International Journal of Safety and Security Engineering
Vol. 15, No. 4, April, 2025, pp. 811-818
Journal homepage: http://iieta.org/journals/ijsse

Hydrological and Soil Characteristics of Long Storage Systems for Food Security in Merauke, Indonesia

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https://doi.org/10.18280/ijsse.150417

Received: 19 February 2025
Revised: 23 March 2025
Accepted: 9 April 2025
Available online: 30 April 2025

Keywords:
hydrology, soil characteristics, food security, water retention infrastructure, Merauke swamp

ABSTRACT

Long storage is an important infrastructure for irrigation water storage in Merauke, but its utilization is not optimal because the water source depends on rainwater, and causes a serious problem. Therefore, it is necessary to know the surface water runoff amount to understand the flood discharge received by long storage. This study aims to determine the value of runoff coefficient and soil characteristics in long storage to determine the effectiveness of long storage in supporting national food security. This research also represents the first investigation of runoff coefficients in Indonesian swamp areas.The study uses soil tests and hydrological analysis. Soil tests through field and lab work identify properties affecting water retention. Hydrological analysis includes calculating discharge and runoff coefficients to evaluate long storage performance. The test results show that the soil around the long storage is low plasticity silt with very low permeability (0.0000544-0.0000744 cm/sec). The runoff coefficient values varied between 0.0969 to 0.7103 each month. Based on the results, we conclude that long storage is suitable for a long-term irrigation water reservoir due to its impermeable soil characteristics, but more efficient integration of groundwater recharge and irrigation systems is needed for its sustainable use.

1. INTRODUCTION

Long storage is a water retaining building that functions to store water in rivers, canals and/or ditches on relatively flat land by holding back water flow to raise the water level so that the volume of water storage increases [1]. The Merauke region has a land surface that tends to be flat with a small land slope so that water is difficult to flow by gravity. Therefore, long storage is widely used to meet agricultural irrigation needs in Merauke. Long storage is in the form of an elongated trapezoidal-shaped excavation of soil with a certain depth which can be seen as in Figure 1 (long storage is shown with an elongated yellow line). The walls and base of the long storage are soil, there is no additional waterproof material such as membrane or concrete. The elevation of the base of the long storage building is lower than the agricultural land and the elevation of the long storage surface is parallel to the agricultural land, so that water is flowed to the agricultural land using a water pump. This condition distinguishes long storage from conventional reservoirs in general.

Since 2005, the government has made the Merauke region a target for large-scale agriculture through the Merauke Integrated Rice Estate (MIRE) program, the Merauke Integrated Food and Energy Estate (MIFEE), and the National Food Barn (LPN) program [2]. The southern part of Merauke Regency has a dry climate with long periods of sunshine. This condition is very beneficial for generative growth and productivity, especially for food crops, as long as there is no water shortage during the vegetative growth period. Merauke also has enormous agricultural land potential, which makes Merauke one of the national food barns to meet food needs in the Merauke Regency and surrounding areas [2, 3]. As the national food barn, water availability plays an important role in the success of agricultural production in supporting sustainable food security [4]. Therefore, water availability needs to be supported by systematic water resource management and adequate infrastructure. Currently, agricultural infrastructure in Merauke is supported by long storage buildings.

