Hydraulic Study on The Use of Gates to Improve Drainage Performance of Dadahup Lowland Irrigation Area

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ABSTRACT
Dadahup lowland irrigation area, known in Bahasa as Daerah Irigasi Rawa (DIR) Dadahup, is one of the Ex-PLG areas that has been now included in the food estate program. It has been experiencing low productivity, producing only 1.7 - 2.9 ton/ha/year of paddy. Farming on lowland areas is often hindered by inundation during rainy season. Such problems were observed at Blok A5 of DIR Dadahup where inundation might last for a long time. Drainage was hindered since the water level in the channel, being at +1.4 to 1.6 m, was higher than the ground level whose elevations were +1.30 m for the right area and +1.00 m for the left area. Flow simulation by employing HEC-RAS is proposed to obtain a drainage system that can overcome this inundation problem. The use of gates in the secondary and tertiary channels was analyzed to improve drainage performance. The results show that by using gates and pumps can reduce the inundation area and maintain the water level in the channel according to cultivation needs. Such as in tertiary channel, the water level in the right tertiary channel can be maintained at +1.30 m ~ +1.46 m, and that in the left tertiary channel can be maintained at +1.12 m.

Keywords: *Lowland irrigation area, food estate program, HEC-RAS, water level*

1. INTRODUCTION

The Indonesian government has opened up tidal land to become agricultural land since 1969 to realize the food self-sufficiency program [1]. The Indonesian government initiated the one-million-hectare peatland project (or PLG) in 1995 as part of the program. This project, known as the "Mega Rice Project", is converting one million hectares of lowland and peatland into agricultural land [2]. The ex-peatland project area is bounded by the Barito River, the Kapuas Murung River, and the Sebangau River. This area consists of five blocks from A to E with total area of 1,462,000 ha. In 2020, the Indonesian government initiated the food estate program to revitalize this area to become Indonesia's food stock region [3].

Dadahup Lowland Irrigation Area, known in Bahasa as *Daerah Irigasi Rawa* (DIR) Dadahup, is one of the Ex-PLG areas that is included in the food estate program. DIR Dadahup has a potential area of 21,226 ha but only 6,111 ha is functional. It produces only 1.7-2.9 ton/ha/year of paddy. Its cropping intensity is once per year (CI 100%) [4]. Such productivity should be considered low. The productivity of irrigated rice fields should reach 8 tons/ha/year [5]. Another opinion stated that an irrigated area with good conditions, farmers are able to crop paddy two or three times per year producing 5-7 ton/ha/year of high-yielding paddy variety [6].

Agricultural problems in lowland areas were due to water insufficiency to meet crop water requirements [7]. Channel conditions are often poorly maintained. Channel sedimentation and full shrubs coverage are common problems. Some irrigation networks do not have tertiary channels and control gates. If any, they are not functioning properly according to the agricultural needs [8]. Tidal lowland areas between Zona II-b and Zona III have complex challenges due to river discharge and tides that affect this area [9]. They impact the land

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being inundated during the rainy season and drought in the dry season. Water in the channel is often stagnant which produce toxic substance and cause acidity which is harmful to paddy growth [10].

Such problem is observed at Blok A5 of DIR Dadahup where inundation and drought are challenges faced in this area. Since the amount of discharge of the Barito River affects the different water levels during rainy and dry seasons [11]. During rainy season, this area can be inundated due to the ground elevation being lower than the channel's water level. During the dry season, there is a possibility that the land will suffer from water shortages and poor water quality.

Considering ground elevation and operational ease differences, the water management system must be divided into smaller blocks. The application of smaller blocks is expected to dilute and circulate acid water more effectively. Water conservation and water management can also be done in a simpler way [11]. The water management in tidal irrigation schemes should meet at least three objectives. The first objective is to provide adequate water for leaching and diluting acid water. The second is drainage of excess water during storm. The third is maintaining the potential acid sulphate soil under reduced conditions to avoid excessive oxidation [12].

