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Performance of Rainwater Harvesting Systems in Institutional Buildings under Different Reliability and Future Economy Benefits

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Abstract: The purpose of this study was to determine the most appropriate size of rainwater storage tank for Swinburne University of Technology Sarawak Campus (SUTS) based on the roof area and rainfall data and to compare its cost-effectiveness to a potable water supply. Daily rainfall data used in this study was obtained from meteorological station at Kuching International Airport, located about 6.3Km from SUTS. Water consumption data was obtained by translating the average monthly water bill provided by the SUTS facilities department. The simulation was conducted using a water balance model with yield-before-spillage (YBS) and yield-after-spillage (YAS) operating rules. The results were compared with Tangki Nahrim software. Additionally, cost analysis of rainwater harvesting system (RWHS) from the aspect of reliability, total cost, water-saving amount/year, payback period were further analyzed for choosing the optimum size of rain harvesting tank at different blocks in SUTS. The unit cost of harvested rainwater per m^3 was evaluated with the water tariff charged by Kuching Water Board (KWB). Results show the optimal tank size for Block A&B and Block G is $60m^3$, while the optimal tank size for Block E is $30m^3$, with a reliability range of 83.5% to 89.5%. The capital cost required for Blocks A&B and G is RM51,310 each, while RM25,655 for Block E. With the installation of RWHS, the total annual water saving cost has amounted to RM8999.32. The payback period for these three blocks ranges from 12.9 years to 15.8 years, with a unit cost of $RM1.87/m^3$ to $RM2.29/m^3$. During the payback period, cost analysis revealed that the unit cost of water is slightly higher than the commercial water tariff rate. However, rainwater was freely supplied after that until the system's life span was reached. Thus, RWHS is the most cost-effective and long-term solution for reducing reliance on potable water supply.

Keywords: rainwater harvesting system, optimum tank size, reliability, yield-after-spillage, yield-before-spillage, Tangki Nahrim.

不同可靠性和未来经济效益下机构建筑雨水收集系统的性能

摘要：这项研究的目的是根据屋顶面积和降雨数据，为斯威本科技大学砂拉越校区确定最合适的雨水储存罐尺寸，并将其与饮用水供应的成本效益进行比较。本研究中使用的每日降雨量数据来自古晋国际机场的气象站，距离斯威本科技大学砂拉越校区约 6.3 公里。用水量数据是通过翻译斯威本科技大学砂拉越校区设施部门提供的平均每月水费而获得的。使用具有溢出前产量和溢出后产量操作规则的水平衡模型进行模拟，并将结果与纳赫林坦克软件进行比较。此外，从可靠性、总成本、节水量/年、投资回收期等方面对雨水收集系统的成本进行了分析，以选择斯威本科技大学砂拉越校区不同街区雨水收集池的最佳尺寸。每立方米收集雨水的单位成本是根据古晋水务局收取的水费来评估的。结果表明，一种和乙和 G 座的最佳储罐尺寸为 60 立方米，乙座的最佳储罐尺寸为 30 立方米，可靠性范围为 83.5%～

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89.5%。一种和乙和 G 座所需的资本成本分别为马来西亚林吉特 51,310，而乙座所需的资本成本为马来西亚林吉特 25,655。随着安装雨水收集系统，每年的总节水成本已达马来西亚林吉特 8999.32。这三个区块的投资回收期从 12.9 年到 15.8 年不等，单位成本为马来西亚林吉特 1.87/立方米到马来西亚林吉特 2.29/立方米。在投资回收期，成本分析显示单位水成本略高于商业水费率。然而，在此之后,雨水可以自由供应，直到系统达到使用寿命。因此，雨水收集系统是减少对饮用水供应依赖的最具成本效益和长期的解决方案。

关键词：雨水收集系统，最佳水箱尺寸；可靠性、溢出后产量、溢出前产量、纳赫林坦克.

1. Introduction

In Malaysia, the most frequent natural disasters are floods and droughts. In 1998, Malaysia faced the most serious water shortage due to unusually dry conditions because of changing climate. It had affected most of the areas in West Malaysia, particularly Klang Valley, parts of Negeri Sembilan, Malacca, Penang, Kedah, and Perlis for 150 days starting from March 1998. The water crisis had affected the urban daily lives. Some restaurants have to limit the operation hours, and toilets were not allowed to be used due to water shortage [1]. Another drought event was occurred in June 2019, as six states in West Malaysia were facing water shortage since dry weather had led to low critical water levels in dams [2].