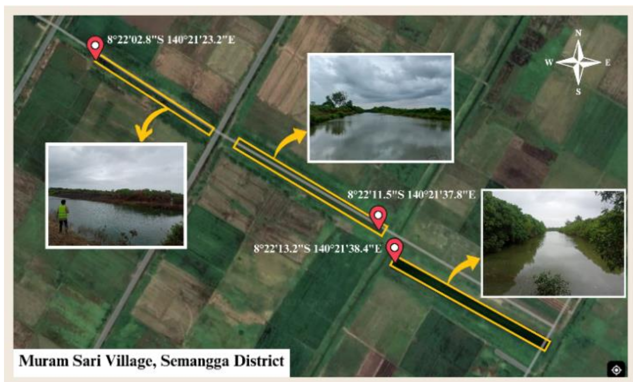

Figure 1. Long storage of Muram Sari

The use of long storage in Merauke is influenced by natural phenomena that occur during the rainy and dry seasons as well as the ebb and flow of sea water. The phenomenon is that during the rainy season the long storage will experience excess water due to high rainfall and saturated soil conditions. This often results in surface runoff from the long storage into agricultural areas because the capacity of the long storage is not able to accommodate the water discharge that enters the long storage. On the other hand, long storage experiences water shortages during the dry season because there is no additional water supply from rain and water sources from rivers do not flow optimally to long storage because the contour of the Merauke area tends to be flat. So that during the dry season, the water needs for agriculture are often not met and during the rainy season it causes losses due to flooding. Long storage water sources that still depend on rainwater are a serious problem, so knowledge is needed about the amount of surface water runoff in long storage to be able to know the amount of flood discharge received by long storage.

Surface runoff plays an important role in the hydrological cycle, especially when it comes to managing water resources and reducing flood risks. The runoff coefficient describes the amount of runoff that occurs in a certain area, and the greater the runoff coefficient, the greater the runoff that occurs [5]. The calculation of runoff coefficients for the characterization of catchment areas underlies various hydrological analyses [6-8]. Climate factors and soil characteristics mainly influence the runoff coefficient value [9, 10]. Studying the variation of runoff coefficient in long storage is very important to understand the hydrological cycle due to natural changes, soil characteristics, and anthropogenic [6, 11, 12].

Although the characteristics of a catchment area are an intrinsic control of surface runoff in response to rainfall, direct measurement remains a major challenge. The values of runoff coefficients are considered constant although in reality, they may vary [13]. In the same catchment area, the value may vary according to intensity, rainfall distribution, moisture conditions, soil characteristics, and land use. In addition, runoff records are the most important input data in water resources management. However, its availability is very limited especially in developing countries compared to rainfall records, especially in medium and small catchments [14]. There are not many studies that directly measure and calculate the runoff coefficient value in medium and small-scale water catchments [15]. Some related studies that have been conducted in several countries include the variability of the runoff coefficient and its relationship to physiographic and climate characteristics in two different catchments [13, 16]. Other studies determine the runoff coefficient value based on analysis of rainfall data and soil characteristics [17-19]. Meanwhile in Indonesia, research for determining the runoff coefficient has only been carried out by comparing the amount of rainfall [13, 20]. This shows that the investigation of runoff coefficient values by investigating soil characteristics in long storage has never been done in Indonesia, especially in swamp areas. Therefore, this study provides a novel value in the form of runoff coefficient records in long storage that can be used to strengthen food security in swamp areas. Runoff coefficient records can help maximize the function of long storage to irrigate rice fields.

The purpose of this study was to investigate the characteristics of the soil and the runoff coefficient value in long storage so that long storage can be utilized optimally in supporting sustainable food security. Investigation of soil characteristics will result in data on soil types and permeability. The calculation of the runoff coefficient value will result in a runoff coefficient value based on actual conditions in long storage. The results of the investigation of soil characteristics and runoff coefficients can then be used as a reference for solutions for providing agricultural irrigation water in Merauke. The results of this study can also provide recommendations to practitioners and policymakers to improve water resource management by taking into account the runoff coefficient value in long storage so that it meets the water needs for agriculture.

2. RESEARCH METHODOLOGY

This section provides an overview of the research implementation process that will be carried out using a case study approach, field surveys, quantitative method and qualitative method. The case study was conducted by taking samples of several long storages from several different agricultural land points in Semangga District, namely 3 long storage points. Semangga District was chosen as the research location because it is one of the largest food barns that supports food needs in the Merauke Regency and surrounding areas. Field surveys were conducted to obtain primary data in the form of existing conditions of long storage and soil sampling for laboratory testing. Laboratory testing produces data on soil characteristics and soil permeability numbers that are used for further analysis. In addition to primary data, secondary data is required in the form of rainfall data, air temperature, relative air humidity, and sunshine duration based on the last 10 years of data (2014-2023) obtained from the Meteorology, Climatology and Geophysics (BMKG) Agency Tanah Miring. Other analysis data in the form of a long storage location map were obtained from the River Basin Center (BWS) Papua Merauke Office. Primary and secondary data are then processed and analysed using quantitative methods. Quantitative methods are analytical methods based on data and are measurable. The results of the analysis are in the form of runoff coefficient values and are then described in the qualitative form to determine the relation between soil characteristics, runoff coefficient, and its effect on long storage performance.

