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Abstract. Water is one of the cornerstones in human survival and a necessity for socio-economic development. Due to that, effective management of water demand especially in the rural area becomes vital. The objective of this study is to conduct a water demand study at Kenyir Lake, Terengganu using Micro-Component Analysis (MCA). Water demand is also being assessed using National Water Services Commissions (SPAN) Guidelines, parallel to water guidelines applied for Malaysia's building and comparison purposes. MCA considers detailed parameters of water use activities of the respective study area, whereas SPAN Guidelines use the fixed values of average daily water demand according to the type of building. The available dataset was interpreted using MCA and SPAN Guidelines, resulting in total daily water demand at Kenyir Lake of 1249.8 m^3 and 1254.1 m^3 respectively. Estimated water demand using SPAN Guidelines is found to be higher than MCA. The value differences occur due to the average water demand value in the guideline that is limited to a specific type of premises and does not comply with premises there. The estimated water demand can be adopted as a baseline for water companies and the government to improve the demand and supply of water.

1. Introduction

Living things such as humans, animals and plants in the world need water to live and survive. Rising population and globalisation cause improper water demand management. Nevertheless, water is a finite and irreplaceable source that can be renewed if it is controlled effectively [1]–[5]. Currently,

more than 1.7 billion people are living around lakes and rivers and they utilise the water recklessly [6]. Water resources either from surface water or groundwater are depleting each day by the human act. Conserving and managing water is the main strategy for future water planning and portrays one of the most important environmentalist acts [7]–[9]. This study manages the water resources at Kenyir Lake thoroughly by estimating the water demand using two techniques: Micro-Component Analysis (MCA) and SPAN Guidelines.

A rural area is an area away from the cities with a low density of population. Now, there is over 44 percent of the people globally living in rural areas [10]. Kenyir Lake is considered a rural area that its development and economy need to be taken care of in the national development plan [11]. The stable state of rural communities from the evolution of agriculture, water resources, services of public health, infrastructure and tourism of rural areas need to be promoted through campaigns and programs [12]. By estimating water demand, the supply and demand at Kenyir Lake will be maintained as well as ensuring the continuity of life for rural communities there.

Predicting and forecasting water demand is significant for design and operational demand. The estimated water demand will be provided data of present and future water consumption of a fixed period [13]. The accuracy of water demand forecasting depends on the data availability including population and water consumption data within the community. There are unpredictable factors affecting water demand which makes it more challenging to project the water demand [14]. The type of water forecasting models also has been a notable discussion among researchers and developers as the output model proved their efficiency [15], [16]. Choosing a reliable water estimation model with a good set of available data increases the accuracy of the result. There is extensive literature regarding water forecasting models featured in studies of Kozlowski et al. [17], Donkor et al. [18] and House-Peters and Chang [19].

Micro-Component Analysis (MCA) or also known as the End-Use model is a recognized method in urban and regional modelling. In Britain and Australia, a large volume of research applied MCA in analysing small areas using survey data [20]. According to [21], the model allows a designed survey to apply at the large area and produce significant estimates on micro-component (households or individuals), also no requirement to increase the sample size. For example, MCA has been practiced for hydraulic network modelling (leakage detection), water quality modelling, an adaptation of water supply systems for drinking, future water demand projection and more related water resources investigations [22], [23]. The model also makes it possible to predict the effect of technology advancement, societal change and water regulation in the coming 25 years [24].

To improve the water demand management of the study area, MCA is applied by considering end-use water activities, maximum capacity, and per capita residual (pcr) at each premise for water demand estimate. End-use activities include proportion, frequency, and volume of water usage per water appliance used at a premise. The maximum capacity of a premise is a multiplying factor and per capita residual is emergency water demand to be applied in MCA, together with the proportion, frequency and volume of water usage [25], [26]. Application of MCA resulting in water demand values of each premise at Kenyir Lake.

In addition, following Malaysia's water requisite, water demand is also estimated using Uniform Technical Guidelines (UTG) Water Reticulation and Plumbing by National Water Services Commission (SPAN). The SPAN Guidelines standardise the planning and design of water distribution systems aligned with Water Services Industry Act 2006 and Water Reticulation and Plumbing Rules 2014 [27]. The water demand is calculated using SPAN Guidelines by multiplying the average daily water demand established in the guideline with multiplying factors collected at each premise.