In contrast, the heavy downpour had caused a flash flood. In developing countries, more buildings and infrastructure are constructed to meet the increasing population growth. The impervious surfaces are obstructing the rainwater infiltrates into the ground. Most of the excess rainwater overflows the waterways, causing flash floods once the existing drainage system cannot cater to the excess rainwater. In order to minimize the impact, a rainwater harvesting system (RWHS) was proposed in new development areas to temporarily store the excess rainfall for non-potable water usage and reduce peak and volume runoff after heavy downpours.

The history of RWHS can trace back to 4000 years ago when people in the Negev desert of Israel collected the runoff from hillsides and stored it in cisterns for agriculture and domestic usage [3]. India adopted RWHS, built with rubble stone during the third millennium B.C., for drinking, bathing, and domestic purposes. In the 19th century, Southern Tunisia had used RWHS for irrigation purposes such as floodwater farming in desert areas of Arizona and New Mexico in the olden days [4]. There is also evidence that many places worldwide have practiced RWHS from the olden days until now.

Nowadays, RWHS is getting more popular as an alternative water source. Apart from residential and agriculture sectors, RWHS also started to be adopted in commercial and industrial sectors. With the changes of evolution, innovative thinking, and advanced technology, various creative and innovative RWHS had been designed. One of the famous examples is Marina Bay Sands, Singapore. The rain oculus at Marina Bay Sands was built with large acrylic and stainless steel structure for toilet flushing purposes and supplying water to the canal for a sampan ride in the mall. RWHS is also adopted in the Marina Bay Sands ArtScience Museum to fill the water pool and flush toilets.

Meanwhile, Jewel Changi Airport in Singapore is also equipped with a gorgeous 40m HSBC Rain Vortex, collecting and storing the rainwater in a storage tank for landscape irrigation of more than 900 trees and 60,000 shrubs [5]. Another example of RWHS is swirling green rooftops at Nanyang Technical University in Singapore for landscape irrigation [6]. Green roof RWHS does not require any storage tanks, and the harvested rainwater was channeled towards the garden directly with a sound irrigation system. Additionally, the green roof itself can filter the pollutants with high reliability and require low maintenance.

Besides, Imteaz et al. had investigated the climatic and spatial variability of potential rainwater savings for Adelaide metropolitan, a large coastal city in Australia [7]. Lani et al. evaluated the performance of small and large scales of RHWS at Johor, Malaysia, for AEON Taman Universiti and AEON Bukit Indah commercial buildings, respectively, under different reliability and future water tariff scenarios [8]. Stec & Zeleňáková analyzed two rainwater harvesting systems' effectiveness in Central Eastern Europe [9]. Imteaz et al. investigated climatic and spatial variations of potential rainwater savings using the water balance model for Melbourne, Australia [10]. The potential of water-saving, optimal tank sizing, and economic analysis for RHWS in Jordan was also carried out by Abdulla [11]. Kim et al. determined optimal storage sizing for indoor arena rainwater harvesting from the aspect of hydraulic simulation and economic assessment for South Gloucestershire, Bristol, South West England, United Kingdom [12]. Meanwhile, the assessment of RWHS for a multi-store residential building in Brazil was also studied by Kuntz & Ghisi [13].

Apart from that, RWHS was also adopted in institutions of higher learning in Malaysia. University College of Technology Sarawak (UCTS), located in Sibu. Sarawak, Malaysia. UCTS was awarded the first university globally for being platinum-rated for Green Building Index (GBI) [14]. The harvested rainwater was stored in the pond inside the university to cool the air condition system and toilets flushing purposes. In contrast, the wastewater collected from toilets was further treated and recycled for garden irrigation.

Meanwhile, Ayog et al. designed the optimum rainwater storage tanks size for non-potable usage of eight residential blocks in Universiti Malaysia Sabah (UMS) [15]. Results revealed that the proposal of RWHS is feasible with the expected annual water bill to save up to RM25,580.00 by installing the appropriate size of rainwater storage tank for each block. Besides, Fatimah et al. found that the optimum rainwater storage tank sizes for an office building (block 5) and institutional building (block 9) for Infrastructure University Kuala Lumpur (IUKL) Campus are 25m^3 and 75m^3, respectively [16].

