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Water Supply Potential for Agropolitan Concept

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ABSTRACT

One of the obstacles to the development of Tongas District - Probolinggo Regency as an agropolitan area is the Limited of availability of water in Tongas Village. Kelampok village only has technical fields area of 105 hectares (14.45%) and the rest are rain-fed. The goverment of Probolinggo regency plans to develop Kelampok Reservoir. This study aims to research the potential of land and water for development of Kelampok Reservoir as a Water source for agriculture. To develop the Kelampok Reservoir engineering model, required main discharge, the location of the reservoir plan, and flood discharge. The results of the main discharge calculation using tank model had a maximum discharge of 332 L/s in The first decade do March and The discharge si only available for November to May. Hydrologically and geologically, the study area has an average rainfall of 1,430 mm/y with the type of Oldeman Climate classification is D4 and dominated by regosol soil types (96.60%). Kelampok Reservoir is engineered with (i) the full capacity of catchment is 7.103 m3 and the effective capacity is 6,877 m^3, (ii) the reservoir has a total width of 10.00 m and an effective width is 9.20 m, and (iii) planned to operate from early July to September (10 decades/10 days) with an discharge output of 789 L/d or 0.913 L/s.

1. INTRODUCTION

The rural development is an important part of regional development, because the rural areas are very vulnerable in order to face global scale changes (Annisa & Santoso, 2019). The concept of a growth pole is a region whose development growth is very fast compared to other regions so that it can be used as a development center that can affect the growth and development of other areas around it (Tuluvolic, 2015). This concept will be success if it is supported by a comprehensive regional planning including internal aspects of social and economic (Nugroho, 2018). However, the main problem that occurs in society is that there is a high economic gap, it marked by high levels of unemployment and poverty, while another problem is the weakening of economic competitiveness at the regional and global levels (Andri, 2014). To solve these problems, Probolinggo district develops the concept of an agropolitan area to increase social prosperity.

Agropolitan is a concept referring to a movement and efforts to develop agricultural areas as a trigger to increase the welfare and economy level of communities. While, keep the sustainability of environment services (Suyanto *et al*., 2019). For example, the development of agropolitan areas through agribusiness development can increase people's income, as well as increase the contribution of the agricultural sector economically (Martadona *et al*., 2014). In Malaysia, the agropolitan program is able to improve the welfare and standard of living of farmers (Ismail *et al*., 2019).

Kelampok Village in Tonggas sub-District, Probolinggo District East Java is an agricultural area which is expected to develop into an agropolitan area. However, the water resources sustainability for the agricultural sector is an obstacle for this area. This is because the Lawean River as a water source of irrigation is only able to supply 14.45% of technical irrigation system or an area of 105 hectares. The rest of the agricultural land is rain-fed land. Rainfed agricultural systems are highly dependent on the availability of rainwater, so it influences agricultural productivity, where during the dry season it is vulnerable to drought leads to experiencing crop failure and increase the potential to reduce the community's economy (Dewi & Wahidin, 2020). One of the efforts to ensure the availability of water supply for agricultural throughout the planting seasons is by constructing the reservoir or *embung* in Bahasa Indonesia (Irfany *et al*., 2014).

Embung is small farm reservoir that has multiple functions and is built to be used as a control for excess water during the rainy season and a source of irrigation water in the dry season. Operationally, the reservoir actually functions to distribute and ensure the continuity of water supply for crops or livestock in the dry and rainy season (Karepowan *et al*., 2015). In this case, the construction of reservoirs is expected to provide more benefits for farming and fisheries systems. The purpose of this research is to identify the potential of natural resources for the development of reservoirs and design it for the improvement of the agricultural system in order to improve the economy in Kelampok village.

2. MATERIALS AND METHODS

The reservoir designed to manage water, it accommodates excess water during the rainy season and provide water during dry season for both of agriculture and household (Chen & Tsai, 2017). One of the aspects that must be examined in reservoir planning is the hydrological analysis. It includes analyze of rainfall intensity, flood discharge plans, mainstay discharge and water requirement (Utami *et al*., 2015). The research steps were presented in the following Figure 1.