This paper gives an overview of the water demand study at Kenyir Lake using two different techniques, MCA, and SPAN Guidelines. Firstly, water demand at each operating premises is computed using MCA. The methodology continues with evaluating water demand at each premises using SPAN Guidelines. Difference between the results will be discussed accordingly. Apart from that, a few useful recommendations of the study are proposed for the government, water companies and communities.

2. Materials and methods

2.1. Case study

Kenyir Lake is the largest lake in Malaysia and this captivating lake is located in the state of Terengganu. The lake covers an area of 260,000 hectares was developed to generate hydroelectric power to provide electricity all over Peninsular Malaysia [28]. The hydropower dam within Kenyir Lake was constructed in the year 1978 and completed in the year 1985. Water in the lake restores every now and then from nine rivers (Lasir, Belimbing, Ketiar, Tembat, Leper, Pertang, Kerbat, Terenggan and Kenyir rivers) directing to the lake [29]. The man-made lake is a famous ecotourism destination and is widely known for its valuable flora and fauna species. The area is concise of more than 8000 species of flowers, 2500 species of plants and trees, 8000 species of orchids, 370 species of birds and 300 species of freshwater fish [30]. There are various activities available at Kenyir Lake such as sport-fishing, visiting attraction parks, camping and jungle trekking [31]. The lake is also equipped with an aquaculture hub for freshwater fish farming, particularly at Como River [32].

The water level in the lake varies from time to time similar to a reservoir. High and low level of lake water was recorded during wet and dry season respectively [33]. To serve the inclination number of local and international tourists to Kenyir Lake from 507,502 tourists in the year 2016 to 808,336 tourists in the year 2017 [34], greater infrastructure and amenities around the lake need to be improved immediately [35]. Improved infrastructure and amenities include maintaining the water availability and sustainability of the lake by estimating the water demand.

2.2. Data description

2.2.1. Micro-Component Analysis (MCA). Water demand estimation can be done with a complete set of data to comply with the chosen method. For Micro-Component Analysis, the data needed to estimate water demand are the proportion for each water appliance used, frequency of water use, the volume of water use and multiplying factor for each premise.

The proportion of households using appliances or activities represents all the activities at each premise in the study area. These proportions are set based on their highest to lowest water usage at Kenyir Lake. Rinaudo [24] explained that water demand is reduced by replacing inefficient appliances with newer ones and counterbalanced the usage of water. It is proven that the proportion of appliances affects the pattern of water demand of an area.

Table 1 presents the proportion of each appliance used (Oi) at Kenyir Lake. The highest proportion of water-consuming appliances is sink followed by other appliances. Most tourists and local communities used the sink primarily for washing hands after using the toilet. Besides that, the study area, which is Kenyir Lake, well-known as a tourist attraction's place showed greater water usage for sink and cleaning in contrast to other appliances.

Table 1. Ownership level or proportion of each appliance for the whole Kenyir Lake.

Proportion (Oi); -	
Toilet	0.91
Shower	0.65
Sink	1.00
Kitchen	0.43
Gardening	0.65
Cleaning	0.91

Each premise has a different frequency of the appliance used (Fi), the volume of water consumed for each activity (Vi) and multiplying factor. However, data of the frequency, the volume of water used and multiplying factor to evaluate the water demand only provided for premises at Pengkalan

Gawi, Kenyir Lake. This is to ensure that the water demand calculation can be pictured precisely and act as an example calculation for other premises.

The frequency of an activity is determined through data collected from interviews conducted with the communities at Kenyir Lake on their water usage. Frequency of use is an important parameter because of differences in overall water consumption primarily from differences of it [36]. The volumes of water consumed at each activity are determined based on past studies or guidelines set by water companies. The most relevant reference on the volume of water used to be applied in the proposed study is Syarikat Air Terengganu (SATU) Guideline [37]. The frequency (Fi) and volume of water consumed (Vi) are expressed in Table 2.

Table 2. Frequency (Fi) and volume (Vi) of water used for an appliance at Pengkalan Gawi, Kenyir Lake.