It was observed that the water usage at Swinburne University of Technology Sarawak Campus (SUTS), an Australian branch campus located in Kuching city, Sarawak, is increasing year by year. The statistic in 2018 annual report shows that student and staff headcounts are increasing yearly, thus led to the increment of water consumption. Hence, it is initiated in this study to investigate the feasibility of installing RWHS to reduce potable water supply dependence.

Even though Sarawak is blessed with abundant rainfall, there remains a general community reluctance to adopt RWHS on a broader scale. This reluctance is caused by a lack of information about the effectiveness of RWHS, lack of life cycle cost analysis, and the optimum storage size required to satisfy the performance requirements under the specific site conditions is unknown. Furthermore, not much researches are conducted on RWHS for commercial, institutional, and large roof areas in Malaysia. Therefore, this paper investigated the potential of rainwater savings for SUTS using a water balance model with yield-before-spillage (YBS) and yield-after-spillage (YAS) operating rules and compared with Tangki Nahrim software. This study determined optimum rainwater storage tank size for non-potable usage of blocks A&B, E, and G in SUTS Campus to reduce the reliability of potable water supply and subsequently reduce monthly water bills. The result analysis presents the detailed assessment of effectiveness and payback periods for the rainwater tanks using daily rainfall data.

2. Study Area

According to Lani et al., the benefits of RWHS for commercial and institutional buildings with larger rooftop areas, higher water consumption rates, and higher water tariffs are more promising than residential areas [8]. The selected study area is Swinburne University of Technology Sarawak (SUTS) Campus, a foreign branch campus of Swinburne University located in Kuching, Sarawak, Malaysia. This campus is operating under a partnership of the Sarawak State Government and Swinburne Australia, and it was established in the year 2000. This campus is situated at 1.5329°N latitudes and 110.3572°E longitudes, with a 6.5 ha (16.5 acres) area at Jalan Simpang Tiga, Kuching, about 10 minutes drive away from the city center. It is surrounded by government offices, commercial buildings, and residential areas with easy access to a few shopping malls, eateries, banks, clinics, houses of worship, supermarkets, etc.

SUTS is one of the most popular private universities in Kuching, with an estimated 4,000 occupants excluding staff in 2019. The main buildings in (SUTS) Campus include car parking, lecture theatre, lecture hall, administration buildings, and hostels. However, the feasibility study of adopting RWHS is only carried out on three blocks, namely Blocks A&B, E, and G. The layout of the SUTS city campus is presented in Fig. 1.

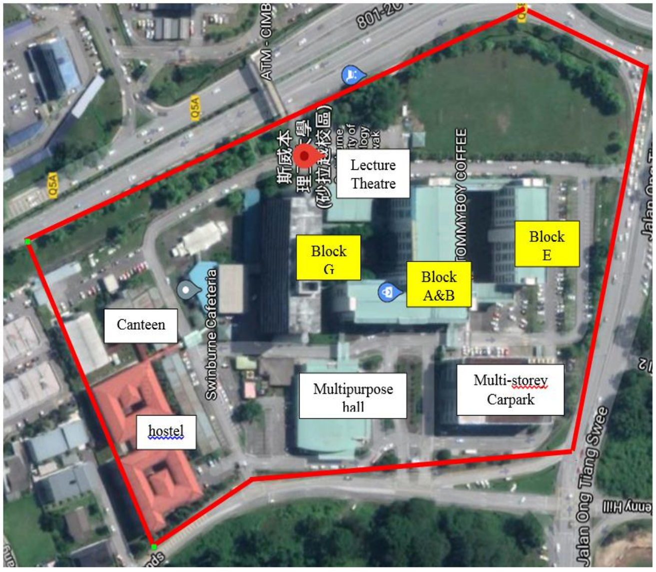
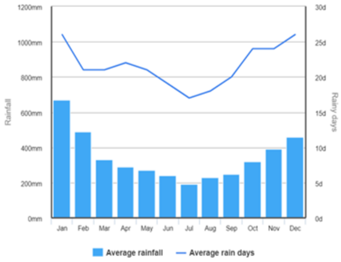


