

# The Study of Potential Retention Ponds in Samudra University to Meet Raw Water Demand and Flood Control

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**Abstract.** This study aimed to evaluate the potential locations and volume capacities of retention ponds at Universitas Samudra (Unsam) to reduce flood discharge, provide raw water supply, and ensure water quality. The experiment was carried out to support the concept of a smart and green campus at Unsam. Water availability was calculated using the FJ Mock model, while water demand was projected based on the number of users. The retention ponds capacity for flood control and raw water availability was assessed using the HEC-HMS model. Water quality testing, including physical, chemical, and biological parameters, was conducted at the BTKLPP Class I Medan laboratory. The results showed that water demand at Unsam was 3 m<sup>3</sup>/day, which could be met by the reliable discharge of 16,344.93 m<sup>3</sup>/day. Although the existing reservoir retention ponds, with a volume of 509,788.80 m<sup>3</sup>, contributed to flood discharge reduction, the quality did not meet the required standards due to high concentrations of Total Coliform and *Escherichia Coli*. However, Cotkala-Unsam retention ponds provided 103,596.96 m<sup>3</sup> of water with quality that met acceptable limits.

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## 1. Introduction

Universitas Samudra (Unsam) is a growing state university located in Langsa City, Aceh Province. The campus spans approximately 50 hectares and frequently experiences annual flood, which significantly impact operations and infrastructure. The occurrence of this flood has damaged newly constructed roads leading to the Faculty of Law, the PGSD Laboratory, and the Basic Laboratory. Additionally, there is obstruction access to the Student Secretariat Building and the Dance Studio. Although flood has not disrupted classes, there is potential for future interference with academic activities when the issues are not addressed. This is particularly due to access problems between older buildings and the newly developed campus facilities, posing safety risks for students and staff.

According to a previous study, Unsam campus located within the Langsa River Basin (LRB) is traversed by a main river experiencing annual flood during the rainy season (Ismida et al., 2021). The urban drainage system, which discharges into the river and estuary in Langsa City, often causes localized flood during heavy rainfall, thereby affecting rural areas around the campus. This issue also impacts Unsam drainage system, as the flows meet with the main drainage channel leading to the Langsa River. However, the primary and secondary drainage systems in the area are unable to manage water flow efficiently due to channel narrowing caused by sediment buildup from severe soil erosion in the critical LRB (F. Isma & Purwandito, 2019). Sediment transport includes both suspended and bed load (Irwansyah et al., 2023; F. Isma & Purwandito, 2020), showing the need for adequate retention ponds to effectively control flood on campus.

Rahmawati et al., (2023) stated that climate change had led to prolonged droughts, showing the need to consider the

potential of a rainwater harvesting system. Adityawan et al., (2024) suggested the need for an automatic polder system to control flood due to changes in land cover following the construction of Yogyakarta International Airport. Generally, retention ponds play a significant role in controlling runoff during the rainy season and maintaining water balance (Zevri & Isma, 2021). At Unsam University, several retention ponds have been built but their capacity is still insufficient, particularly during extreme rainfall. This is because the design cannot handle the increased frequency of flood caused by changing rainfall patterns, leading to overflow.

The deficiency of retention ponds is significantly attributed to the high water flow from the PTPN I plantations and downstream settlements near the IAIN CotKala reservoir. Additionally, soil erosion in LRB has led to sediment accumulation, obstructing water flow in campus main drainage channels, which reduces the efficiency of retention ponds (Isma et al., 2019; Irwansyah, Isma, & Ismida, 2023). Rainfall data from the PTPN I station show an increasing trend of extreme rainfall events in the Langsa area over recent years. In October 2022, rainfall reached 404 mm at the Kebun Lama Station (KLM), causing severe flood around the Unsam campus. The occurrence of flood was previously often associated with daily rainfall ranging from 100 to 200 mm. The data showed a long-term trend of increasing rainfall intensity, which raised the risk of future flood. To address the challenge, this study explored how the changing rainfall patterns affected flood management planning at Unsam campus. The rise in extreme rainfall events underscores the need for improvements in campus flood management system (Förster et al., 2005; Trilita et al., 2020).

Based on the description, this study aimed to address knowledge gaps, particularly in evaluating the capacity of

existing retention ponds to reduce flood risk and identify potential locations for new construction. The function of retention ponds was also explored as sustainable sources of raw water while maintaining water quality. This is critical for supporting the future of Unsam as a Smart and Green Campus, enhancing understanding of flood management within and around the campus to promote more sustainable water management practices (Day et al., 2009; Florince et al., 2015; Lauda et al., 2017; Singh, 2018). As part of the Green Campus concept, Unsam is committed to implementing efficient environmental management practices, including optimizing the use of water resources. Sustainable management through conservation and recycling is in line with the main goals of the Green Campus concept to reduce excessive water consumption and maximize resource use efficiency. This is essential for ensuring adequate raw water availability and maintaining environmental sustainability (Förster et al., 2005; Trilita et al., 2020; Ujianto et al., 2022). Efficient use also plays a major role in minimizing the environmental impact of uncontrolled water consumption, which is in line with the Green Campus concept of Unsam.

## 2. Study Area, Data Collection and Methods

### Study Area

The study area is located within the Unsam campus environment, which falls under the Langsa River Watershed Area. This designation makes the area a catchment for water from the PTPN I Langsa plantation, as shown in Figure 1. Consequently, the study area holds the potential to serve as a runoff collection through the implementation of retention ponds.

Figure 1 shows the study area which is equipped with two retention ponds located around Unsam. These include the Old Unsam Pond (coordinates: lat: 4°27'4.78"N; long: 97°58'21.10"E) and the New Unsam Pond (coordinates: lat: 4°27'23.25"N; long: 97°58'21.27"E). Additionally, there is one

retention pond near IAIN CotKala Langsa (coordinates: lat: 4°27'23.23"N; long: 97°58'13.11"E). All these locations form part of a single Catchment with a total area of 8.334 km<sup>2</sup>.

### Data Collection

The rainfall data used in this study was obtained from the Kebun Lama Station (KLM) of PTPN I Langsa, from 2010 to 2022. This station was selected due to the proximity to the study area, ensuring that the rainfall data was highly representative of conditions at Unsam. The data were used to design rainfall analysis for the estimation of extreme rainfall intensities that could trigger flood and simulate surface runoff within the Unsam campus catchment area. To map the topography and delineate the catchment area, this study used Digital Elevation Model Nasional (DEMNAS) data, downloaded from the official website of Badan Informasi Geospasial (<https://tanahair.indonesia.go.id/demnas/#/demnas>). DEMNAS data played an essential role by providing information for catchment delineation, determining flow direction, as well as estimating land elevation and slope conditions. This information was used for modeling surface runoff and identifying areas vulnerable to flood during heavy rainfall events.