	Type of Premises					
Parameter	Offices of KETENGAH & Tourist Information Centre	Kenyir Elephant Conservation Village (KECV)	KECV (Stay in)	Food Stalls	Public Toilets	Prayer Rooms
	Frequency (F_i); -					
Toilet	3.0	2.0	6.0		1.0	
Shower			2.0		1.0	
Sink	1.0	1.0	1.0		1.0	1.0
Kitchen	1.0		2.0	3.0		
Gardening	1.0	1.0	1.0			
Cleaning	1.0	1.0	1.0		1.0	
	Volume (V_i) in litre; -					
Toilet	13.5	13.5	13.5		9.0	
Shower			75.0		75.0	
Sink	12.0	12.0	29.0		29.0	12
Kitchen	12.0		180.0	360.0		
Gardening	240.0	960.0	960.0			
Cleaning	67.0	200.0	200.0		800.0	

The multiplying factor means the maximum number of people for each premise at Pengkalan Gawi, Kenyir Lake is established in Table 3. Public toilets recorded as the highest number of people at 2215 people while Lawit Lodge has the lowest number of people at 24 people only. Usually, tourists that come to Kenyir Lake will stop by at Pengkalan Gawi and uses the public toilets there. It is proven by the study of Gössling et al. [38] that tourists utilise water upon using the toilet and related activities. The rooms available at Lawit Lodge are very limited, so only 24 people can fit at the respective accommodation. Development Authority Terengganu Tengah (KETENGAH) has confirmed the maximum capacity of people can fit at each premise.

Table 3. Multiplying factors at Pengkalan Gawi, Kenyir Lake.

Type of Premises	Multiplying Factor
Lawit Lodge	24 people
KETENGAH and Kenyir Information Center Office	69 people
Kenyir Elephant Conservation Village (KECV)	139 people
Food Stalls	11 unit
Public Toilets	2215 people
Prayer Rooms	554 people

2.2.2. SPAN Guidelines. The average daily water demand referring to the Uniform Technical Guidelines for Water Reticulation and Plumbing by SPAN ranges from 50 to 1500 litres per unit (room, person, stall) [27]. The chosen values of average daily water demand suited the premises in the study area.

The types of premises or buildings investigated at the study area were resorts, houseboats, attraction parks, national parks, camping sites, offices of KETENGAH and Tourist Information Center, public toilets, prayer rooms, food stalls, and aquaculture sites at Sungai Como. Based on the guidelines, the recommended types of premises or buildings that suit the study area are a hotel, wet market, education institutions, a fully residential school with hostel facilities, a mosque or place of worship and a stadium. The suitable average daily water demand from the guidelines for this study as discussed with SPAN's officers are hotel (1500/room), wet market (1500/stall), education institutions (100/person), a fully residential school with hostel facilities (250/person), mosque (50/person) and stadium (55/person).

The type of premises in the guideline and the study are different from one another. But, as agreed by SPAN officers, those are the values similar to the study. In estimating water demand using SPAN Guidelines at Lawit Lodge, 10 rooms are used as the multiplying factor instead of 24 people. Only average daily water demand and multiplying factor for premises at Pengkalan Gawi, Kenyir Lake are included as they have the same flow of calculation.

3. Model description

Two techniques of MCA and SPAN Guidelines are used to estimate water demand. These methods have a distinctive way of getting water demand value. The parameters involved are the proportion of appliance used, frequency of water used, the volume of water used, average daily water demand (from SPAN Guidelines) and multiplying factor.

3.1. Micro-Component Analysis (MCA)

Micro-Component Analysis (MCA) is the method applied for this study following the United Kingdom Water Industry Report (UKWIR) [39]. MCA model focuses on water follow at 'micro' outputs such as toilet, kitchen and sinks in a premise relative to its demographic until climate data [40]. Factors influencing daily water consumption (habits and patterns of water usage) are explored in MCA to enhance the understanding of the method.

The information of proportion, frequency and volume of water use for each appliance were implemented in water demand estimation. The information on the water usage for each appliance was collected by on-site investigation at Kenyir Lake. In MCA, the water demand is calculated by per capita consumption. The parameters of water usage in each appliance portray the water demand of a premise. The formula used to estimate water demand following UKWIR [39] is as in Equation (1).

$$pcc = \sum (O_i \cdot F_i \cdot V_i) + pcr \quad (1)$$

where pcc is per capita consumption, Oi is the proportion of households using appliance or activity, Fi is the average frequency of use of appliance or activity, Vi is the volume of water consumed by appliance or activity per use, and pcr is per capita residual demand. In the proposed study, the total per capita consumption is the total water demand of an area per person.