Fig. 1 Layout of STUS City Campus



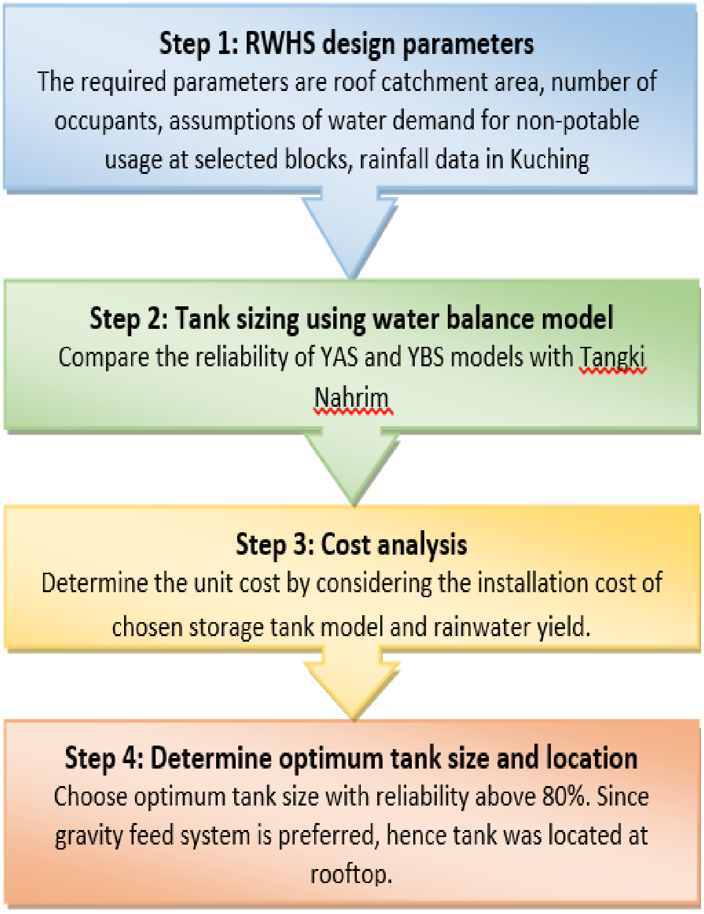
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	
mm	670	490	330	290	270	240	190	230	250	320	390	460	=4,200
Days	26	21	21	22	21	19	17	18	20	24	24	26	= 259

Fig. 2 Average rainfall data in Kuching [17]

Kuching is the capital city of Borneo and enjoys tropical rainforest climate. The rainy season is during Northeast Monsoon between November and March [18], usually accompanied by storms, and it can rain continuously for hours or even days. According to Rodgers, Kuching is considered the wettest city in Malaysia and receives substantial rainfall throughout the year [19]. Referring to the rainfall statistic as presented in Fig. 2, Kuching has an annual average of 4,200 mm rainfall and 259 raining days. Since Kuching is experiencing a significant amount of rainfalls throughout the year, the adoption of RWHS for domestic usage is a remedy to reduce the stormwater runoff or as backup storage during water disruption.

3. Methodology

The conceptual framework to design optimum tank size for Blocks A&B, E, and G in SUTS, is presented in Fig. 3.



Step 1: RWHS design parameters
The required parameters are roof catchment area, number of occupants, assumptions of water demand for non-potable usage at selected blocks, rainfall data in Kuching

Step 2: Tank sizing using water balance model
Compare the reliability of YAS and YBS models with Tangki Nahrim

Step 3: Cost analysis
Determine the unit cost by considering the installation cost of chosen storage tank model and rainwater yield.

Step 4: Determine optimum tank size and location
Choose optimum tank size with reliability above 80%. Since gravity feed system is preferred, hence tank was located at rooftop.