2.1 Research framework

This research is divided into 3 stages as seen in Figure 2. The first stage is the preparation stage which is carried out to formulate the problem, determine the research objectives, identify the research location, design the research to be conducted, and determine data requirements. The second stage is the implementation stage, in this stage primary and secondary data collection, field surveys, soil permeability tests in the laboratory, and hydrological data processing are carried out. The third stage is the final stage in the research, the data that has been processed is then analyzed and the results are concluded.

2.2 Time and location of research

The research was conducted for 3 months, from June 2024 to August 2024. The research location is in Muram Sari Village, Semangga District with 3 long storage points. The position of the long storage is shown with a blue line as shown in Figure 3.

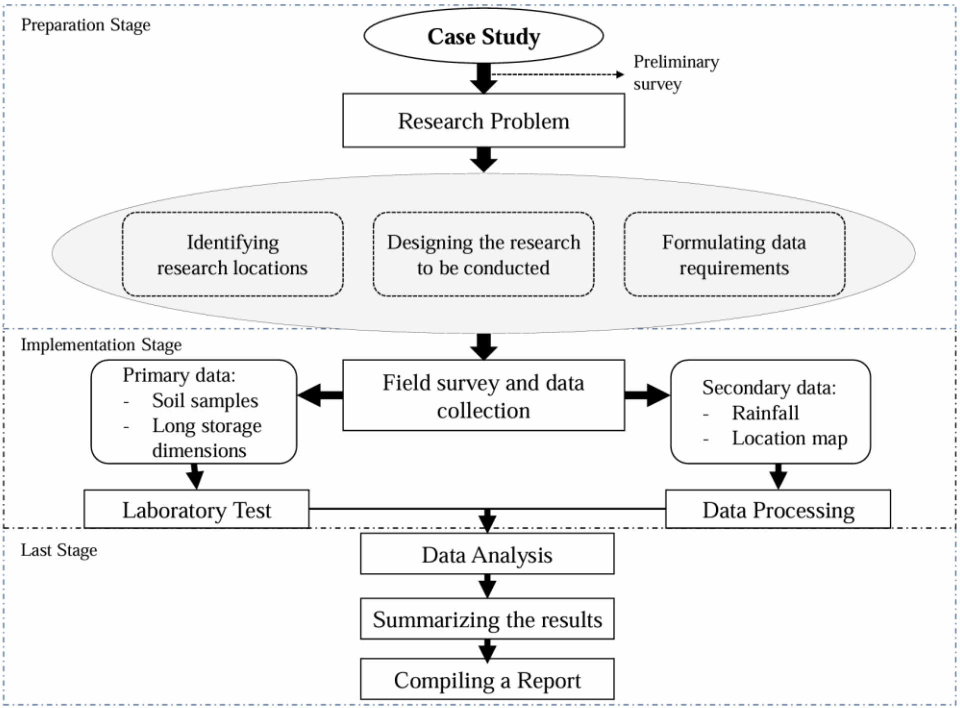

Figure 2. Research framework

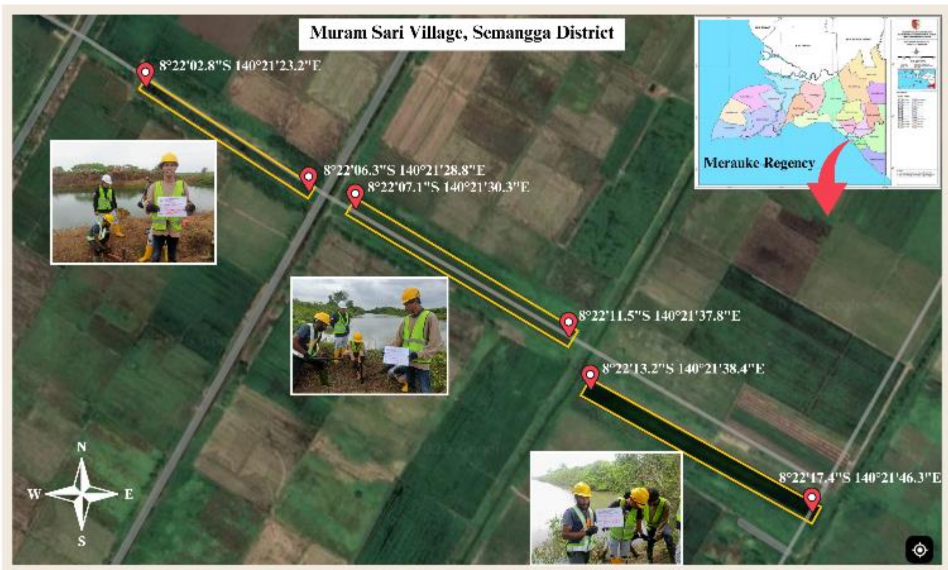

Figure 3. Research location

2.3 Soil test

The soil investigation aims to see the effect of soil properties on the potential for water loss in long storage during the rainy season. The soil investigation begins with a field survey and soil sampling in the long storage using the hand boring method to take soil samples. Hand Boring aims to visually examine soil characteristics regarding color, grain size, and soil type and measure the depth of the groundwater table. Hand boring was carried out at 3 long storage locations, soil sampling up to the limit of the groundwater table that can be known at the time of handboring. The soil samples were then used for soil characteristic tests and soil permeability values in the laboratory. The soil characteristic test used the Unified Soil Classification System (USCS) method. USCS is a soil classification system developed by the United States Army Corps of Engineers in 1948 and later adopted by various civil engineering institutions and organizations around the world [21-23]. The USCS was designed to provide a standardized way to classify soils based on their particle size and plasticity characteristics, which are important in determining the mechanical behavior of soils in a civil engineering context [24].