Field measurements were conducted to collect detailed elevation data for existing retention ponds and drainage networks within Unsam campus. These measurements included data on ponds height, capacity, and the physical condition of the drainage systems. Furthermore, direct measurements offered additional accuracy needed to calibrate the hydrological model and ensure that runoff simulations were in line with real-world conditions in the field. This study also used land cover data obtained from the Ministry of Environment and Forestry, accessible through the Lapak GIS website (<https://www.lapakgis.com/2019/05/shapefile-peta-tutupan-lahan-klhk-2017.html>). The data provided valuable insights into the distribution of land use types, including oil palm plantations owned by PTPN I and residential areas. This

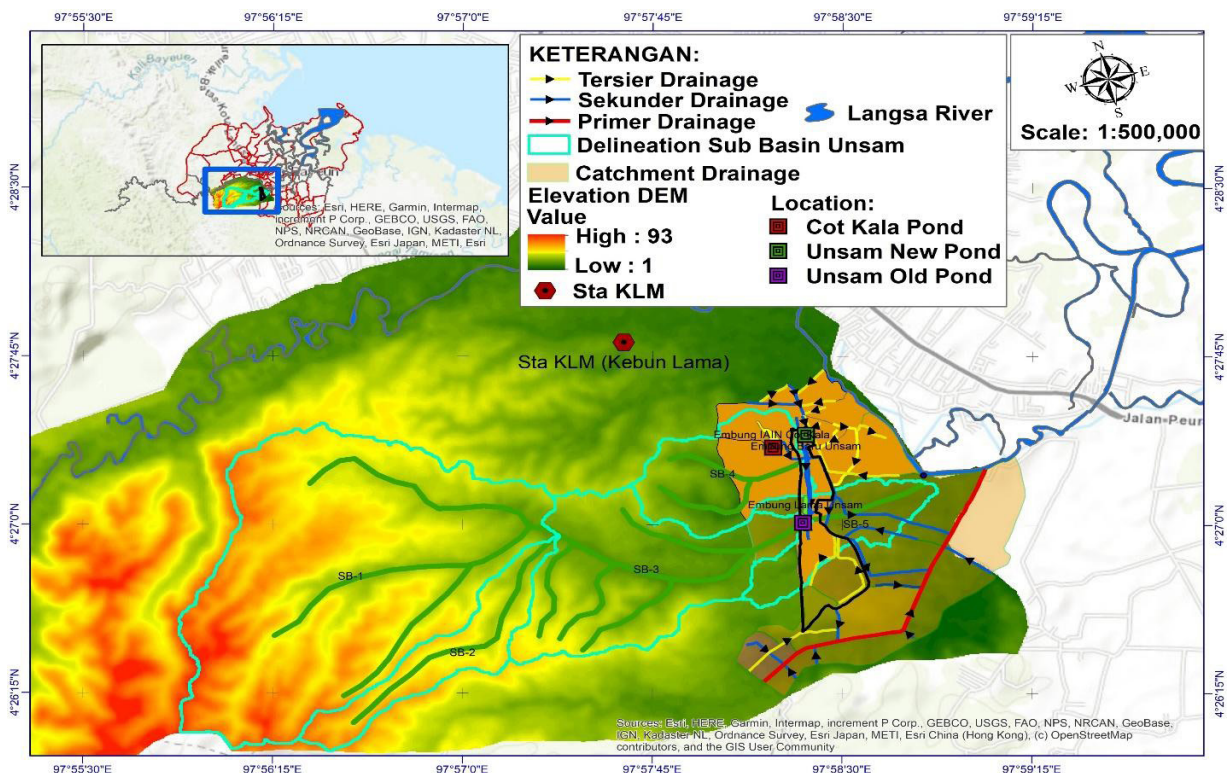


Figure 1. Study Area

information was used to understand how different land cover types influenced infiltration rates and surface runoff in Unsam Catchment.

The dimensions of the existing retention ponds at Unsam were measured using a Bench Mark (BM) located at the Faculty of Engineering, with reference to the Mean Sea Level (MSL). This measurement was used to determine the elevation of ponds bottom, which also served as a reference for assessing the potential dimensions of new and existing ponds. The analysis was carried out to ensure sustainable water availability and effective flood control at Unsam. Generally, the determination of elevation is crucial for understanding the dead storage condition in the context of retention ponds. Dead storage refers to the volume of water stored at the bottom of the pond that cannot be drained or used. This portion often contains water and does not directly contribute to the active storage capacity during flood events.

In this study, dead storage was typically designed to accommodate sediment and prevent contamination in ponds. The effective storage volume was calculated as the volume of water that could be stored and used during flood, namely water held above the dead storage level. This differs from the total storage volume, which includes the entire ponds capacity, including dead storage. Effective storage volume only accounts for the portion that can be used for flood control.

To support the geological and soil analysis, this study incorporated geological data from the Global Hydrological Soil Group, which can be accessed at ([https://daac.ornl.gov/SOILS/guides/Global\\_Hydrological\\_Soil\\_Group.html](https://daac.ornl.gov/SOILS/guides/Global_Hydrological_Soil_Group.html)). The data were used to determine soil characteristics within Unsam Catchment, which significantly impacted the soil water absorption capacity and the magnitude of surface runoff. Subsequently, the combination of various data sources, including rainfall, topography, elevation, land cover, and soil type, was used to conduct a comprehensive analysis of flood discharge potential and retention ponds efficiency within Unsam campus area. This analysis was carried out to provide targeted recommendations for improving water management infrastructure within the study area.

## Methods

This study used various comprehensive and complementary analytical methods. The multidisciplinary methods incorporated the use of statistical distribution to analyze design rainfall and FJ Mock calculated water availability. Hydrological modeling using HEC-HMS combined with the Curve Number (CN) method was used for flood discharge simulation (F. Isma, Kusuma, Nugroho, et al., 2024; Zahroni et al., 2024). Additionally, sampling methods were applied in the water quality analysis of retention ponds. Water demand calculations were performed according to national standards, following the guidelines of SNI-03-7065-2005 and criteria from the Ministry of Public Works. These combination methods were designed to provide more accurate solutions for addressing flood challenges and sustainable water management in the campus environment, with the workflow shown in Figure 2.

Figure 2 shows the workflow for evaluating retention ponds at Unsam campus, starting with the analysis of annual maximum rainfall from 2010 to 2022. Daily rainfall data was used to calculate design rainfall, focusing on extreme events that could cause flood. The analysis was conducted using statistical distribution methods such as Normal, Log Normal, Log Pearson III, and Gumbel (F. Isma, Kusuma, Adityawan, et al., 2024). The results produced design rainfall for 2 and 5-year return periods, which was used to estimate flood discharge. These distribution methods have proven effective in various studies, including the study (Ismida et al., 2021), and are frequently used in long-term analysis, particularly for flood risk evaluation.

The Digital Elevation Model Nasional (DEMNAS) data were processed with HEC-HMS version 4.11 using GIS tools. These included Preprocess Sinks, Preprocess Drainage, Identify Streams, Break Point Manager, and Delineate Elements to delineate the Unsam sub-basin. DEM data were also used to identify flow direction and analyze the topography of the study area through QGIS 3.34 to determine areas prone to runoff during heavy rainfall. Potential areas for new retention ponds were identified based on flow accumulation toward lower elevations in the downstream part of catchment.