Fig. 3 Research methodology flow chart

Daily rainfall and water consumption at SUTS Campus were monitored for the past three years, from 2017 until 2019. Daily rainfall data for Kuching International Airport located at 1.4870° N, 110.3416° E, about 6.3Km from SUTS Campus was obtained from Sarawak Hydrological Year Books published by the Department of Irrigation and Drainage Sarawak [20]. The potential rainwater harvesting (PRH) can be calculated using Eq.1.

$$PRH = (R_I \times C \times ART) - \text{First flush} \qquad (1)$$

where R_I is the daily rainfall, C is the runoff coefficient, C is 0.95 for metal roofing [21], ART is the top roof area, and *the First flush* is 1 mm of rainfall.

3.1. RWHS Design Parameters

The RWHS design parameters for Blocks A&B, E, and G in SUTS are tabulated in Table 1. The harvested rainwater was only collected for toilet flushing and general cleaning. According to Hanson, the full flush volume for a dual flush toilet is 6 liters, and the half flush volume is 3 liters [22]. It is assumed that there is a full flush or two half flushes that amounts to 6 liters per person per day, as the students only come to campus for lectures and tutorials. The general cleaning for washrooms is estimated to be 300 liters/block/day. Besides that, each person's daily potable water consumption is assumed to be 6 liters, where 1 liter for drinking and 5 liters for the handwash basin [23], [24]. Thus, the daily water demand estimation (WDE) for toilet flushing can be calculated using Eq. 2.

$$WDE = \text{no. of occupants} \times \text{toilet capacity} \qquad (2)$$

Table 1 RWHS design assumptions

Block	A & B		E		G	
Roof length (m)	53.5		47		75	
Roof width (m)	28		17		18	
Catchment area (m^2)	1500		800		1350	
Runoff coefficient	0.9 for metal					
First flush	1 mm					
No. of toilets	88		60		64	
No. of occupants	2000		800		1500	
Assumptions for potable water consumption	6 litres/person/day					
Assumptions for general cleaning	300 litres/block/day					
Dual saving toilet flush	3 litres / 6 litres					
Assumptions	3 liters/flush					
Assumptions	2 flushes/day					
Toilet Flushing (T.F.) / General Cleaning (G.L.)	T.F.	G.L.	T.F.	G.L.	T.F.	G.L.
Average daily rainwater demand (L)	12,000	300	4,800	300	9,000	300
Total daily rainwater demand (L)	12300		5100		9300	
Average daily rainwater demand (%)	97.56	2.44	94.12	5.88	96.77	3.23
Average monthly rainwater demand (L)	369,000		153,000		279,000	
Average daily rainwater demand (L/person)	6.15		6.375		6.2	

3.2. Sizing of Rainwater Tank

The mass balance computation was adopted to determine the sizing and storage capacity of the rainwater tank [25]. The inflow of the rainwater tank is the volume of rainwater collected at the rooftop, whereby the outflow in this case study is water used for toilet flushing and general cleaning. Two main criteria for determining the optimum tank size are a) storing sufficient rainwater tank to meet the water demand, b) minimizing the number of days for water spillage and empty tank. The simulation approach for determining water demand and rainwater availability uses a water balance model with yield-before-spillage (YBS) and the yield-after-spillage (YAS) operating rules. The YBS model is the concept of harvesting rainwater and using it at the same time. The balance was kept for the usage of the following days. The formula for YBS is presented in Eq. 2. The water volume balance within the storage tank (V_t), which is kept for subsequent day use, is presented in Eq. 3.

$$YBS\ (\mathrm{m}^3) = \min\ [D_t;\ V_0 + V_p] \tag{2}$$

$$V_t = V_0+V_p-YBS-V_s \tag{3}$$

where the D_t is the water demand during time-step (m^3), V_0 is the Initial water volume in a storage tank (m^3), V_p is the volume of rainwater stored in a tank (m^3), V_s is the Spillage volume (m^3), and V_t is the water volume balance within the storage tank, which is kept for next day use (m^3).

In contrast, the YAS model is the concept of storing harvested rainwater first until it is full. After that, the excess rainwater was overflowed for daily usage. Therefore, the storage volume of rainwater tanks adopting the YAS operating rule is much lower than YBS. The formula for YAS is presented in Eq. 4. The leftover water volume within the storage tank (V_l) is presented in Eq. 5.

$$YAS\ (\mathrm{m}^3) = \min\ [D_t;\ V_0 + Q_t] \tag{4}$$

$$V_l = V_0+Q_t-YAS \tag{5}$$

where D_t is the water demand during time-step (m^3), V_0 is the Initial water volume in a storage tank (m^3), Q_p is the volume of rainwater added to the storage tank during time-step (m^3), and V_l is the leftover water volume within the storage tank (m^3).