2.1. Dependable Flow

Dependable flow has to be identify minimal available water for crop water requirement (Fakhrurrazi *et al*., 2019). Dependable flow was estimated using rainfall simulation method into flow (Rainfall - Runoff Model) on Tank-Model. This was because Kelampok River did not have water gauge monitoring station. Tank-Model formulates a concept of water balance as follows (Pancawati *et al*., 2019):

$$\Delta S = (R + Q_{in} + G_{in}) - (ET + Q_{out} + G_{out}) \tag{1}$$

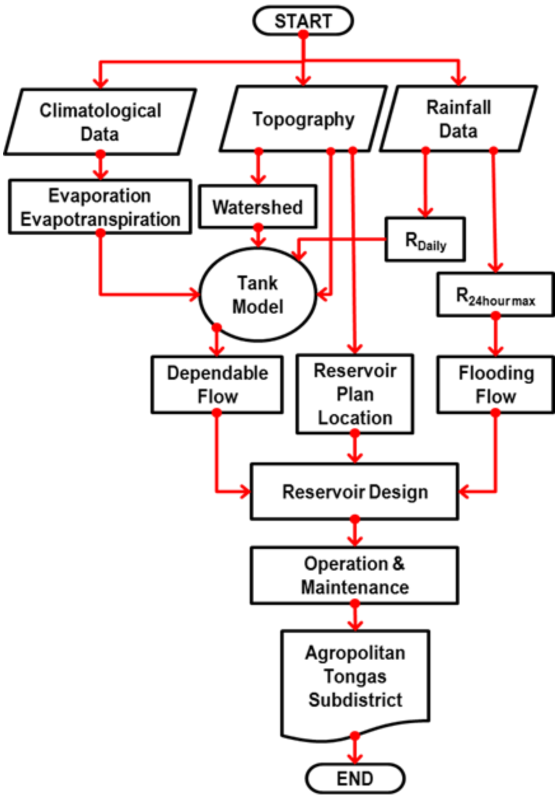

Figure 1. Research method

where ΔS = storage change (m^3); R = precipitation (mm); Q_{in} = debit inflow ($meter^3$/second); G_{in} = debit inflow ground water ($meter^3$/second); ET = evapotranspiration (milimeter); Q_{out} = debit outflow ($meter^3$/second); G_{out} = debit outflow ground water ($meter^3$/second). Outflow consisted of two parts, namely:

$$q_{up} = (h_1 - h_2)CI_{up} \tag{2}$$

$$q_{lw} = (h_1 - PS)CI_{lw} \tag{3}$$

$$q_{out} = q_{up} + q_{lw} \tag{4}$$

where q_{up} = surface runoff (L/s); q_{lw} = sub surface runoff (L/s); h_1 and h_2 = soil moisture (mm); PS_1 = initial storage (mm); C = tank hole coefficient. The three level tanks in series were presented in Figure 2.

The outflow (q) would become the river flow, so that if it was put into equation:

$$Q = \frac{q_{total} \times A}{24 \times 3600} \tag{5}$$

where Q = river discharge ($meter^3$/second); q_{total} = thickness of the flow (mm/d); A = the width of river flow area (km^2).