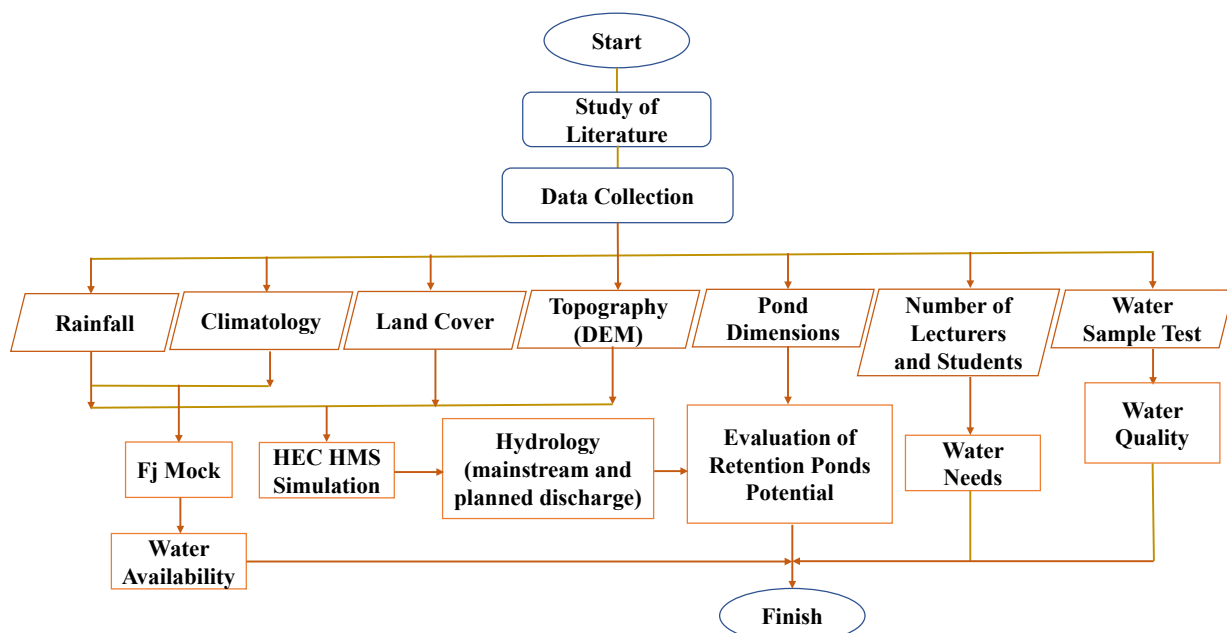


Figure 2. Methodological Flow Chart

Water demand at Unsam campus was calculated based on the number of students and staff actively using the campus facilities. This calculation was conducted on an annual basis, considering seasonal variations affecting water use. The guidelines applied followed SNI-03-7065-2005 (SNI-03-7065-2005 Tentang Tata Cara Perencanaan Sistem Plambing, 2005), which governed the planning of plumbing systems in Indonesia. For non-domestic water needs, such as for campus operations, the calculations followed the criteria set by the Department of Public Works in Water Supply Criteria (Standar Nasional Indonesia, 2012), ensuring that the water demand was computed in accordance with national standards.

The FJ Mock method was used to estimate reliable discharge or water availability during the dry season by evapotranspiration, which was calculated through the modified Penman. This method was selected due to the ability to provide accurate estimates by considering climatological factors such as sunshine duration, wind speed, humidity, and temperature. Climatological data was obtained from BMKG Malikussaleh in North Aceh, which accurately showed the local climate conditions. The Penman method was considered superior to the simpler method due to the presence of dynamic local climate factors, leading to more precise estimations of water loss through evaporation and transpiration. This supported the FJ Mock method in providing more realistic estimates of water availability at Unsam campus.

Flood discharge and flow volume simulations were performed using HEC-HMS version 4.11, a widely accepted tool for modern hydrological modeling. The data used for the simulation included design rainfall from the 5-year return period, land cover, and geological conditions. These inputs were used to calculate the CN for estimating surface runoff and flow volume based on land cover and the infiltration capacity of the soil influenced by the geological composition. The simulated flow volume was used to evaluate the capacity of existing retention ponds at Unsam campus and identify potential areas for new natural retention ponds to mitigate flood risks and ensure water availability during the rainy season.

Water quality in retention ponds at Unsam was tested through sampling at three major areas, namely the outflow from Cotkala-Unsam retention ponds, New, and Old Unsam ponds. Sampling was conducted on August 15, 2023, following rainfall events to observe the potential influence of fertilizers from the nearby palm oil plantation entering ponds due to runoff from catchment areas. These sampling locations were strategically selected based on their role as low-lying areas

that served as natural retention ponds. Water quality analysis included physical parameters such as turbidity (NTU), total dissolved solids (TDS), temperature, taste, and odor. Chemical parameters such as pH, fluoride, hardness ( $\text{CaCO}_3$ ), nitrite ( $\text{NO}_2$ ), nitrate ( $\text{NO}_3$ ), and iron (Fe) were also tested. Biological analysis was performed to detect Total Coliform and *Escherichia coli*, essential for determining whether the water meets raw water standards referenced from studies by Nandal et al., (2020); Sukristiyono et al., (2021); Widyastuti & Haryono, (2016). Water quality testing was carried out in the Laboratory of the Environmental Health and Disease Control Technical Center (BTKLPP) Class I in Medan.

The selection of new retention ponds locations at the Unsam campus was based on several critical criteria. These included the analysis of water flow direction, distance from the main campus roads, and proximity to the palm oil plantation owned by PTPN I. Additional factors considered were the distance from areas planned for future campus development. This analysis was performed to ensure that the new retention ponds could function optimally in reducing flood risks while supporting sustainable campus development.

Despite the significant contribution, there are several limitations to the data used in this study. Although the rainfall data is representative, local micro-climatic variations might not be fully captured due to the limited availability of nearby weather stations. The KLM station of PTPN I, the closest rainfall station, has limited data, with daily records available for only 13 years. This poses challenges in understanding the long-term impacts of climate change. Therefore, future studies should incorporate climate change considerations for improved prediction in rainfall variability. The resolution of the DEMNAS data is not sufficiently detailed for smaller areas with highly varied topography. These limitations can affect the accuracy of the hydrological simulations, showing the need for careful interpretation of results.

### 3. Result and Discussion

The delineation of catchment from the DEM data produced five catchment draining into the Langsa River outlet with a total area of 8.334 km<sup>2</sup>, as shown in Figure 3. The majority of this catchment is covered by oil palm plantations owned by PTPN I.

Figure 3 shows the delineation of inflow and outflow from Unsam Catchment. The Cotkala ponds flow toward Unsam and are located within catchment 4 (SB-4), while the old Unsam ponds, denoted as Junction 2 (JC-2), exits towards the sink (Langsa River). In this study, the planned discharge