The inundation that occurred during rainy seasons at Block A5 DIR Dadahup is presented and discussed in this paper. This paper aims to overcome this inundation problem by using gates in secondary and tertiary channels. Therefore, the correct water management and gate operation rule is needed to adapt with that condition. In addition, further research is also needed regarding the effectiveness of using gates during the dry season as adaptive infrastructure in both conditions.

2. MATERIAL AND METHOD

DIR Dadahup is a tidal irrigation scheme located between Zone II-b and Zone III. Zone II-b water level is influenced by the tides during wet and dry seasons. This area is also known as freshwater tidal lowland where there is no salinity intrusion. The drainage performance can be done by gravity during the dry season and irrigation during wet and dry seasons. In Zone III water level is influenced by river discharge, tidal influenced only during the dry season. In this area no salinity intrusion has been found, the ground elevation is relatively high and the irrigation capability only uses pumps. More details can be seen in Figure 1 and Table **1** [9].

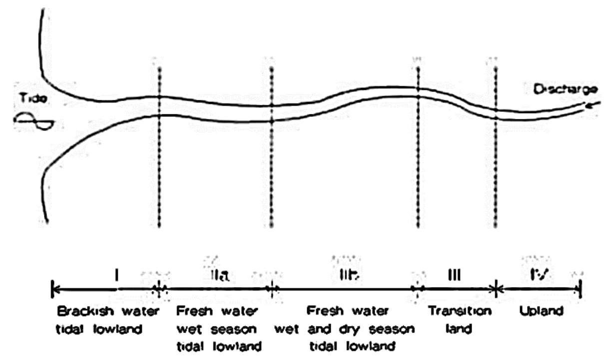


Figure 1 Illustration of river zonation in relation to salinity, drainage and irrigation [9].

Table 1. River zonation system in relation to salinity, drainage and irrigation [9]

Zone	Water Level	Salinity, drainage and Irrigation
I	Influenced by the tides during wet and dry season	Brackish, drainage by gravity during low tide. No possibility for supplementary irrigation
II-a	Influenced by the tides during wet and dry season	Salinity intrusion during dry season, drainage by gravity during low tide, supplementary irrigation only during wet season
II-b	Influenced by the tides during wet and dry season	Fresh water lowland, no salinity intrusion, drainage by gravity during low tide, and irrigation during wet and dry season
III	Influenced by river discharge, tidal influenced only during the dry season	No salinity intrusion, ground level is relativity high, irrigation only by pumps
IV	Determine only by river discharge	No tidal influence, upland

Block A5 DIR Dadahup is the main locus of this paper. Block A5 is divided into two sections, namely Block A5 Right and Block A5 Left. This area covers 1,632 ha with secondary channel Q – Q2' along ±3,300 m, five right tertiary canals and five left tertiary canals with each tertiary channel length of ±2,500 m. This block's ground elevation ranges from +0.57 m to +1.74 m with average elevations are +1.30 m for the right area and +1.00 m for the left area. More details can be seen in Figure 2.