The volumetric reliability (R_v) for both YBS and YAS operating rules can be determined using Eq. 6.

$$Rv = \sum YBS/\sum Dt \text{ or } \sum YAS)/\sum Dt \tag{6}$$

Results were compared with Tangki Nahrim, a rainwater harvesting simulation software developed by the National Hydraulic Research Institute of Malaysia (NAHRIM). The software can be downloaded for free from NAHRIM official website: www.nahrim.gov.my. Tangki Nahrim was developed after the 1998 drought in Malaysia and consists of twenty years of rainfall data for various cities in Malaysia. It generates the storage efficiencies, the volume of rainwater harvested and delivered, the coefficient of rainwater utilization, and the percentage of the empty tank.

3.3. Cost Analysis

The rain harvesting tanks for Blocks A&B, E, and G were located on the rooftop, and the harvested rainwater was delivered to each toilet through a gravity feed system. The harvesting tanks were located at existing roof slabs that used to house the storage tanks previously. Thus no electricity charge was imposed. The only cost involved is a capital cost for purchasing and installing the RWHS is tabulated in Table 2.

The cost of the polyethylene harvesting tank with the size of 1.8m^3, 10$m^{3,}$ and 25m^3 are presented in Table 3. After considering various factors such as UV exposure over time, water quality, and maintenance, the design life of a polyethylene harvesting tank is estimated to be at least 20 years [26]. The payback period can be calculated using Eq.4, with a commercial water tariff rate of RM1.06 /m^3.

Payback period = Total Cost/Amount of water-saving (4)

Table 2 Capital cost incurred in this analysis

Parameter	Unit	Reference
Runoff coefficient	0.9	[27]
Cost of pipe	RM24.1/m	[28]
Maintenance cost	RM133/month	Estimated
Retrofitting cost	RM4000/pipe	Estimated

Water tariff	RM1.06/m^3	[29]
Replacement of tank	After 20 years	Estimated
Life span of the system	20 years	Estimated

Table 3 Cost for different sizes of harvesting tank

Model	Liters	m^3	RM
RST400	1,800	1.8	1,200
R119CC	10,000	10	8,500
RS280CC	25,000	25	22,000

4. Results and Discussions

Various tank sizes were investigated to determine the volumetric reliability using YBS, YAS, and Tangki Nahrim models. The results are presented in Table 4. Results revealed that the YBS model has slightly higher reliability for all the tank sizes than the YAS model. It indicates that YBS operating rule is optimistic as it harvests rainwater and delivers for daily usage simultaneously. In comparison, the balance allowed continuous usage on the following days. Conversely, the result of the YAS operating rule is more conservative as it only allows the delivery of rainwater after the storage tank is full. Hence, the YBS operating rule is more likely to be adopted for the RWH storage tank design as it receives more rainwater and has higher reliability than the YAS model.

It was observed that YBS operating rule has closer reliability to the Tangki Nahrim simulation model for all the investigated tank sizes with a maximum difference of 2.98%. Meanwhile, YAS operating rule has a higher difference of 5.8% for all the investigated tank sizes among Blocks A&B, E, and G. Therefore, it can be deduced that Tangki Nahrim is adopting YBS operating rule.

The results revealed that the reliability of RWHS increases along with the increment of tank sizes. Block A&B and Block G achieve 100% reliability at the tank size of 400m^3. However, Block E achieves 99.90% of reliability at the tank size of 120m^3. That is mainly due to the number of occupants in Block E is lesser. Hence, smaller tank size is appropriate to fulfill the water demand. However, choosing the tank size with 100% might not be the most optimal choice since a bigger tank size requires a higher capital cost for purchasing and installing RWHS. Hence, cost analysis is required to determine the optimum tank size for each block.