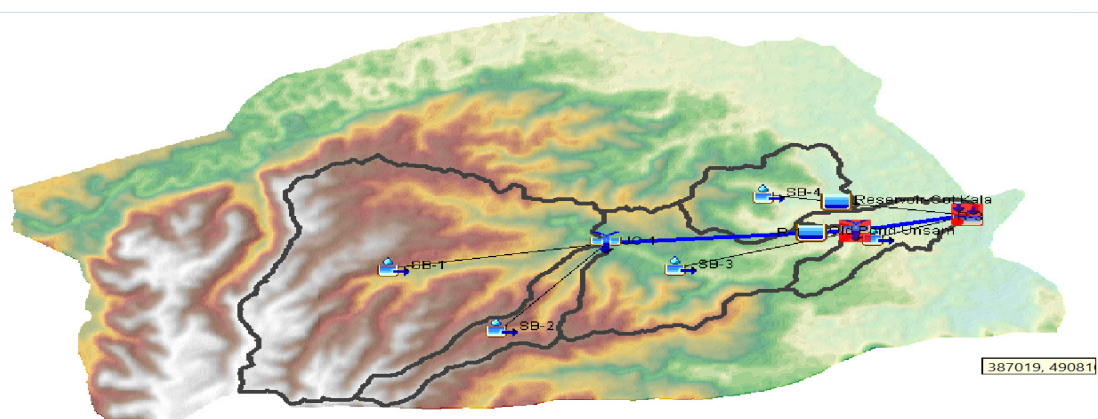


Figure 3. Delineation of the Unsam Catchment

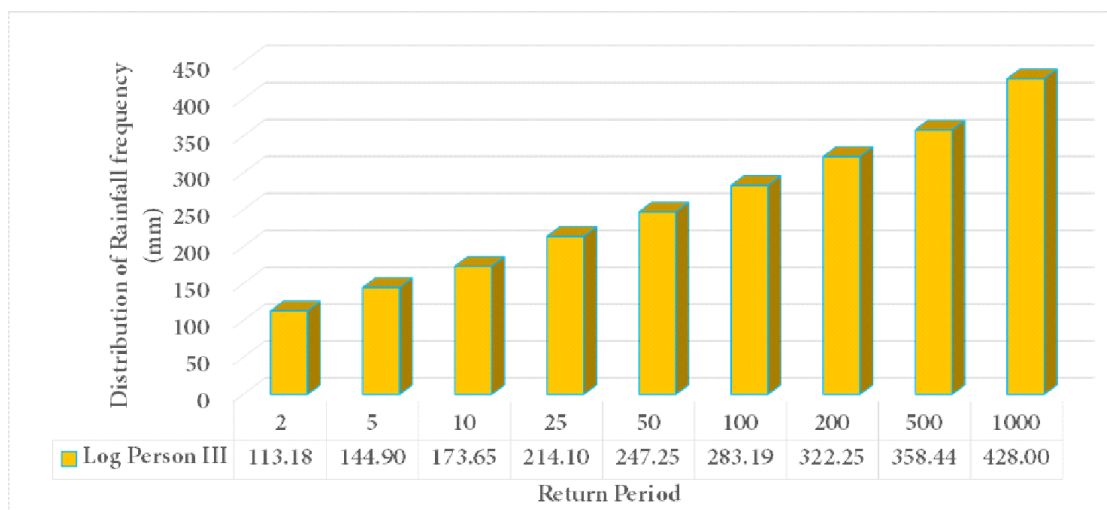


Figure 4. Return Period Rainfall Plan from KLM Station

Table 1. Hydrological Parameters for Planned Discharge Return Period

Catchment	Luas (km <sup>2</sup> )	Persen Luas	Curve Number (CN)	Max Storage (S)	Initial Abstraction (I <sub>a</sub> )	I (Flow Length) (km)	l (ft)	y (Slope)	y (%)
SB - 1	4.410	52.91	81.51	57.631	11.526	4.108	13182.55	0.1070	10.70
SB - 2	0.710	8.52	82.14	55.227	11.045	2.886	9259.78	0.1126	11.26
SB - 3	1.713	20.56	80.37	62.022	12.404	3.348	10743.934	0.06606	6.606
SB - 4	0.874	10.49	82.82	52.701	10.540	1.731	5554.245	0.06392	6.392
SB - 5	0.627	7.53	84.08	48.091	9.618	1.859	5968.346	0.0364	3.64
Total	8.334	100	81.66	57.049	11.410	13.933	44708.864		

Table 2. Planned Discharge Potential Inflow Volume into Retention Pond

Time	Junction - 2 (JC-2) Unsam				Catchment 4 (SB - 4) (Cot kala - Unsam)			
	Discharge Q <sub>2</sub> (m <sup>3</sup> /s)	Volume	Discharge Q <sub>3</sub> (m <sup>3</sup> /s)	Volume	Discharge Q <sub>2</sub> (m <sup>3</sup> /s)	Volume	Discharge Q <sub>3</sub> (m <sup>3</sup> /s)	Volume
00:00	0	0	0	0	0	0	0	0
01:00	0	0	0	0	0	0	0	0
02:00	25.36	365,184	1.462	31,579.2	5.258	132,501.6	0.375	9450
02:00	25.36	365,184	1.462	31579.2	5.258	132501.6	0.375	9450
03:00	35.402	509,789	46.046	994,593.6	3.58	90216	9.047	227984.4
04:00	16.501	237,614	58.341	1,260,165.6	2.11	53172	5.479	138070.8
05:00	11.056	159,206	23.238	501,940.8	1.446	36439.2	3.017	76028.4
06:00	6.369	917,13.6	15.519	335,210.4	0.351	8845.2	2.002	50450.4
07:00	4.241	610,70.4	9.273	200,296.8	0.065	1638	0.48	12096
08:00	2.777	399,88.8	6.168	133,228.8	0.01	252	0.088	2217.6
09:00	1.533	220,75.2	3.232	69,811.2	0.01	252	0.014	352.8
10:00	0.744	10,713.6	2.563	55,360.8	0.01	252	0.014	352.8
11:00	0.127	1,828.8	1.397	30,175.2	0.01	252	0.014	352.8
12:00	0.275	3,960	1.025	22,140	0.01	252	0.014	352.8
13:00	0.198	2,851.2	0.537	11,599.2	0.01	252	0.014	352.8
14:00	0.172	2,476.8	0.449	9,698.4	0.01	252	0.014	352.8
15:00	0.161	2,318.4	0.354	7,646.4	0.01	252	0.014	352.8
16:00	0.132	1,900.8	0.229	4,946.4	0.01	252	0.014	352.8
17:00	0.14	2,016	0.285	6,156	0.01	252	0.014	352.8
18:00	0.1	1,440	0.198	4,276.8	0.01	252	0.014	352.8
19:00	0.099	1,425.6	0.188	4,060.8	0.01	252	0.014	352.8
20:00	0.079	1,137.6	0.165	3,564	0.01	252	0.014	352.8
21:00	0.067	964.8	0.135	2,916	0.01	252	0.014	352.8
22:00	0.051	734.4	0.126	2,721.6	0.01	252	0.014	352.8
23:00	0.043	619.2	0.036	777.6	0.01	252	0.014	352.8

for surface runoff estimation, based on maximum rainfall data from the KLM over 13 years, was calculated for various return periods, as shown in Figure 4.

The planned rainfall for return periods of 2 and 5 years was used to determine the distribution of rainfall over time. This served as the runoff volume against the potential volume of the retention ponds as both inflow and outflow. The results showed that surface runoff was influenced by the CN of land cover, predominantly composed of plantations and settlements. This caused a delay in peak flood discharge in the catchment area, as shown in Table 1.

Table 1 shows the condition of catchment parameters that flow into Unsam campus area, with a CN value of 81.66 and Initial Abstraction (Ia) of 11.41 as the initial loss value, which is closely related to the S value (maximum storage capacity). The parameter influencing the runoff volume of a watershed is the impervious area (water-resistant) obtained from the planned discharge for return periods in Table 2.

The reliable discharge was calculated using the FJ Mock method, which simulated the monthly water balance based on the relationship between rainfall, evapotranspiration, and watershed characteristics, as shown in Figure 5. The estimated minimum reliable discharge available was 0.18 m<sup>3</sup>/second or 15,552 m<sup>3</sup>/day at 80% condition and 0.17 m<sup>3</sup>/second or 14,688 m<sup>3</sup>/day at 90% condition. These conditions were considered reliable in meeting the water needs of old Unsam retention ponds.

Table 3 shows that water demand for both students and faculty members is 3 m<sup>3</sup>/day based on the number of occupants in the Unsam Campus Building.

The 90% reliable water supply can still meet the water demand on Unsam campus, particularly during a 50% increase in occupants. The planned discharge for a 2-year return period has the potential to fulfill the water demand, but accommodating the excess discharge requires an expansion of existing ponds. To meet this water demand, water quality should be ensured for potable use within the study area. Furthermore, the maximum potential of retention ponds in handling the excess discharge for 2-year return period is shown in Figure 6.