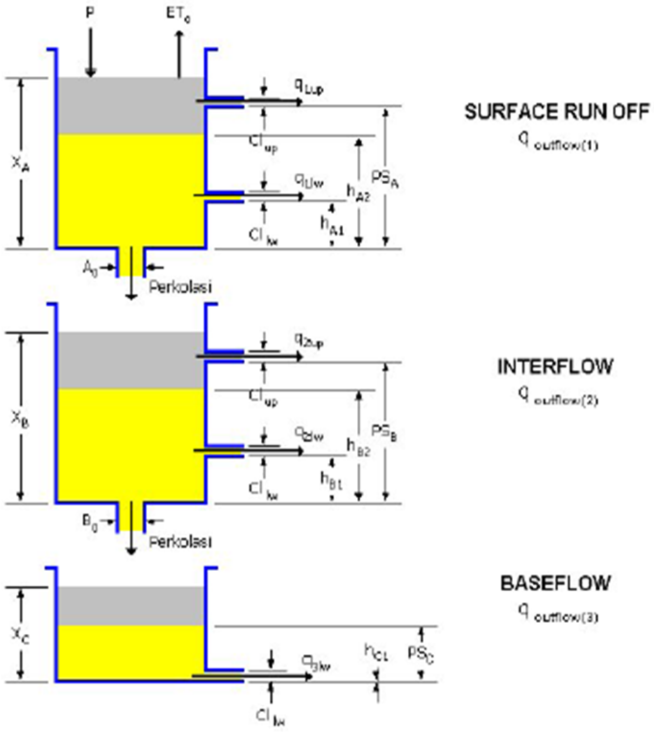

Figure 2. Tank model

2.2. Resorvoir Plan Location

Topography data used to obtain ground level information to identify location to build reservoir (Afani *et al*., 2019). Topography information obtained from the spatial processing of the land use 2014 map from Geospatial Information Board. Moreover, to choose a suitable location for the reservoir requires a site survey and considering several things (Muslim, 2017), including: (1) The basin site must sufficient to accommodate water, preferably less absorb water in the geo-engineering aspect to prevent water losses, (2) The location is near villages that require water to reduce energy lose due to too long distribution network, (3) Easy to access.

2.3. Flood Discharge

The flood discharge analysis used average daily maximum rainfall data from six rainfall stations. Rainfall stations include Bayeman, Lumbang, Sapeh, Boto Gardu, Muneng and Patalan.

2.4. Reservoir Design

The engineering model of the reservoir is based on the main discharge, the location of reservoir plans, and the flood discharge. The determination of the size of reservoir refers to the Circular Letter of the Minister of PUPR in 2018 concern to Guidelines for the Construction of Small reservoir and Other Water Storage Buildings in the Village, stating that small reservoir is able to accomodate water with a storage volume of 500 m^3 to 3000 m^3 with a maximum height is 3 meters (from the bottom to the top of the embankment) (Menteri PUPR, 2018).

3. RESULTS AND DISCUSSION

3.1. Dependable Flow of Kelampok River

The main discharge is the amount of flow discharge that is expected to always be available to fulfill the water requirement throughout the year with the minimum possible risk of failure (Mayasari, 2017). The main discharge is calculated using the Tank Model that will be presented in Figure 3, while the characteristics of the Model Tank are presented in Table 1. Tank model simulation produces the main discharge only from November to May with a maximum flow discharge of 332 litres/sec in First decade of march.

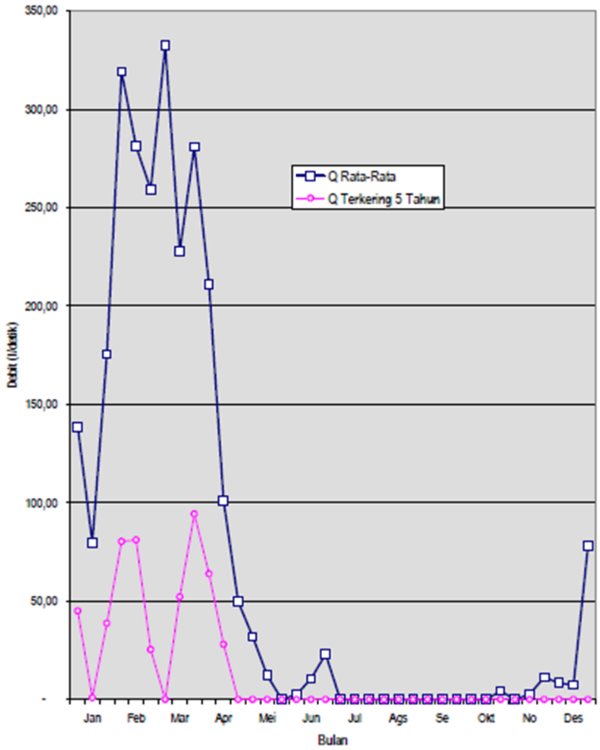

Figure 3. Dependable flow

Table 1. Tank Model Characteristic

No	Tank Model	Parameter					
		Perkolasi	Lower		Upper		Max Dept
			Heigth	C	Heigth	C	
1	Tank A (Surface Runoff)	0,21	20,00	0,25	50,00	0,12	73,72
2	Tank B (Interflow Runoff)	0,15	5,00	0,20	25,00	0,05	72,73
3	Tank C (Base Runoff)	0,00	0,00	0,03	–	–	36,71