The USCS classifies soils into two main categories: coarse-grained soils and fine-grained soils. This classification is based on the particle size of the soil and the plasticity of the soil. Soil testing based on the USCS method involves several important steps to determine soil classification: Grain Size Analysis, Atterberg Limits Test, and visual and tactile soil identification [25]. In addition, laboratory soil testing also produces soil permeability values. Permeability testing was conducted using undisturbed soil samples with the Falling Head method. This method is suitable for measuring the permeability of fine-grained soils [26], as Merauke is a swamp area where the soil tends to be predominantly fine-textured. Soil permeability is the ability of soil to flow water or fluid through its pores. Soil permeability testing, often referred to as soil hydraulic conductivity test, aims to measure how easily water can move through the pore space in a soil mass. The permeability value helps in analyzing the capacity of long storage to meet irrigation needs. The soil permeability test uses the Falling Head method. The Falling Head method is used for fine-textured soil. The soil permeability coefficient is determined by the following equation [27]:

$$k = 2{,}303 \frac{V_w L}{(h_1 - h_2) t.A} \log \frac{h_1}{h_2} \quad (1)$$

2.4 Hydrology analysis

Hydrological analysis is the study of the distribution, movement, and properties of water above and below the earth's surface [28]. Hydrological analysis aims to understand and manage the hydrological cycle and the various processes involved in the movement of water in the natural environment. The main components in the hydrological analysis calculated in this study include monthly potential evapotranspiration, the mainstay discharge of each long storage in each month, and the runoff coefficient in each long storage.

2.4.1 Penman method of evapotranspiration

Evapotranspiration is a combination of evaporation and transpiration [29, 30]. Evapotranspiration plays an important role in hydrological analysis because it affects the water balance of an area, especially agricultural areas. Therefore, the calculation of water needs for irrigation needs to take into account the amount of evapotranspiration. The calculation of evapotranspiration uses the modified Penman equation [31-33]:

$$Et_0 = c.\{W.Rn + (1-W).f(U).(es - ea)\} \quad (2)$$

The data required for calculating evapotranspiration (ET_0) is climatological data from the Meteorology, Climatology and Geophysics (BMKG) Agency Tanah Miring Merauke which is located between 08°23'14.736" Southern Latitude and 140°31'01.007" East longitude. The climatological data used consists of air temperature data (℃), relative humidity (%), and sunshine duration (minutes) measured over the last 10 years from 2014-2023. These data are then analyzed to obtain monthly Evapotranspiration values (ET_0).