Figure 6 shows the potential and evaluation of retention ponds storage area at Unsam campus based on the inflow volume from a 2-year design storm. The inflow discharge in SB-4 (CotKala – Unsam), with a volume of 132,501.6 m<sup>3</sup>, was derived from hydrological modeling using specialized software. This model incorporated historical rainfall data to determine the 2-year design storm and local geographic conditions, as shown in Table 2. Currently, the IAIN Cotkala retention ponds have a capacity of 28,904.64 m<sup>3</sup>, measured directly in the field based on area and depth. This shows the need for the construction of new retention ponds around Unsam with a volume of 103,596.96 m<sup>3</sup> (132,501.6 m<sup>3</sup> minus 28,904.64 m<sup>3</sup>) and land area of 39,998 m<sup>2</sup> with a depth of 2.59 m. The potential for new retention ponds at Unsam, which can be implemented through adjustments in the ponds area and depth, aims to reduce excess runoff from catchment area. An evaluation is also essential for the existing pond, covering an

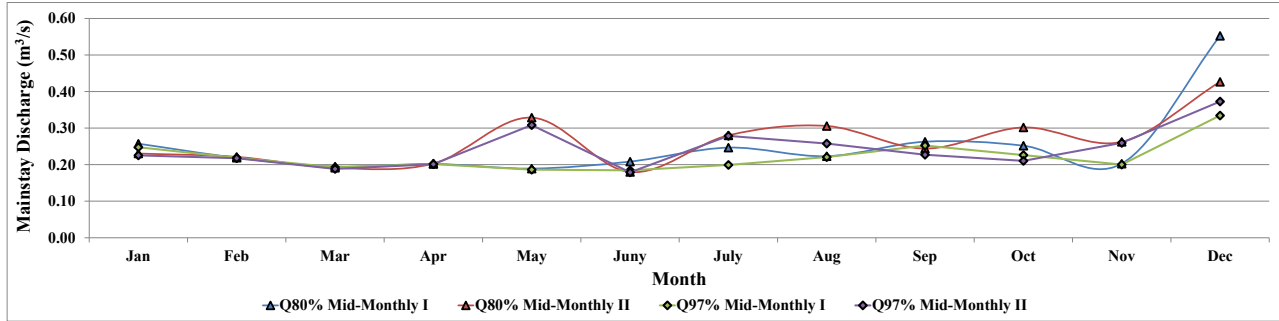


Figure 5. Availability of Reliable Water Supply at 80% and 97% in the Unsam Catchment.

Table 3. Unsam Campus Water Needs

Building	Lecturer	Employee	Student	Person capacity	Water Requirements liters/person/day	Water Requirements (Liter/day)	Water Requirements (m3/day)
Hukum	27	12	545	584	10	5,840	0.24
Ekonomi	40	15	1187	1242	10	12,420	0.52
Teknik	75	20	1550	1645	10	16,450	0.69
FKIP	85	19	1604	1708	10	17,080	0.71
Pertanian	34	15	841	890	10	8,900	0.37
Rektorat	20	129	-	149	10	1,490	0.06
UPT Perpustakaan	1	9	-	10	10	100	0.004
UPT Lab Dasar	1	5	-	6	10	60	0.003
Lab PGSD (Prodi PGSD dan Pend Jasmani)	21	1	947	969	10	9,690	0.40
<b>Total</b>						<b>72,030</b>	<b>3.00</b>

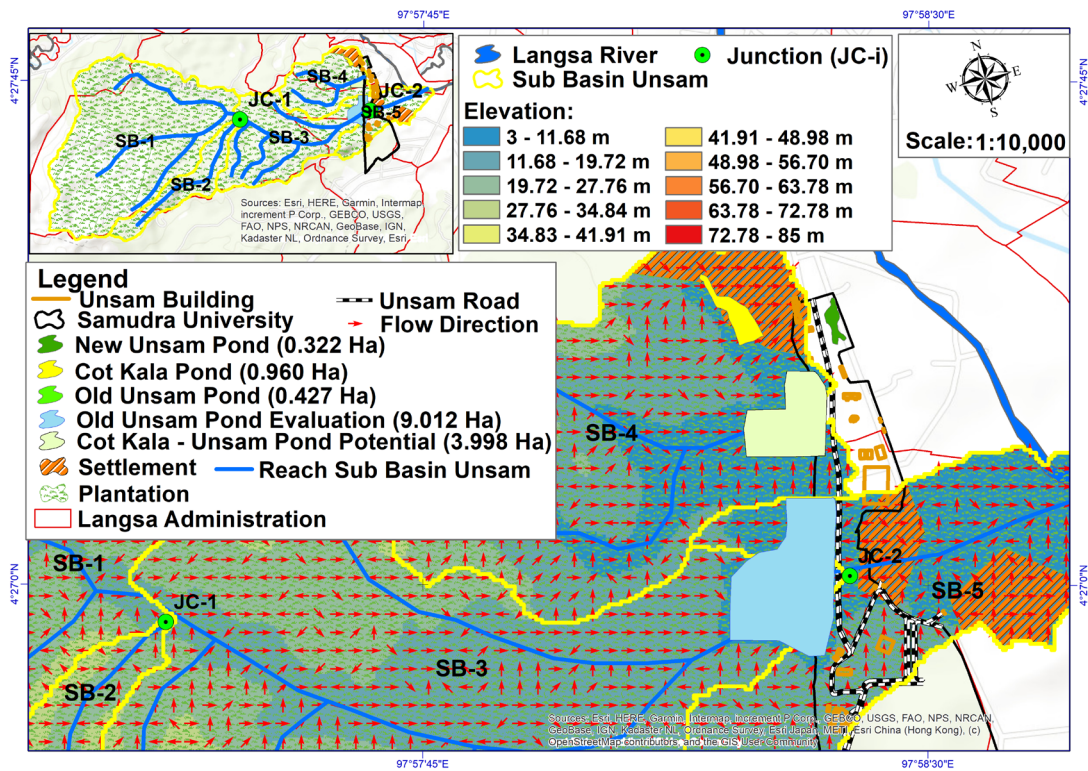


Figure 6. Potential for retention ponds in Unsam environment

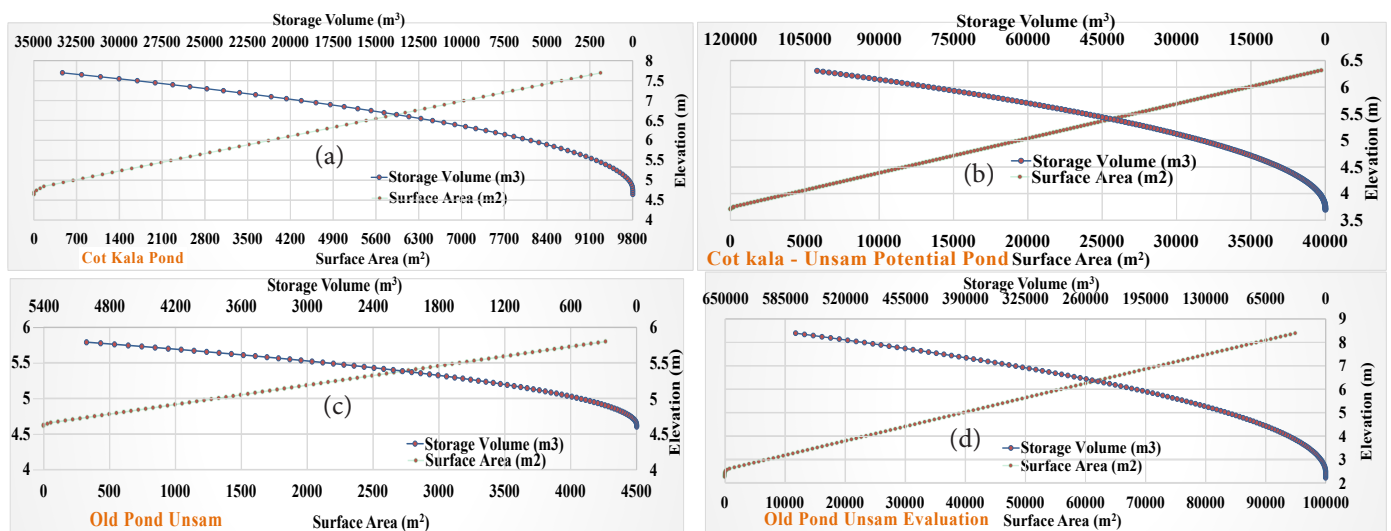


Figure 7. Relationship between elevation, area, and volume Ponds

area of 9.012 hectares, and for the potential Cotkala-Unsam retention ponds, which span 3.988 hectares. However, the implementation of this plan requires cooperation between institutions, including Unsam campus, PTPN I, and IAIN CotKala.