3.2. Resorvoir Plan Location

Study area was divided into two areas: (i) Service area design on Kelampok Village to supply water, where nowadays relied on the rain-fed agricultural system; and (ii) Klumpit River Watershed has river outlet that has a potential as a reservoir. Klumpit River Watershed ended in three sub watersheds with the total area of 5.151 km^2, with the slope of Sub Watershed A was 0.0327, the slope of Sub Watershed B was 0.0399 and the slope of Sub Watershed C was 0.0396. Land use of Klumpit watershed consisted of settlement of 19 Ha (3.77%), (ii) rain-fed field of 363 (70.56%) and (iii) plantation of 132 Ha (25.67%). Service area design and Klumpit River Watershed were presented in Figure 4. In general, the type of soil in the study area is dominated by regosol soil of 699.786 Ha covered 96.60% of the village area. Regosol soil in general had a texture of sandy clay, so that the need of water was quite high (1.5 $L{\cdot}s^{-1}{\cdot}Ha^{-1}$).

3.3.Flood Discharge

The potential of Kelampok village rainfall shows that the annual rainfall average is amount 1.430,03 mm/years with D4 of oldeman climate type (can only planted with rice or crops once a year depending on the availability with irigation water). in this sense growing seasion only available once per year during rainy season which is from November untill May (Figure 5a). thus to be able to do farming system it is nacessary to develop a reservoir to harvest rainfall as water supply for irrigation system in the study area (Average monthly rainfall is presented in Figure 5a).

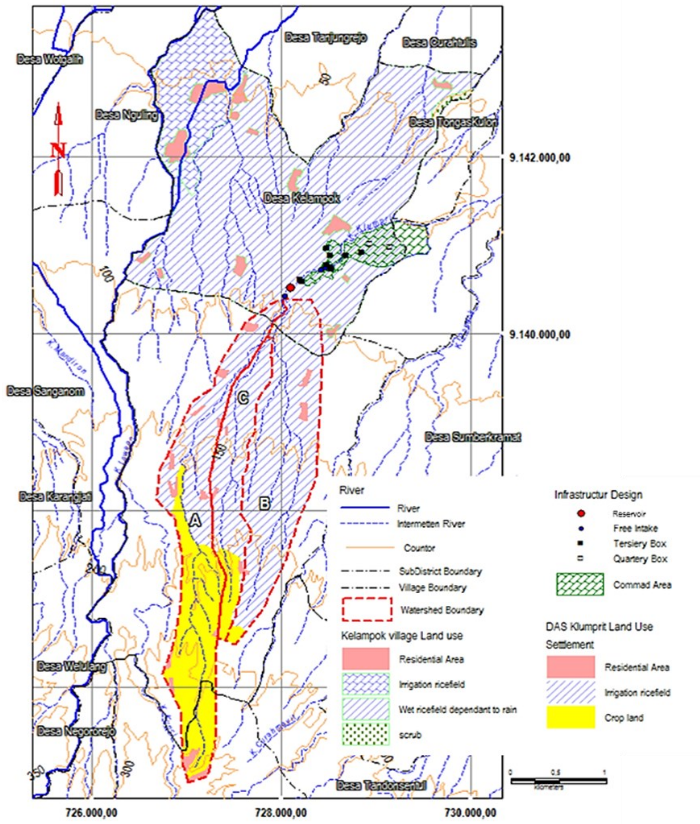

Figure 4. Research site (yellowed area)

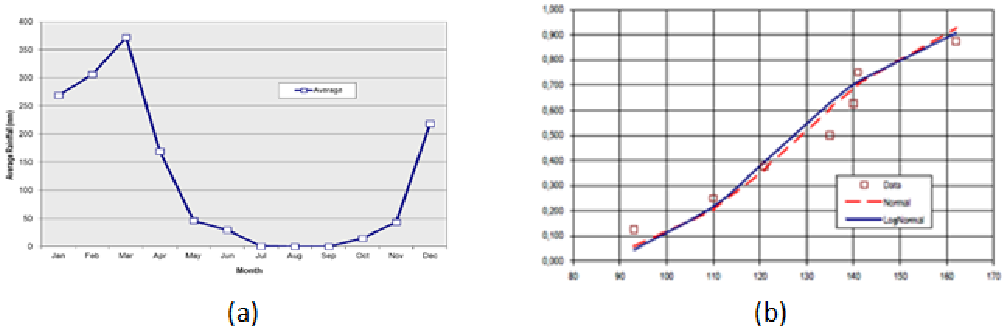

Figure 5. Potential rainfall of Kelampok Watershed: (a) average monthly rainfall and (b) rainfall distribution

Other than the average monthly rainfall, rainfall data itself could be interpreted as maximum rainfall of 24 hours (flood discharge). Maximum 24 hours rainfall will be presented in a normal distribution and normal log distribution (Figure 5b). Maximum 24 hours rainfall (Weibul distribution) has a different probabilitas 10,6% normal probability while normal log distribution is 12,9% so the maximum 24 hours rainfall distribution is calculated based on normal distribution. Maximum 24 hours rainfall distribution in 25 years repeat periode of normal distribution is 168 mm. The values is used for engineering the dimension of reservoir embankment.