2.4.2 Dependable flow of F.J. mock method

The dependable flow is the minimum long storage flow at a certain opportunity level that can be used for water supply purposes. The calculation of the dependable flow is intended to find the amount of water available for irrigation water needs with the calculated risk of failure. The dependable flow value is calculated using the F.J. Mock method. The principle of the F.J. Mock method states that rain falls on the catchment area, some will be lost due to evapotranspiration, some will directly become runoff and some others will enter the soil or infiltration occur [34]. The first step in calculating the dependable flow using the F.J. Mock method is to calculate the limited evapotranspiration value with the following equation:

$$Et = Et_0^* - E \quad (3)$$

$$E = Et_0^* \text{x} \left(\frac{m}{20}\right) \text{x} (18 - n) \quad (4)$$

The limited evapotranspiration value calculated using the formula above can then be used to calculate the water balance using the following equations:

$$\Delta s = P - Et \quad (5)$$

$$Surface\ Runoff = PF \text{ x } P \quad (6)$$

$$SS = \Delta s - Surface\ Runoff \quad (7)$$

$$SMC_{(n)} = SMC + SS \quad (8)$$

$$WS = \Delta s \quad (9)$$

2.4.3 Runoff coefficient

The runoff coefficient is the ratio between the amount of rainwater that turns into surface flow with the total rainfall that falls on a certain area [13]. This runoff coefficient is important in determining the volume of water flowing to the long storage, which is then used for irrigation. Runoff coefficient values range from 0.0 - 1.0. A value of 0.0 means that all rainfall is lost in abstractions such as infiltration, interception, and evaporation and no rainfall is converted into runoff. Conversely, a value of 1.0 means that no rainwater loss occurs and becomes runoff. The runoff coefficient in this study was calculated using a mathematical method. The runoff coefficient from the mathematical calculation is then compared to the runoff coefficient value with the equation stated by Hassing [35]. The coefficient values stated by Hassing present a method for determining factors that influence the relationship between rainfall and flow, namely topography, soil permeability, land cover, and land use with criteria as in Table 1.

Table 1. Flow coefficient for the Hassing method

Flow Coefficient C = Ct + Cs + Cv					
Topography (Ct)		**Soil (Cs)**		**Vegetation (Cv)**	
Flat (< 1%)	0.03	Sand and gravel	0.04	Forest	0.04
Wavy (1-10%)	0.08	Sandy loam	0.08	Agriculture	0.11
Hills (10-20%)	0.16	Clay and silt	0.16	Grassland	0.21
Mountains (> 20%)	0.26	Rock layers	0.26	No corps	0.28

3. RESULTS AND DISCUSSION

In this section, the discussion of research results shows the relationship between soil characteristics and runoff coefficient (C) values at three long storage points in Muram Sari Village, Merauke, as part of efforts to provide sustainable long-term water irrigation. The analysis was conducted using quantitative and laboratory approaches, referring to the USCS soil classification standard and the runoff coefficient method based on empirical and comparative data from the Hassing method.

3.1 Soil test

Hand boring at 3 (three) long storage points obtained the depth of the groundwater table, namely at point 140 cm at point 01, 120 cm at point 02, and 120 cm at point 03. Soil sampling was carried out every 20 cm depth until the depth of the groundwater table. Laboratory test results using USCS classification and SNI 03-1965-1990 on the three long storages can be seen in Table 2.