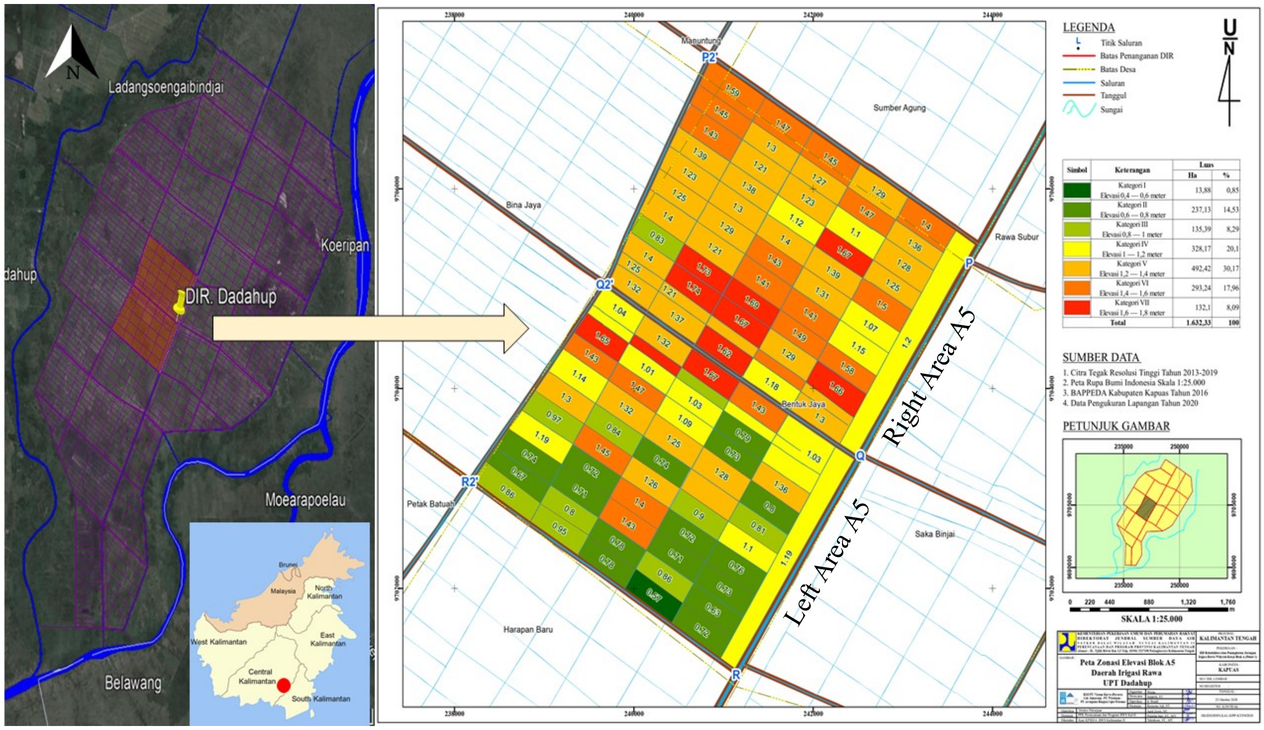


Figure 2 Location spot image and irrigation canal network of Blok A5 DIR. Dadahup [13] [14].

This paper simulates the condition of network system during rainy season. Drainage was hindered since the water level in the channel, being at +1.4 to 1.6 m, was higher than the ground level whose average elevations were +1.30 m for the right area and +1.00 m for the left area, so this area will be inundated for a long time as shown in Figure 3.

Figure 3 Inundation that occurred in Block A5 DIR Dadahup.

The concept of improving the micro water management in this area is to treat this area like a folder system. This system aims to isolate this block, so it does not affect or be influenced by other blocks. Some of advantages of this system are protecting the lower areas from overflowing excess water from higher areas, accelerating the discharge of excess water into the river, expediting the circulation of water in the channel and simplifying the operation and maintenance of the channel [11].

This paper focuses on improving drainage performance during rainy season by using gates in secondary and tertiary channels. Tidal influence by main primary channel and auxiliary primary channel entering into secondary and tertiary channels of Block A5 will be regulated by these gates. These gates have functioned as the regulator, regulating the channel's water level according to cultivation needs.

Flow simulation by employing HEC-RAS is proposed to obtain a drainage system that can overcome this inundation problem. The data for the simulation of the HEC-RAS model are longitudinal and cross-sectional sections of the channel, hydraulic control structure layout, boundary condition (upstream and downstream), hydrological data, and terrain data. Flow simulation due to water level fluctuations should be carried out using unsteady flow analysis [15]. The hydraulic simulation was carried out under four scenarios. Figure 4 and Table 2 present these four simulation scenarios.

Several previous studies have also used mathematical models to assist in evaluating the drainage performance of a lowland irrigation network system [15] [16] [17].