3.4. The Design of Reservoir Kelampok

Reservoir is a building to store water built in depressed area, such reservoir would store water in rainy season, and water would be used by the people of a village during dry season to fulfill the need of water. Reservoir was designed with the following component of building (Figure 6):

Figure 6. The Design of Kelampok Reservoir

1. Reservoir Catchment

Reservoir catchment is a building to store flowing water in Klumprit River. Both sides of the catchment were supported by embankments, while upstream was supported by weirs. Water capacity for little reservoir is Mount 500m^3 – 3000 m^3 with maximum height is 3m (from the bottom untill the top of embankment) (Kementerian PUPR, 2018). Kelampok reservoir catchment was designed at the elevation of +91,00 masl with the height of the weir 5.00 m and the basic of taking of 1.20 m. The volume of catchment at the static capacity is 226 m^3, full capacity is 6.877 m^3. In this sense, Kelampok reservoir was not included in small reservoir. The engineering of the model, based on the goverment financial capability of Probolinggo regency (the greater of the embankment volume, the greater of embankment height and embankment manufacturing cost). The capacity curve of Kelampok reservoir is presented in Figure 7.

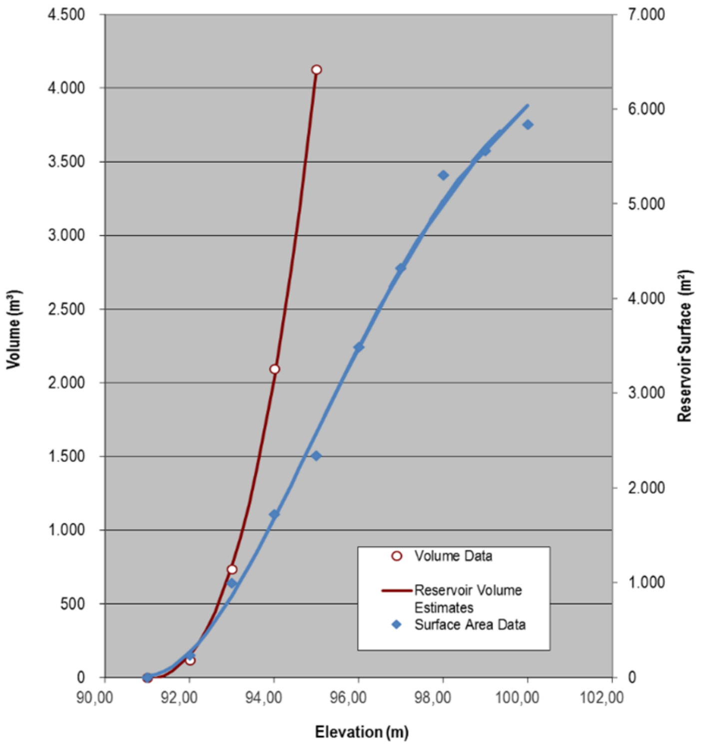

Figure 7. Capacity curve of Kelampok Reservoir

2. Reservoir Weir

A weir has a function to hold the water catchment held. If the water surpassed the capacity of catchment, then the water would exceed and flowed back to the river. Weir has a total width of 10.00 m and effective width of 9.20 m. Besides function as the catchment holder, weir also functions as affluent construction with the flowing capacity of flood of 32 m^3/second.

3. Reservoir Overflow

The design of the Reservoir overflow is based on the calculation of flood discharge. Calculation of flood discharge shows the greater results than the estimated discharge using the Weduwen method in the 100-year Re-period of 24.149 m^3/s. However, this designation also takes into global climate change and the environment.

4. Reservoir Wings
The reservoir wings are located at the right/left of the weir. Beside its function as the holder over the weir stability, it also functions as a catchment holder.