Unsam currently has new ponds with an area of 3,221 m<sup>2</sup>, a depth of 1.27 m, and a storage capacity of 4,090.67 m<sup>3</sup>. However, this pond does not account for the inflow volume from SB-4, limiting the ability to reduce runoff volume during heavy rainfall, which causes flood at Unsam. The new pond only receives inflow from domestic wastewater generated by the surrounding community through the drainage system. Based on the surface runoff model using HEC-HMS, the inflow volume from Junction-2 (JC-2) is 509,788.8 m<sup>3</sup>. Therefore, the old Unsam pond, with a capacity of 4,863.27 m<sup>3</sup>, is insufficient to accommodate runoff from the 2- and 5-year

design storms. As shown in Figure 2, both design storms have rainfall intensities of 113.18 mm/day and 144.90 mm/day, which generate surface runoff volumes of 509,789 m<sup>3</sup> and 1,260,165.6 m<sup>3</sup>, respectively.

An evaluation of the capacity of old ponds is essential to reduce surface runoff from the Unsam Catchment (JC-2). Natural ponds area of 90,120 m<sup>2</sup> with a depth of 5.90 m is required to store 526,902.85 m<sup>3</sup> of runoff. To optimize the functionality, retention ponds can be equipped with a sluice gate to regulate the water volume. This is followed by the discharge of excess water into the drainage system and directed towards the Langsa River system. However, the discharge control must consider the capacity of drainage system to prevent the risk of flood downstream. The relationship between area and storage capacity, along with the evaluation and potential of new retention ponds at Unsam is shown in Figure 7.

Figure 7 shows several aspects related to the storage volume of Unsam natural retention ponds, including water availability and flow reduction. In Figure 7(a), the storage volume of the IAIN Cotkala-Unsam retention ponds at an elevation of +6.695 m+MSL is 14,530.72 m<sup>3</sup> with an area of 6,079.80 m<sup>2</sup>. The dead storage is set at an elevation of +5.045 m+MSL with a volume of 327.99 m<sup>3</sup> and an area of 799.97 m<sup>2</sup>, leading to an effective storage volume of 14,202.73 m<sup>3</sup>.

In Figure 7(b), the condition of the Cotkala-Unsam retention ponds is described through the relationship between area and storage volume at an elevation of +5.430 m+MSL. The storage volume reaches 44,262.82 m<sup>3</sup> with an area of 26,113.8 m<sup>2</sup>. The dead storage is at an elevation of +3.99 m+MSL with a capacity of 1,001.80 m<sup>3</sup>, producing an effective storage volume of 43,261.02 m<sup>3</sup>.

Figure 7(c) shows the potential of Cotkala-Unsam retention ponds in reducing flow volume. At an elevation of +5.458 m+MSL, the pond has an area of 26,575.90 m<sup>2</sup> and a storage volume of 45,843.51 m<sup>3</sup>. The dead storage is recorded at 1,123.12 m<sup>3</sup> at an elevation of +4.00 m+MSL, while the effective storage volume reaches 79,038.03 m<sup>3</sup> at +5.99 m+MSL. The total storage volume is 103,681.34 m<sup>3</sup> with a maximum elevation of +6.31 m+MSL, while the bottom is at +3.70 m+MSL.

The evaluation of the old Unsam ponds, as presented in Figure 7(d), shows the relationship between area and storage volume at an elevation of +6.39 m+MSL. The storage volume is 252,947.43 m<sup>3</sup> with an area of 62,456.15 m<sup>2</sup>. The dead storage is at an elevation of +2.79 m+MSL with a volume of 1,825.02 m<sup>3</sup>, producing an effective storage volume of 526,902.85 m<sup>3</sup> at +7.99 m+MSL. The total storage volume of the pond reaches 545,558.59 m<sup>3</sup> with an area of 90,120 m<sup>2</sup> at an elevation of +8.24 m+MSL, while the bottom is at +2.24 m+MSL. The reduction in design flow after evaluating the existing and new ponds at Unsam is shown in Figure 8.

Figure 8 shows the reduction in flood discharge for the 2-year return period after the evaluation and addition of potential ponds in the Unsam campus environment. At the old ponds, there is a 36.97% reduction in peak discharge in Figure 8 (a), while a 33.82% decrease is obtained at the IAIN Cotkala, as shown in Figure 8 (b). Additionally, there is a delay in peak discharge for 1-2 hours.

The pond evaluation conditions contribute positively to the future water supply at the Unsam campus. Regarding water demand, water quality testing from ponds is essential to ensure

suitability for washing, bathing, and drinking purposes. The sampling points for water body samples are indicated in Figure 9.

Water samples were subjected to quality testing in the Laboratory of the BTKLPP Class I in Medan. The testing includes physical, chemical, and biological parameters based on the raw water quality standards according to Government Regulation No. 22 of 2021. Physical properties refer to characteristics that can be directly observed by the naked eye and other senses. Changes in the color and odor of water are indicators of a decline in water quality (Dai et al., 2020; Sukristiyono et al., 2021). Based on observation, the physical properties of water from the three ponds appear to be relatively good, as shown in Table 4.

The laboratory test results in Table 5 show that water from the three ponds on campus is tasteless and odorless, with relatively low turbidity values. TDS, which represent the amount of dissolved solid matter, serve as an indicator of the total particles or substances present in the form of organic or inorganic compounds. High solid content shows the presence of hazardous contaminants, such as sulfate and arsenic bromide. In this study, the TDS value of new ponds is the highest at 122.8 mg/l because water source is from domestic waste within the community around Unsam campus.

Water is considered good at temperatures between 20°C - 30°C, as deviation from air temperature shows contamination (Agudelo-vera et al., 2020). In this study, measurements taken show temperature of approximately 37°C. This high temperature can be attributed open area around ponds, allowing water body to be directly exposed to high sunlight intensity. Additionally, other factors include land cover and vegetation at the banks. According to the World Health Organization (WHO), the mineral content in freshwater is considered safe without negative impact on health. The laboratory test results for the chemical quality of the water from the three ponds are shown in Table 5.

The chemical parameters influencing water quality are shown in Table 5. These include pH value, an index for pollution, which has a direct effect on life within the ecosystem (Khatri & Tyagi, 2015). Iron (Fe) in the form of Fe<sup>3+</sup> ions also influences water quality, causing disturbances such as a metallic taste and unpleasant odor. The presence of Fe can originate from soil causing a brownish discoloration on white clothes, and stains on bathroom fixtures. Although Fe is an essential metal required in certain quantities by living organisms, it can become toxic when present in excess amounts (Zoroddu et al.,