Table 2. Scenarios geometries regarding gate placement and pump station

Simulation Scenarios	Secondary Gate	Tertiary Gate	Pump	Description
No gate	-	-	-	Without gate structure
Secondary gates	√	-	-	Gate structure at secondary channel
Tertiary gates	√	√	-	Gate structure at secondary and tertiary channels
Pumps	√	√	√	Gate structure at secondary and tertiary channels + pump station

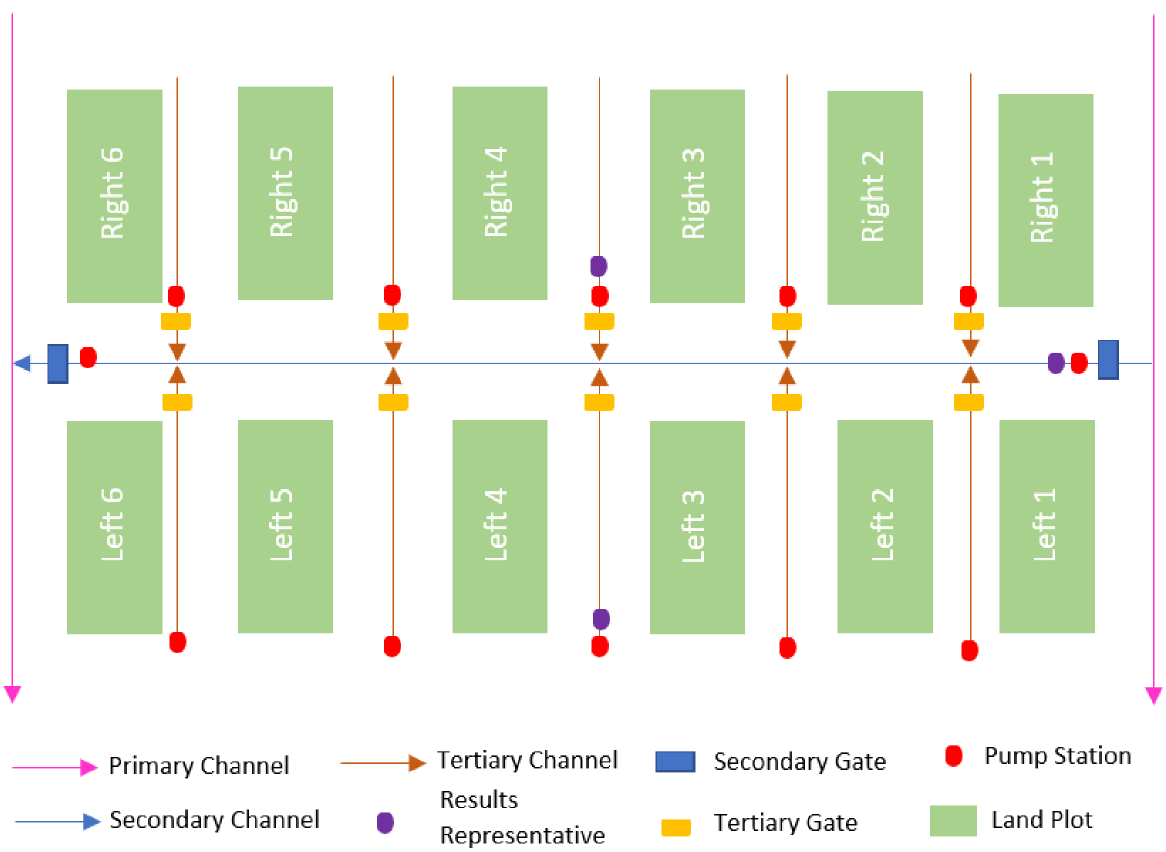


Figure 4 System layout.