5. Reservoir Intake
Intake water buildings are located at the right and left in the basic elevation of the reservoir utilization. Such intake water building functions to maintain the water output from the reservoir. Intake Water buildings are equipped with flume measurement building to maintain the flow.

6. Plank Plate
Over the weir, a plank plate was designed to inspect the reservoir.

3.5. Reservoir (Embung) Kelampok Operation

The sustainability of resrvoir Kelampok needs to be supported by Operation and Maintenance (OP), so that an optimum benefit could be obtained (Notoatmojo & Rivai, 2001). Reservoir Operation was carried out as follows (Figure 9):

1. Rainy Season
In rainy season up to the end of dry season, reservoir catchment should always be full, so that it is able to increase the soil capability to absorb the water.
2. Dry Season
   a. Early March to April. The availability of dependable flow is still able to water service area as well as to fill the reservoir. The operation of intake water gate should be match with the water need.
   b. Early May to June. The availability of dependable flow is used to fill the reservoir and cultivated/strived not used.
   c. Early July to September. Water availability was obtained from the output of reservoir catchment. The capacity of reservoir if it was conducted an output for 10 decades, then the output from the reservoir was 789 l/day or 0.9131/second.

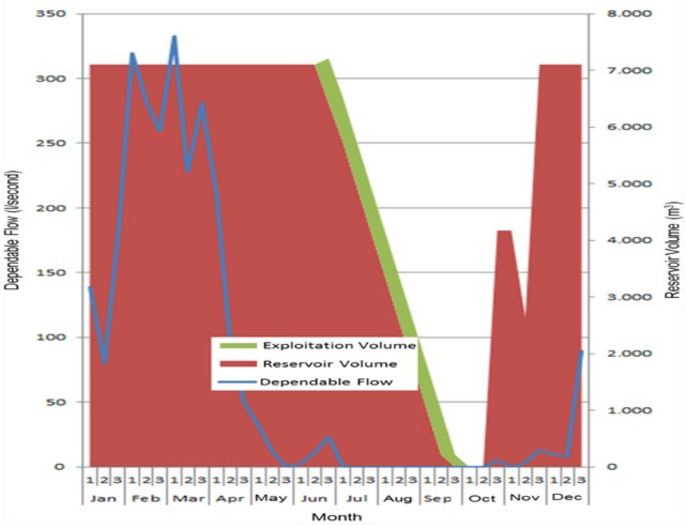

Figure 8. The Operation of Kelampok Reservoir

Maintenance is activity that maintain the irigation components and Building so that it can always function properly in order to facilitate the implementation of operations and maintain its sustainability. Reservoir Kelampok maintenance was carried out as follows:

Routine Maintenance

1. Every 10 days, inspection should be done to monitor the reservoir building.
   A. Damages should be recorded, and repairs should be planned when the catchment was empty (in August - September).
   B. Grass maintenance is carried out on the reservoir embankment, the grass should not exceed 10 cm from the ground surface.
   C. Cleaning the former olie that attachedin the sluice door by brushed with solar, then replaced with a new olie (SAE 40) every twenty days.
   D. Painting sluices once a year.
   E. At the end of the dry season or the beginning of the rainy season and the condition of the water reservoir is fully filled, a total opening is carried out to reduce the sediment of the reservoir. Disposal of sediment should also be done manually for sediment that are not carried away.
2. Repair / replacement is based on the results of inspections every 10 days and is carried out when the reservoir is not filled with water, especially landslides of embankment.
3. Emergency maintenace are carried out when existing damage could threaten the safety of the building.

4. CONCLUSION

The development of Kelampok Reservoir is based on hydrological and geological aspects of the Klumpit River Watershed: (i) average rainfall is 1,430 mm/year; (ii) Oldeman climate classification type is D4; (iii) main discharge is only from November to May with a maximum flow discharge is 332 litres/sec in First decade of March; and (iv) the soil type is dominated by regosol (96.60%). Kelampok Reservoir is engineered with (i) The full capacity of catchment is 7.103 m^3 and the effective capacity is 6,877 m^3, (ii) the reservoir has a total width of 10.00 m and an effective width si 9.20 m, and (iii) planned to operate from early July to September (10 decades/10 days) with an discharge output of 789 litres/day or 0.913 litres/second. The sustainability of Embung Kelampok needs to be supported by adequate operation and maintenance.

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