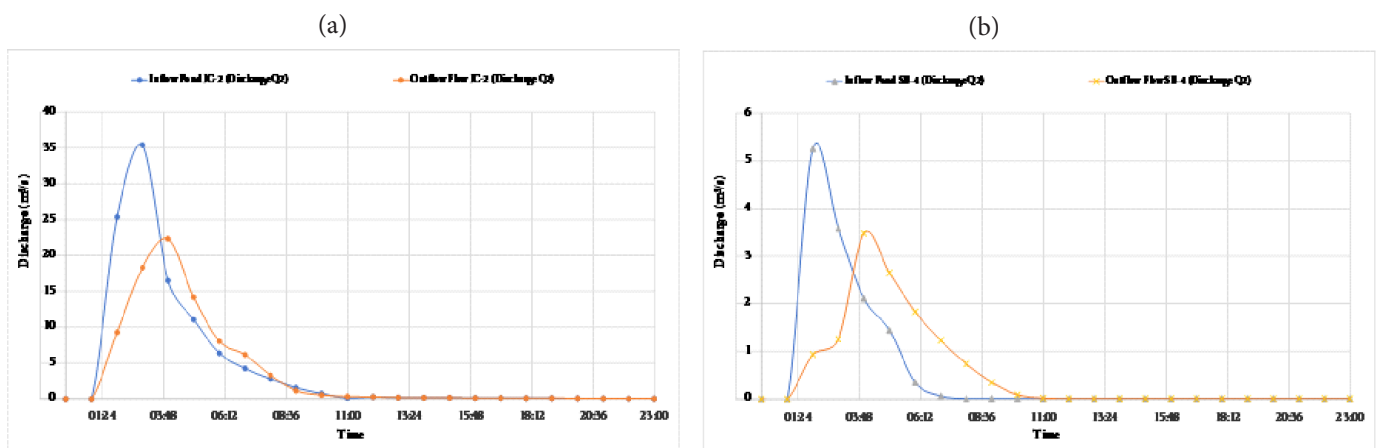


Figure 8. Reduction of Flood Discharge After and Before Ponds



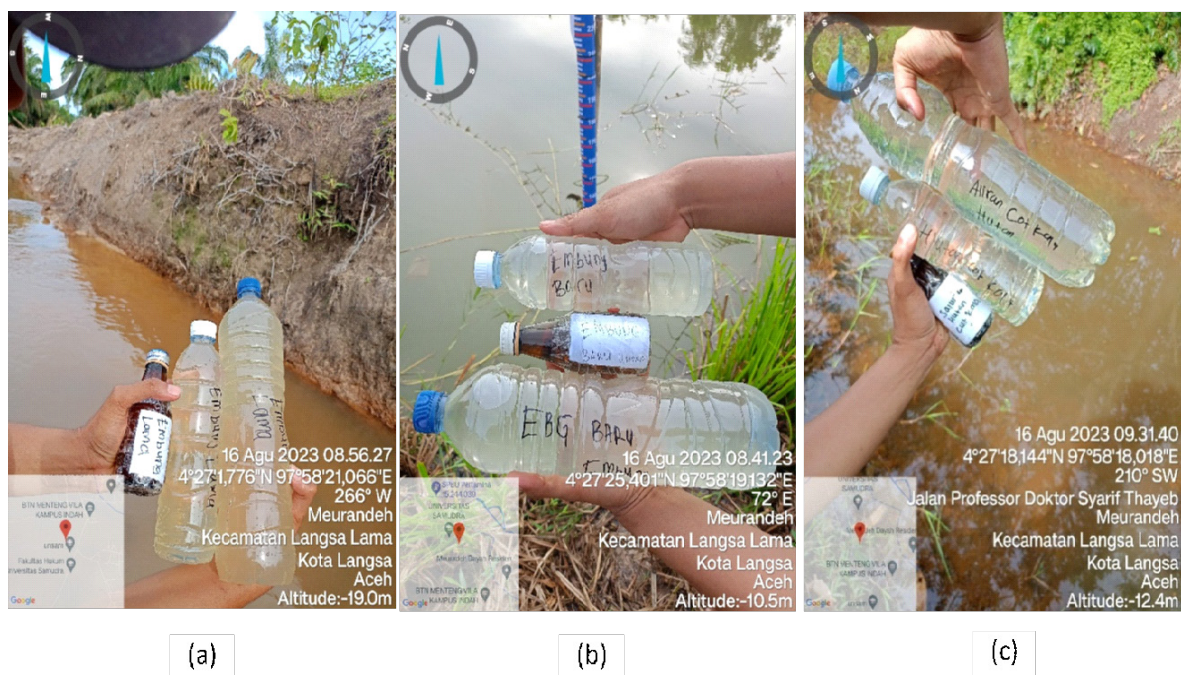


Figure 9. Unsam Campus Retention Ponds Water Sample

Table 4. Water Quality Physical Parameters in Unsam Campus Retention Ponds

No.	Sampling Location	Kekeruhan (NTU)	Dissolved Solids (TDS) (mg/l)	Temperature (°C)	Flavor	Smell
1	Old Pond Unsam	1.22	28.88	27.3	Tasteless	Odorless
2	New Pond Unsam	1.29	122.8	27.4	Tasteless	Odorless
3	Hutan Cot Kala – Unsam Pond	1.28	70.5	27.3	Tasteless	Odorless
	Maximum Allowable Level	25	1000	Air Temperature	-	-
	Test Method	Tubidimetri	Elektrometri	Insitu	Organoleptis	Organoleptis

Table 5. Water Quality Chemical Parameters in Unsam Campus Retention Ponds

No.	Sampling Location	PH	Flourida (mg/l)	hardness (CaCO <sub>3</sub> ) (mg/l)	Nitrit (NO <sub>2</sub> )	Nitrat (NO <sub>3</sub> )	Iron (Fe)	Mangan (Mn)	Zink (Zn)
1	Old Pond Unsam	6.3	<0.02	113.2	0.037	2.2	2.440	0.075	0.012
2	New Pond Unsam	5.9	<0.02	11.6	0.02	1	0.075	0.283	0.005
3	Hutan Cot Kala – Unsam Pond	6.9	< 0.02	110.4	0.013	0.5	0.957	0.048	0.011
	Maximum Allowable Level	6.5 - 8.5	1.5	500	0.06	10	0.3	0.4	0.05
	Test Method	Insitu	Spektrofotometri	SNI 06-6989.12-2004	Spektrofotometri	Spektrofotometri	APHA 3120B, 22 nd ed. 2012	APHA 3120B, 22 nd ed. 2012	APHA 3120B, 22 nd ed. 2012

2019). The consumption of water containing high levels of Fe can induce nausea and damage the lining of intestines, as well as death in severe cases. Fe content exceeding 1 mg/l is also capable of causing irritation to the eyes and skin.

Water hardness refers to the total content of Ca<sup>2+</sup> and Mg<sup>2+</sup> ions in water. Generally, hardness is expressed in terms of milligrams of calcium carbonate (CaCO<sub>3</sub>) per liter and is considered undesirable in household or industrial use (Astuti *et al.*, 2015; Verma, 2018). According to the Standard

for Environmental Health Quality for Sanitation Needs, the maximum allowable limit for hardness is 500 mg/l. This shows that water with hardness above the threshold may lead to health issues such as cardiovascular disease and kidney stones (Nyoman *et al.*, 2018). In this study, laboratory analysis of water hardness in the three ponds showed values below the maximum allowable limit according to hardness standards. This showed that in terms of hardness level, the water from the three ponds was considered safe for consumption.

Nitrate ( $\text{NO}_3$ ) is another chemical parameter that disrupts water quality (Amalia et al., 2021). It has the potential to flow towards lower water sources such as springs, and rivers, disrupting the nutrient levels and directly impacting overall quality (Kane et al., 2016). Excessive levels of nitrate can lead to significant problems with water quality, accelerate eutrophication, and cause rapid growth of aquatic plants, thereby affecting parameters such as dissolved oxygen levels and temperature (Bhateria & Jain, 2016; M. F. Isma & Isma, 2019; World Health Organization, 2009). Based on the Indonesian Ministry of Health Regulation No. 32/MENKES/2017 on Standard Environmental Health Quality, all three nitrate concentration values observed in this study were below the allowable threshold of 10.0 mg/l. The water quality standard values for all three water samples fell within Class 1, showing suitability as a source of drinking water.

Nitrite is not found in drinking water, except when groundwater sources experience nitrate reduction due to Fe salts. Moreover, the presence of nitrite in drinking water should raise concern regarding potential contamination, as the established limit is 0.06 mg/l. The acute toxic effect of nitrite is methemoglobinemia, where more than 10% of hemoglobin is converted into methemoglobin (Mohanty et al., 2017). When this conversion exceeds 70%, there is a tendency for bloody diarrhea followed by convulsions, coma, and death in severe cases (Nadhila & Nuzlia, 2021). After examining the water quality test results, the nitrite content in the three ponds of Unsam campus remained below the established standard and could be considered safe for consumption.