3. RESULTS AND DISCUSSION

3.1 Gates and Pumps

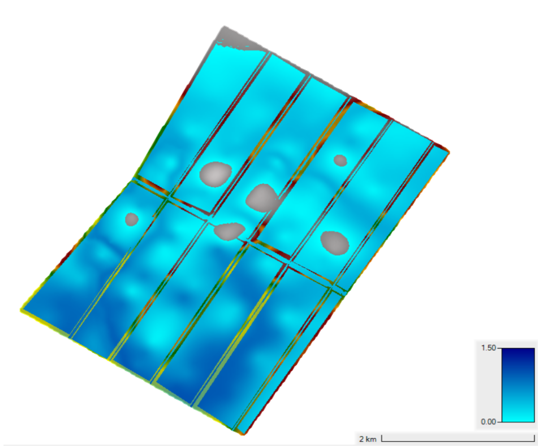
The gate designs were determined for supply and drainage of the Block A5 system. These gates are expected to adapt for both conditions. However, this paper only discusses the use of these gates to improve drainage performance. The type of gate is a sluice gate placed in the secondary and tertiary channels. The gate dimension at secondary channel was 2x2 m whose invert is at +0.4 m and consists of 4 gates at each structure. The gate structures are placed at the upstream and downstream ends of the secondary channel. Whereas the gate dimension at tertiary channel was 1.5x1.5 m whose invert are ranging of -0.5 to -0.8 m and each structure consists of 1 gate. The gate structures for the tertiary channel are placed at every downstream of the channel. The gate operation rules use the specified reference by the water level in the channel. For example, the gate structure at secondary channel, the gates begin to close when water level reference on secondary channel reaches +1.45 m and the gates begins open when water level reference on secondary channel is down to +1.40 m. In general, the gate operation rules in this paper are the gates close when water level in the channel is high enough and open again when water level in the channel is low enough due to cultivation needs and drainage purposes. The type, size, and operation rules of these gates could later be redesigned as the need for drainage may vary.

In addition, the use of pumps certainly improves the drainage performance of this network system. There are two pumps for the tertiary channel at each pumping station. Meanwhile, there are ten pumps in the secondary channel at each pump station. The pump operation based on the water level, where the pump starts up when the water level reaches a certain height and shuts down when the water level has down to a certain height. For example, the operation of the pump at secondary channel, where the pump starts up when water level on secondary channel reaches +1.45 m, and the pump shuts down when water level on secondary channel down to +1.30 m. The number, capacity and operation rule of the pump could later be redesigned as the need for drainage may vary.

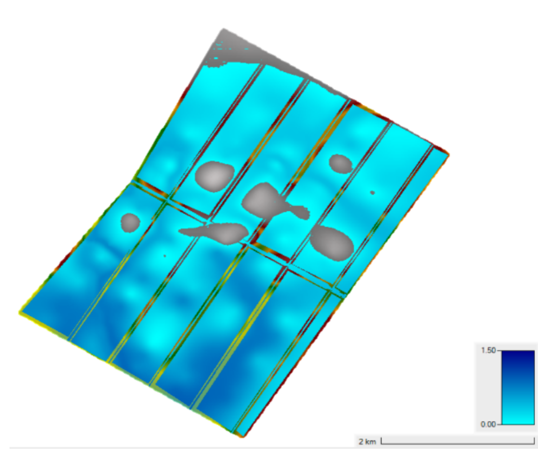
3.2 Hydraulic Simulation Results

The analysis using HEC-RAS was simulated for ±5 days (120 hours) from 21-25 Nov 2021 with Stage Hydrograph as boundary conditions in upstream and downstream. In addition, rainfall event was modelled using 2D Flow Area with precipitation as a boundary condition. In this model, the stage hydrograph and the precipitation event are based on real conditions measured on 21-25 Nov 2021.