Table 2. Laboratory test results

Long Storage Point	% Passing Sieve No. 200 (Diameter 0.075 mm)	Soil Type	Permeability, k (cm/sec)
Point 01	93.18%	ML or silt	0.0000632
Point 02	96.294%	ML or silt	0.0000544
Point 03	90.36%	ML or silt	0.0000744

The soil test results from three long storage points in Table 2 show a uniform soil type of low plastic silt (ML), with a percentage of passing sieve no. 200 between 90.36% and 96.294%. Based on the USCS classification and SNI 03-1965-1990, low plasticity silt has low permeability and infiltration characteristics. This is reinforced by the results of the permeability test using the Falling Head method where the average permeability of the soil at the research site is 0.000064 cm/sec. The permeability coefficient of silt soil is tested using the Falling Head method as this method is suitable for fine-grained soils with low water flow rates. In this test, a fixed pressure between 50-100 kPa is used, with a hydraulic gradient of less than 1 for soft soils and 1-5 for hard soils. The soil samples used were undisturbed soils molded directly with a molding ring, then saturated with water to remove air in the system. The water level drop in the burette pipe was recorded every 1-2 hours, until the flowing water reached a steady flow condition. The permeability coefficient was calculated based on the change in water level with respect to time, with the results falling into the very low category of 0.0000544-0.0000744 cm/sec. This permeability coefficient value is classified as very low based on the ASTM D5084 geotechnical classification. This indicates that the soil is relatively impermeable and supports longer water retention in long storage. This is favorable in the context of irrigation but the water retention capacity is also not as great as that of clay, which makes these soils more prone to saturation under low to moderate intensity rainfall conditions.

3.2 Hydrology analysis

Hand boring at 3 (three) long storage points obtained the depth of the groundwater table, namely at point 140 cm at point 01, 120 cm at point 02, and 120 cm at point 03. Soil sampling was carried out every 20 cm depth until the depth of the groundwater table. The results of laboratory tests using Indonesian National Standards (SNI) at the three long storages are as follows:

3.2.1 Evapotranspiration (ET_0)

Evapotranspiration analysis using the Penman method based on meteorological parameters. The results of evapotranspiration analysis can be seen in Figure 4.

Figure 4 is bar chart of the monthly evapotranspiration value for the year 2014-2023. In the bar chart, it can be seen that the value of evapotranspiration at the beginning and end of the year is large, while in the middle of the year, it decreases. This is influenced by meteorological parameters such as air temperature (°C), relative air humidity (%), and length of sunshine (minutes). Evapotranspiration calculation is needed to determine the amount of water loss and calculate the mainstay discharge. The recapitulation of average monthly evapotranspiration is shown in Table 3.

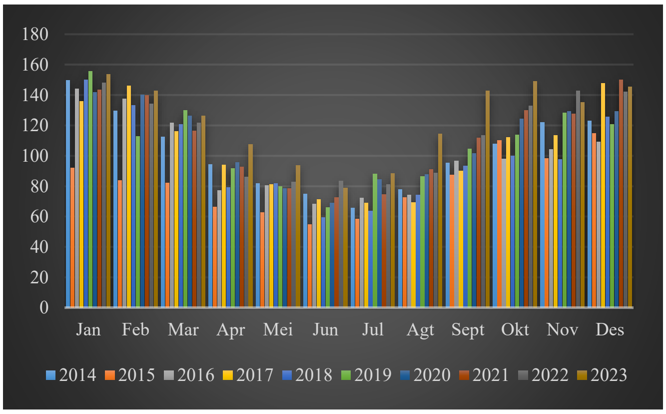

Figure 4. Monthly evapotranspiration graph (ET_0) in 2014-2023

Table 3. Average monthly evapotranspiration (ET_0) in 2014-2023

Month	Evapotranspiration (mm/month)
January	141.42
February	129.96
March	117.32
April	88.47
May	80.12
June	69.83
July	74.48
August	83.65
September	103.67
October	117.74
November	119.79
December	130.72

Table 4. Discharge recapitulation in the long storage of Muramsari village

Month	Discharge (Q_1) (m^3/sec)	Discharge (Q_2) (m^3/sec)	Discharge (Q_3) (m^3/sec)
January	0.00450	0.00544	0.00521
February	0.00855	0.01035	0.00990
March	0.01190	0.01440	0.01378
April	0.00751	0.00909	0.00870
May	0.00436	0.00527	0.00504
June	0.00227	0.00274	0.00262
July	0.00135	0.00164	0.00157
August	0.00082	0.00099	0.00095
September	0.00062	0.00075	0.00072
October	0.00033	0.00041	0.00039
November	0.00053	0.00065	0.00062
December	0.00380	0.00460	0.00440

Table 4 shows that the highest average evapotranspiration value occurred in January, which was 141.42 mm/month, and the lowest average evapotranspiration value occurred in June, which was 69.83 mm/month. The evapotranspiration value is high in January due to the high temperature and length of irradiation which amounted to 29.10°C and 211.20 minutes. While in June the evapotranspiration value is low due to low temperature and length of irradiation which amounted to 28.06°C and 107.04 minutes.

