occurred consists of existing lining on the right and left sides, which has experienced sporadic damage such as cracking, sinking, detachment, and collapsing. Some of the repair recommendations include replacement using precast concrete K-300 with reinforcement in the form of top beams, bottom beams, and diagonal beams. As for the right or left side lining, reinforced concrete beams of K-225 with dimensions of 20 x 30 cm can be used. The bottom beam should be reinforced concrete measuring 25 x 40 cm with a strength of K-225. Meanwhile, the space between the precast concrete K-300 slab and the diagonal beam can be filled with a layer of sand.

4. Conclusion

The results of the irrigation network assessment indicate that the level of physical and functional damage to the Sragi secondary channel infrastructure is >40%. This level of damage falls into the category of very poor condition, with a classification of severe damage that requires repair or replacement. Some of the damage is primarily observed in the existing lining of the channel, from Hm 50+00 to Hm 75+68. The damage mostly affects stone masonry and precast concrete. The recommendations provided include repairing or replacing damaged sections with precast concrete K-300 for the lining while preserving the existing stone masonry and concrete that are still in good condition.

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