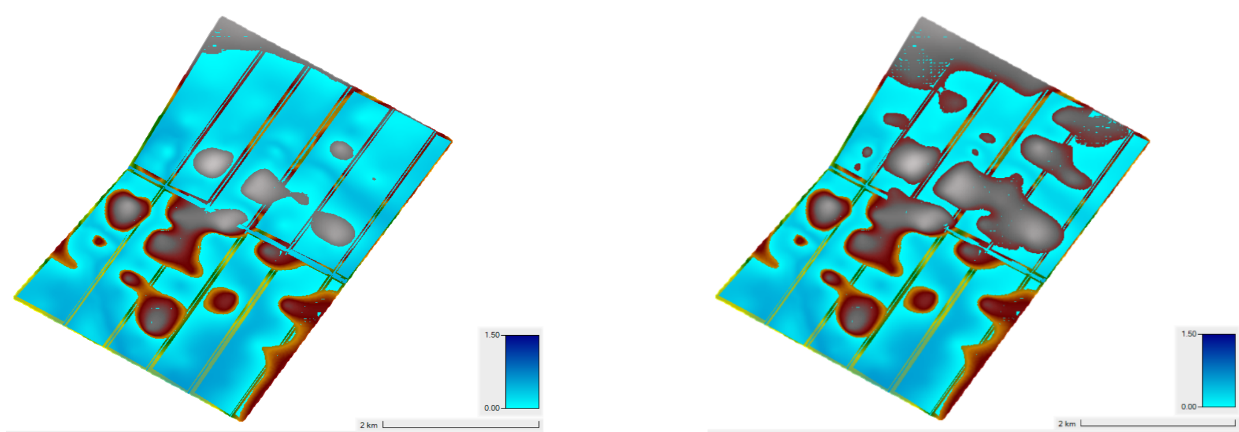
Based on simulated flow, the inundation area that occurred is shown in **Figure 5**. In the condition without the gate, inundation occurred in almost area plots in both the right and left areas of Block A5. By putting gates at secondary channel, the inundation area can be slightly reduced. The use of gates in secondary and tertiary channels, the inundation area especially on the left area can be reduced and its better than in the previous scenario. Meanwhile, using pumps at the end or outlet of the channel, the inundation area is greatly reduced than in another scenario. Based on **Table 3**, it can be seen in the no gate scenario that the highest inundation for the right area ranges from 0.44 ~ 0.58 m and for the left area ranges from 0.47 ~ 1.01 m. The inundation height in the secondary gates scenario can be reduced to ± 9 cm in each area plot. The use of gates in secondary channels impacts the Block A5 micro water management, which can avoid the influence of tides. For the tertiary gates scenario, the inundation height has similar results to the secondary gates scenario on the right area. However, the difference is the inundation level on the left area. The existence of gate structures, especially in the left tertiary channel, protected the lower area (left area) from overflowing excess water from the higher area (right area). The result shows that the highest inundation on the left area ranges from 0.04 ~ 0.59 m which means the water level can be lowered significantly. By using pumps, the results show that the highest inundation of the right area ranges from 0.19 ~ 0.26 m and for the left area ranges from 0.04 ~ 0.59 m, so this is much better than another scenario. As a result, where water cannot be drawn by gravity (due to the elevation of the area being lower than the surrounding area or water level in the channel higher than ground level), the use of a pump is an alternative that can be used to reduce the inundation level.



(a)



(b)



(c) (d)

Figure 5 Inundation area: (a) no gate; (b) secondary gates; (c) tertiary gates; (d) pumps.

Table 3. The highest inundation in each area

Simulation Scenarios	**Right Area Block A5 (m)**						**Left Area Block A5 (m)**					
	Right 1	**Right 2**	**Right 3**	**Right 4**	**Right 5**	**Right 6**	**Left 1**	**Left 2**	**Left 3**	**Left 4**	**Left 5**	**Left 6**
No gate	0.50	0.49	0.47	0.44	0.48	0.58	0.47	0.98	1.01	0.97	0.93	0.90
Secondary gates	0.42	0.41	0.38	0.35	0.38	0.49	0.39	0.89	0.92	0.88	0.84	0.82
Tertiary gates	0.42	0.41	0.38	0.35	0.38	0.49	0.04	0.55	0.59	0.56	0.52	0.50
Pumps	0.26	0.25	0.22	0.19	0.24	0.34	0.04	0.55	0.59	0.56	0.52	0.50

The simulation results for water level fluctuations in the secondary channel, right tertiary channel and left tertiary channel can also be seen in Figure 6, Figure 7 and Figure 8 below:

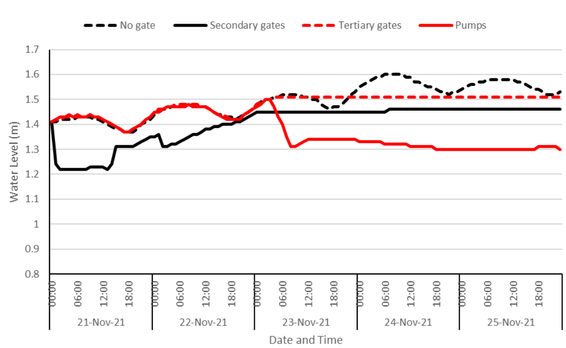


Figure 6 Water level on the secondary channel.