Table 5. Recapitulation of runoff coefficient (C) of the surface of long storage in Muramsari Village

No.	Bulan	Curah Hujan (mm)	Long Storage 01			Long Storage 02			Long Storage 03		
			Volume Curah Hujan (m^3)	Volume Limpasan (m^3)	Koefisien Limpasan (C)	Volume Curah Hujan (m^3)	Volume Limpasan (m^3)	Koefisien Limpasan (C)	Volume Curah Hujan (m^3)	Volume Limpasan (m^3)	Koefisien Limpasan (C)
1	Jan	267.89	50899.30	12,040.31	0.2366	61614.90	14,575.11	0.2366	58936	13,941.41	0.2366
2	Feb	240.54	45702.90	20,687.30	0.4526	55324.60	25,042.52	0.4526	52919.20	23,953.72	0.4526
3	Mar	316.59	60152.70	31,864.40	0.5297	72816.40	38,572.69	0.5297	69650.50	36,895.62	0.5297
4	Apr	170.99	32488.30	19,471.63	0.5993	39327.90	23,570.92	0.5993	37618.00	22,546.10	0.5993
5	May	107.13	20354.30	11,665.48	0.5731	24639.40	14,121.37	0.5731	23568.10	13,507.40	0.5731
6	Jun	43.53	8270.21	5,874.65	0.7103	10011.30	7,111.42	0.7103	9576.030	6,802.22	0.7103
7	Jul	39.96	7592.69	3,621.45	0.4770	9191.16	4,383.86	0.4770	8791.54	4,193.25	0.4770
8	Aug	40.89	7768.96	2,196.23	0.2827	9404.53	2,658.59	0.2827	8995.64	2,543.00	0.2827
9	Sep	38.60	7333.78	1,605.21	0.2189	8877.74	1,943.15	0.2189	8491.75	1,858.66	0.2189
10	Oct	45.59	8661.97	896.83	0.1035	10485.50	1,085.63	0.1035	10029.60	1,038.43	0.1035
11	Nov	75.24	14295.60	1,385.03	0.0969	17305.20	1,676.61	0.0969	16552.80	1,603.71	0.0969
12	Dec	207.61	39445.80	10,185.64	0.2582	47750.20	12,329.98	0.2582	45674.10	11,793.89	0.2582

3.2.2 Long storage discharge

The mainstay discharge in long storage is calculated using the F.J. Mock method which takes into account the influence of evapotranspiration values. Based on the results of the evapotranspiration analysis above, the results of the mainstay discharge analysis can be seen in Table 5.

Table 5 shows that the water discharge in the long storage is available throughout the year. The average annual discharge for the three long storage points ranges from 0.00033-0.0144 m^3/second. The peak discharge occurs in March (rainy season) which is 0.01190 m^3/sec in long storage 01, 0.01440 m^3/sec in long storage 02, and 0.01378 m^3/sec in long storage 03. Meanwhile, the minimum discharge occurs in October (dry season) which is 0.00033 m^3/second in long storage 01, 0.00041 m^3/second in long storage 02, and 0.00039 m^3/second in long storage 03. This discharge reflects good long-term storage capacity as a long-term water reservoir, but remains limited by dependence on rainwater.

3.2.3 Runoff coefficient

The runoff coefficient value is calculated by mathematical methods based on the ratio of runoff volume and rainfall volume at each long storage point. A recapitulation of the runoff coefficient at each long storage can be seen in Table 5.