According to the Indonesian Ministry of Health Regulation No. 492/2010 regarding the requirements for drinking water quality, fluoride is an inorganic chemical substance directly related to health, with a maximum allowable level is 1.5 mg/L. Fluoride has beneficial effects in preventing dental caries at appropriate concentrations (Sfandy R et al., 2019). However, health impacts can occur when the concentration in drinking water exceeds safe levels for an extended period. This can lead to skeletal and spotted enamel damage in both children and adults. A deficiency of fluoride in drinking water can lead to dental caries. In cases of severe poisoning, bone defects, paralysis, and even death may occur. Based on laboratory tests conducted on the three ponds of Unsam campus, all fluoride levels remained below the established standard, falling within the safe category for consumption.

The levels of heavy metals such as zinc (Zn), manganese (Mn), and iron (Fe) are usually sourced from waste pollution. Consumption of water contaminated with zinc (Zn) can lead to physiological disturbances, mortality, and the extinction of certain species (Khayan et al., 2017). The high risk of pollution in the Kaligarang River requires a detection system for water pollutants as an early warning of contamination. A deficiency

of zinc in the human body can lead to decreased growth rate, reduced appetite, and food intake, as well as other conditions such as glossitis, alopecia, immune system disorders, impaired wound healing, pressure ulcers, burns, and more. Excessive Zn intake, reaching two to three times the Recommended Daily Allowance (RDA) can reduce copper absorption. Consuming Zn at levels 10 times the RDA can affect cholesterol metabolism, alter lipoprotein values, and accelerate the occurrence of atherosclerosis. Moreover, the minimum allowable Zn concentration for human consumption is 0.05 mg/l.

The presence of Fe content in drinking water can cause nausea when consumed, with large doses damaging the intestinal walls, and potentially leading to death. Fe content exceeding 1 mg/L is capable of causing irritation to the skin and eyes. When the solubility of Fe in water exceeds 10 mg/L, it can cause an odor. Despite the negative effect, Fe has positive impacts, serving as an essential component in the formation of red blood cells. However, when exceeds the limit set by the Ministry of Health, further treatment is essential (Kustomo, 2022). In this study, Fe content in the old Unsam ponds was 2.440 mg/l, and in the IAIN Cotkala had 0.957 mg/l, both exceeding the standard limit of 0.3 mg/l.

A manganese (Mn) contaminant level greater than 0.5 mg/L can cause an unusual taste in groundwater, leaving a brownish color on clothes after washing, and potentially causing liver damage (Mekonin et al., 2022; Rahaman, 2018). According to the standard regulations of the Indonesian Ministry of Health No. 32/2017, the maximum allowable Mn level in clean water is 0.5 mg/L (Ministry of Health Republic of Indonesia, 2017). In this study, the average Mn content in the groundwater was 0.1 mg/L, still meeting the standard for clean water quality and considered suitable for consumption by the public. Based on laboratory test results from the three ponds at Unsam campus, Mn content remains below the established standard.

In this study, water quality testing for biological parameters was conducted using indicators for Total Coliform and *Escherichia Coli* bacteria content. The presence of coliform bacteria originated from waste, agricultural residues, and contamination with human/animal feces (Lollino et al., 2015; Widyastuti & Haryono, 2016). The laboratory results showed that water in both the old and new ponds at Unsam campus was contaminated due to the presence of coliform bacteria. However, Cotkala-Unsam retention ponds were found to be uncontaminated, as shown in Table 6.

The Total Coliform parameter is useful in determining the quantity of *Escherichia coli* and aerobic bacteria present in water. *Escherichia coli* bacteria generally originate from human feces, infiltrating the soil and entering the groundwater system. Meanwhile, aerobic bacteria typically come from decomposed animals or plants in the soil. These bacteria can be harmful

Table 6. Water Quality Biological Parameters in Unsam Campus Ponds

No.	Sampling Location	Total Coliform (MPN/100 ml)	Escherichia Coli (MPN/100 ml)
1	Old Pond Unsam	2200	330
2	New Pond Unsam	2200	170
3	Cot Kala – Unsam Pond	0	0
	Maximum Allowable Level	1000	0
	Test Method	APHA 9221B 23rd ed.2017	

when ingested, disrupting the digestive system (Agus *et al.*, 2019). The minimum allowable limit for Total Coliform is 1000 MPN/100 ml and *Escherichia coli* is 0 MPN/100 ml. From the laboratory test results, it was observed that the old Unsam ponds were contaminated with Total Coliform count of 2200 MPN/100 ml and *Escherichia Coli* count of 330 MPN/100 ml. This contamination occurred from the residues of the palm oil plantation operated by PTPN I Langsa. Additionally, the new Unsam ponds were contaminated with an *Escherichia coli* count of 170 MPN/100 ml and Total Coliform count of 2200 MPN/100 ml. This was attributed to domestic waste from the community entering the ponds through the urban drainage system.

#### 4. Conclusion

In conclusion, this study showed that hydrological conditions of Unsam land had good potential to provide sufficient water volumes to meet the campus water demand. However, the current retention ponds were unable to handle excess runoff from the catchment area, which flowed into Unsam from the surrounding plantation areas. The water demand on Unsam campus was estimated to be 3 m<sup>3</sup>/day, showing the need for optimizing the potential storage capacity in the old and Cotkala-Unsam retention ponds. The flow discharge at SB-4 (Cotkala-Unsam) was 132,501.6 m<sup>3</sup>, with a 509,788.8 m<sup>3</sup> flow volume from Junction-2 (JC-2). Currently, the old ponds had a storage capacity of 4,863.27 m<sup>3</sup>.

The capacity of the existing retention ponds showed the inability to manage the excess flow from the catchment area, particularly surrounding plantation areas. Therefore, expanding and optimizing the retention ponds at the old pond location and the IAIN Cotkala-Unsam area successfully reduced peak flow by 36.97% and 33.82%, with a peak time delay of 1–2 hours, respectively. This showed the importance of evaluating and planning retention systems to mitigate flood risk and provide a more reliable water source for the campus. The reduction of flood flow in Unsam environment would have long-term positive impacts, such as reducing the risk of property damage due to waterlogging, which could reduce the cost of maintaining and repairing campus infrastructure.

The water quality from several retention ponds showed that not all sources could be used as a clean water supply. Although the physical parameters in the three potential retention ponds met standard limits, chemical analysis showed excessive levels of heavy metals such as Zn and Fe in the old Unsam ponds, exceeding the applicable standard limits. Biologically, contamination in the old and new ponds, with Total Coliform and *Escherichia Coli* levels exceeding standards, showed the need to improve water management practices. Technical measures to reduce biological contamination, specifically *Escherichia Coli*, were recommended to improve water quality for consumption.

These results showed that retention ponds had the potential to support more sustainable water management on Unsam campus. However, water quality should be improved through technical mitigation actions before use. In this context, continuous efforts to manage and monitor water quality as well as storage capacity were essential to achieving long-term goals in line with the environmental sustainability of the campus. To support the sustainability of Unsam campus and ensure the effectiveness of retention ponds as water source and flood control measures, several recommendations were made. These included an integrated water management method, including

adjusting storage capacity of retention ponds to ensure sufficient supply during dry season and controlling flood runoff during the rainy season. Efficient water distribution infrastructure should be developed, followed by installing real-time sensors to monitor water quality and quantity. The implementation of natural infiltration or technical systems could help filter pollutants and maintain water quality, as well as chemical or biological treatments using water treatment technologies such as aeration or microorganisms could clean the water from organic or chemical pollutants.

Educational campaigns should be implemented to raise campus community awareness regarding water conservation. This included the efficient use of water and the optimization of green technologies, such as rainwater harvesting and groundwater recharge. In the long term, regular monitoring of the effectiveness of retention ponds, both in terms of storage capacity and water quality, must be conducted periodically. This could be performed through advanced technologies such as remote sensing and drones to provide accurate data and support evidence-based decision-making.

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