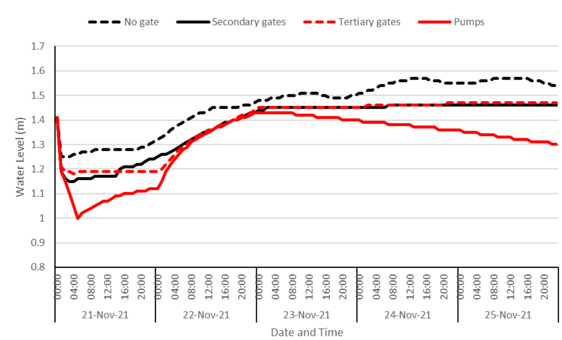


Figure 7 Water level on the right third tertiary channel.

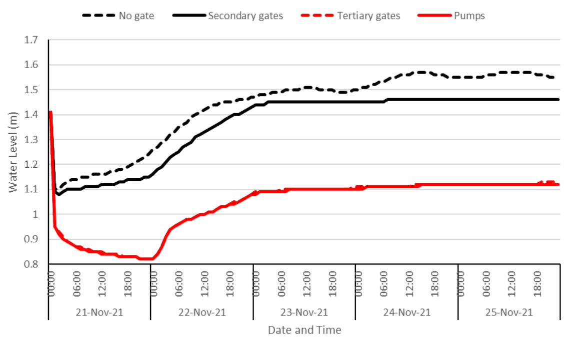


Figure 8 Water level on the left third tertiary channel.

The result on the no gate scenario shows that water level fluctuation at secondary channel can reach +1.60 m (Figure 6). This causes tidal water to enter deep into the irrigation network system and inundate the area plot. Meanwhile, rainwater on the area plot cannot be drained due to the high water level in the channel. This is also shown in Figure 7 and Figure 8, where the water level in the right and left tertiary channels is more than +1.50 m (in no gate scenario). On the secondary gates scenario, the water level at secondary channel can be maintained at an elevation of +1.46 m (Figure 6). As well on the right and left tertiary channels, the water level can be maintained at an elevation of +1.46 m (Figure 7 and Figure 8). The tertiary gates scenario shows that the water level at the secondary channel can be maintained at +1.50 m and the right tertiary channel has similar results to the secondary gates scenario where the water level can be maintained at an elevation of +1.46 m. (Figure 6 and Figure 7). However, with the existence of gate structures especially on the left tertiary channel, the left area is protected from overflowing excess water from higher areas. The result shows that the water level at the left tertiary channel can be maintained at an elevation of +1.12 m (Figure 8). The result of the pumps scenario shows that using pumps effectively maintains the water level in the channel. For secondary channel, the water level can be maintained at an elevation of +1.31 m (Figure 6), right tertiary channel of +1.31 m (Figure 7) and left tertiary channel of +1.12 m (Figure 8) so that the rainwater on the area plot can be drain to the channel and out of the system, so the inundation area can be reduced significantly.

Based on best practice, the tolerance for inundation in the paddy fields is generally ±0.2 m. Such results in the right area with an average ground elevation of +1.30 m where the water level in the tertiary channel can be maintained at +1.30 ~ +1.46 m (secondary gates, tertiary gates and pumps scenarios). Likewise, with the left area wherewith an average ground elevation of +1.00 m, the results show that the water level in the tertiary channel can be maintained at an elevation of +1.12 m (tertiary gates and pumps scenarios). This indicates that the water level in the channel can be regulated by using gates and pumps according to cultivation needs.

4. CONCLUSION

Farming on lowland areas is often hindered by inundation during rainy season. Such problem is observed at Blok A5 of DIR Dadahup where inundation may last for a long time. This paper analyzed the use of gates to improve drainage performance. The hydraulic simulation was run using HEC-RAS to obtain a drainage system that can overcome this inundation problem. The results show that by using gates and pumps can reduce the inundation area and maintain the water level in the channel according to cultivation needs. Such as in tertiary channel, the water level in the right tertiary channel can be maintained at +1.30 m ~ +1.46 m, and that in the left tertiary channel can be maintained at +1.12 m.

AUTHORS' CONTRIBUTIONS

All authors contributed equally based on their expertise.

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