Table 5 above shows that the runoff coefficient (C) in the three long storages has the same value with a variation of 0.0969 - 0.7103 which shows significant variation throughout the year. This occurs because the three long storage points are in adjacent locations with similar soil characteristics, topography, and vegetation. Comparatively, the empirical C value is higher than the theoretical C value of Hassing's method of 0.30 for the combination of flat topography, silt soil, and agricultural vegetation. This difference indicates that the empirical method more accurately captures the actual conditions in the field, including the effects of soil saturation and the dynamics of local microclimate changes. Whereas the Hassing method is limited in capturing the effects of climate change, anthropogenic, and soil saturation. Therefore, the calculation of the direct runoff coefficient value based on field conditions is important because each region has different conditions.

Table 5 also shows that the runoff coefficient value during the dry season is greater than during the rainy season. This is influenced by the type of soil in the long storage based on the results of laboratory tests, namely silt soil. In the dry season, the soil is denser and drier, so runoff is higher, while in the rainy season, the soil is wetter and looser, so infiltration increases and runoff decreases. This indicates that long storage is an infrastructure that can be used to store water in the long term.

4. CONCLUSION

This research shows that the long storage system in Merauke has great potential as a long-term water storage infrastructure to support agricultural irrigation. Soil test results at three locations showed that all locations have a uniform soil type, namely silt with low plasticity (ML) based on USCS classification and SNI 03-1965-1990. The percentage passing the no. 200 sieve ranges from 90.36%-96.294%, and the average permeability value is very low at 0.000064 cm/sec, which indicates the relatively impermeable nature of the soil and functions well in water retention. In terms of hydrology, the results of evapotranspiration analysis for 10 years (2014-2023) show that the highest value occurs in January (141.42 mm/month) and the lowest in June (69.83 mm/month). Discharge analysis using the F.J. Mock method shows that water discharge is available throughout the year, with the highest discharge value in March (0.0144 m^3/second) and the lowest in October (0.00033 m^3/second). This indicates that although the long storage is able to store water quite well during the rainy season, there is limited water supply during the dry season due to dependence on rainfall. The runoff coefficient (C) ranged from 0.0969-0.7103, with the highest value occurring during the dry season. This is due to the hardened and dry soil conditions that reduce infiltration. Conversely, in the rainy season, the soil becomes looser and absorbs more water, so the runoff value decreases. Comparison with Hassing's theoretical value (C = 0.30) shows that the empirical method provides a more representative estimate of the actual conditions in the field. Based on these results it can be concluded that water loss in long storage is small, so long storage in Muram Sari Village has good capacity for irrigation. However, it is necessary to integrate an effective groundwater recharge system and irrigation system so that it does not only depend on rainwater. In addition, the influence of infiltration and percolation values in this study has not been taken into account so further research needs to be done to find out whether the soil in the long storage is truly impermeable and can meet long-term irrigation needs.

ACKNOWLEDGMENT

The authors would like to thank the Directorate of Research, Technology and Community Service (DRTPM) of the Republic of Indonesia for providing financial support for this research, Musamus University for its support so that the implementation from the preparation of the proposal to the research could be completed properly, as well as data support from the River Basin Center (BWS) Papua Merauke and the Meteorology, Climatology and Geophysics (BMKG) Agency Tanah Miring. Thanks also to the Civil Engineering Laboratory of Musamus University for providing research facility support.

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NOMENCLATURE

A	cross-sectional area of soil sample
C	runoff coefficient
E	difference between potential evapotranspiration and limited evapotranspiration (mm)
ea	actual vapor pressure (kPa)
es	saturated vapor pressure (kPa)
Et	limited evapotranspiration (mm/month)
Et_0	evapotranspiration (mm/day)
f(U)	wind speed (km/day, m/second, knot)
h_1	initial water head height
h_2	final water head height
k	permeability coefficient (cm/second)
L	length of soil sample (mm)
m	exposed surface (%)
ML	silt
n	number of rainy days in a month
P	monthly rainfall (mm/month)
PF	percent of rainfall that becomes runoff
Rn	net radiation (mm/day)
SMC	soil moisture capacity (taken as 50 mm - 205 mm)
$SMC_{(n)}$	nth month soil moisture (mm)
SNI	Indonesian Nasional Standard
SS	soil water content (mm)
USCS	unified soil classification system
W	temperature and temperature-related factors
WS	excess water (mm/month)
°C	temperature

Greek symbols

Δs	rainwater reaches the ground surface (mm/month)