Two main factors that determine the optimum size of the storage tank are reliability and the cost of installing RWHS. Analyzing the RWHS cost vs. volumetric reliability graph can determine the most appropriate size of rain harvesting tank. The exponential RWHS cost vs. volumetric reliability graph is fitted into two linear lines, one with a gentle slope and another linear line is a steep slope. The gentle slope illustrates that the system reliability was improved significantly by a little increment of cost. In contrast, the steep gradient linear line reveals the system reliability was not be much improved even invested a lot for the system. The intersection point of these two linear graphs presents the rational reliability of RWHS.

Fig. 4 and 5 present the rational reliability of RWHS for Blocks A&B and E is approximately 83.5% and 89%, respectively. The RWHS cost for block A&B is RM51,000 and RM45,000 for Block E. The optimum tank size for both blocks was found to be 60m^3. Results also revealed that the annual water saving for Block A&B and E are RM3,980.65 and RM3,243.22, respectively. Meanwhile, the rational reliability of 89.5% was found for Block G with RWHS cost of RM25,000, as presented in Figure 6. The results also revealed that the optimum tank size for Block G is 30m^3, with water-saving up to RM1,775.45 per year.

Table 4 Volumetric reliability of YAS, YBS, and Tangki Nahrim for different tank sizes at Blocks A&B, E, G

Block	Operating Methods	YAS	YBS	Tangki Nahrim
	Tank Size (m^3)	Reliability		
A&B	40	72.12%	75.99%	77.47%
	80	82.63%	84.44%	86.85%
	100	85.43%	86.80%	89.46%
	200	93.56%	94.38%	96.54%
	400	100.00%	100.00%	100.00%
E	30	85.39%	87.86%	89.91%
	60	94.16%	95.24%	97.35%
	90	98.28%	98.74%	100.00%
	120	99.90%	99.90%	100.00%
	150	100.00%	100.00%	100.00%
G	30	74.83%	77.80%	80.63%
	60	85.83%	87.68%	90.14%
	100	91.77%	92.88%	95.86%
	200	99.06%	99.27%	100.00%
	400	100.00%	100.00%	100.00%

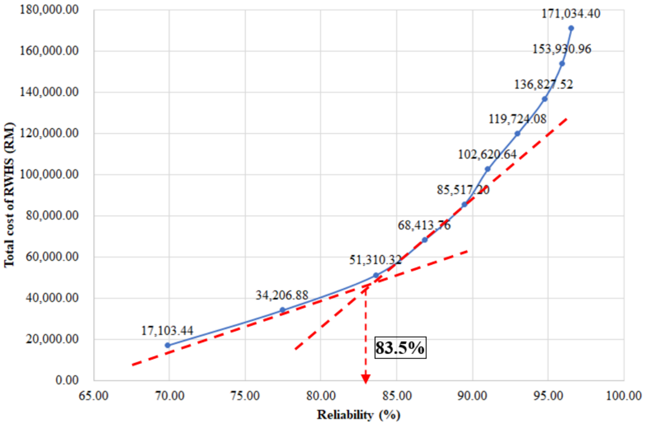


Fig. 4 System cost vs. reliability of RWHS for Block A&B in SUTS

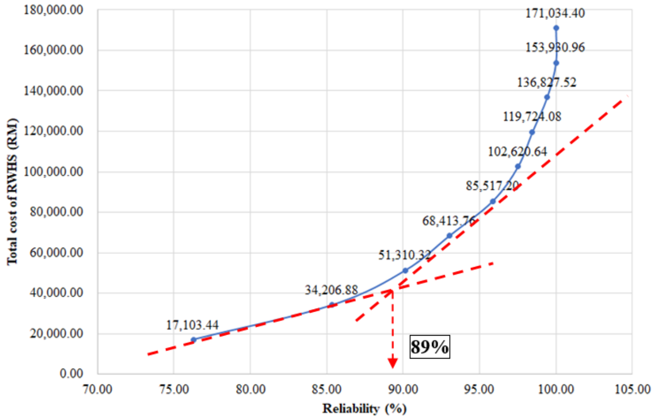


Fig. 5 System cost vs. reliability of RWHS for Block G in SUTS

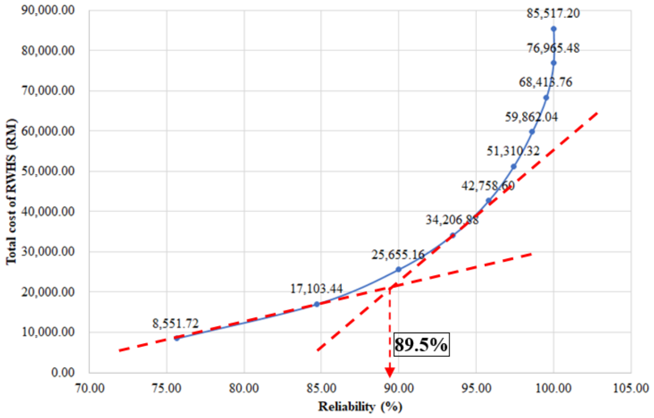


Fig. 6 System cost vs. reliability of RWHS for Block E in SUTS

After analyzing Figures 4 to 6, six numbers of storage tanks with 10m^3 capacity each were designed for Blocks A&B and Block G, while Block E only required three numbers of storage tanks with 10m^3 capacity as it is expected to have lesser people accessing the blocks. Table 5 summarizes the optimum rainwater storage tank size, which is determined based on the cost analysis where the reliability falls between 83.5% to 89.5%. With the installation of six storage tanks with 10m^3 capacity for Blocks A&B and G together with piping systems, the total cost required is RM51,310 for each block. Meanwhile, the total cost for installing three numbers of storage tanks with 10m^3 capacity for Block G required RM25,655. With the installation of RWHS, the annual water saving cost for Block A&B, E, and G have amounted to RM3980.62, RM1775.45, and RM3243.22, respectively. The payback period for these three blocks ranges from 12.9 years to 15.8 years, with a unit cost of RM1.87/m^3 to RM2.29/m^3. During the payback period, the unit cost of water is slightly higher than the commercial water tariff rate of RM 1.06/m^3, charged by the Kuching Water Board (KWB). However, after the payback period, the rainwater was freely supplied until the end of the system life span. Therefore, RWHS is feasible to be adopted in this project, and it is a sustainable way to conserve the water resource for long-term consideration.

Table 5 Summary of optimum RWH tank size for Blocks A&B, E, and G in SUTS Campus

Block	**A&B**	**E**	**G**
No. of 10m^3 storage tank, m^2	6	3	6
Total tank size, m^3	60	30	60
Reliability, %	83.5	89.0	89.5
Total cost, RM	51,310.00	25,655.00	51,310.00
Water-saving amount, RM/year	3980.62	1775.45	3243.22
Payback period, yr	12.9	14.4	15.8
Unit cost, RM/ m^3	1.87	2.09	2.29

5. Conclusion

The results indicate that the YAS operating rule is more conservative, while the YBS operating rule is more optimistic and produces more comparable results to Tangki Nahrim software. With an annual average rainfall of 4,200 mm and roof dimensions of 53.5mX28m, 47mX17m, and 75mX18m, the optimal tank sizes for Blocks A&B, E, and G at SUTS institutional buildings were determined to be 60m^3, 30m^3, and 60m^3, respectively, with a reliability of 80–90%. The cost of installing the RWHS is RM51,310 for Blocks A, B, and G; and RM25,655 for Block G.

Results also revealed that the annual water saving for Block A&B, E, and G is RM3,980.65, RM3,243.22, and RM1775.45, respectively, with a total water saving cost up to RM8999.32 per year with annual water saving of 9745.5m^3 after installation of RWHS. The payback period for these three blocks ranges from 12.9 years to 15.8 years, with a unit cost of RM1.87/m^3 to RM2.29/m^3.

The unit cost of RWHS during the payback period turned out to be more expensive than the KWB commercial water tariff rate of RM1.06/m^3. However, it is a sustainable and cost-effective practice because it reduces reliance on potable water supply and safeguards its long-term water supply and environment. Primarily, it reduces the likelihood of flash floods by temporarily storing rainwater and reducing surface runoff. As a result, the installation of RWHS at SUTS is feasible for Kuching City's sustainable development.

However, it must be pointed out that this research has its limitations. The obtained results will significantly alter if the rainfall data is altered due to the climate change impact, resulting in extremely dry conditions during droughts and extremely heavy downpours during rainy seasons. Additionally, if there is a change in the water tariff charged by KWB, the results will change drastically.

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