On the other hand, the value of per capita residual (pcr) demand is pertinent in the calculations of water demand since it acts as emergency water demand required at the premise when an interruption in water supply occurs. For purpose of water demand calculation, the value of per capita residual (pcr) is kept at a constant value [39]. In the proposed study, pcr is assumed as a fraction of per capita consumption (pcc) as recommended by Butler [41]. The value of per capita residual (pcr) demand in the proposed study is assumed as 0.5 of per capita consumption (pcc) at each activity.

Estimation of the total water demand of each premise is then completed by considering the multiplying factor. Therefore, Equation (2) is established by making Equation (1) the basis. The parameters included in Equation (2) are included in the data description section. Kame'enui [42] stated

that steps of gathering information and choosing the flow of investigation are crucial to the expansion of a valid and feasible framework.

$$Total\ pcc = [\sum (O_i \cdot F_i \cdot V_i) \times Multiplying\ Factor] + pcr \quad (2)$$

3.2. *National Water Services Commission (SPAN) Guidelines*

National Water Services Commission (SPAN) is introduced by the government of Malaysia to supervise water and sewerage services. Also, SPAN is in charge of tracking the water tariffs, setting up the management framework and licensing for the water industry. One part of the SPAN Guidelines used was the Uniform Technical Guidelines (UTG) for Water Reticulation and Plumbing. Equation (3) displaced the water demand calculation using SPAN Guidelines. Referring to the factors used in the SPAN Guidelines, the number of rooms is used rather than the number of people. The water demand is estimated using Equation (3).

$$Water\ demand = Average\ daily\ water\ demand\ from\ SPAN\ Guidelines \times Multiplying\ Factor \quad (3)$$

Water demand values using SPAN Guidelines are calculated by multiplication of average daily water demand and multiplying factors for each premise. The selected average daily water demand is included in the data description section as it is the parameter. For another parameter of multiplying factor, follows Table 3 with only one difference. The difference is for Lawit Lodge premise uses 10 rooms instead of a maximum capacity of 24 people.

4. Results and discussion

4.1. Micro-Component Analysis

Table 4 present a water demand calculation using MCA for offices of KETENGAH and Tourist Information Centre. The offices of KETENGAH and Tourist Information Center (TIC) resulted in 5.4 m^3 of daily water demand. A similar calculation is done for other premises to find their daily water demand and was established in Table 5. The total daily water demand at Kenyir Lake was estimated to be at 1249.8 m^3. The topmost daily water demand is for the houseboat (662.0 m^3) followed by the public toilet at Pengkalan Gawi (291.0 m^3), Rumah Rehat Persekutuan (42.8 m^3) and Kenyir Water Park (34.5 m^3), while other premises are calculated to be at a very low daily water demand of less than 30 m^3.

Table 4. Water demand calculation at the office of KETENGAH and Tourist Information Centre.

	Per Capita Consumption, $pcc = (O_i \cdot F_i \cdot V_i) \times$ *Multiplying Factor* (litre)	Per Capita Residual, $pcr = 0.5\ pcc$ (litre)	Final Per Capita Consumption, *Final pcc = pcc + pcr* (Equation 1) (litre)
Toilet	2543.0	1271.5	3814.5
Shower			
Sink	828.0	414.0	1242.0
Kitchen	5.2	2.6	7.8
Gardening	156.0	78.0	234.0
Cleaning	60.7	30.4	91.1
Total Water Consumption (per day)			5389.4 litre / 5.4 m^3

Table 5. Daily water demand estimated using Micro-Component Analysis at Kenyir Lake.

Type of Buildings/Premises	Daily Water Consumption (m^3)
Lake Land Resort	20.3
Musang Kenyir Resort	17.9
Surya Rakit Resort	15.5
Kenyir Eco Resort	22.7
Petang Island Resort	24.5
Tanjung Mentong Resort	22.7
Rumah Rehat Persekutuan	42.8
Lawit Lodge	9.5
Houseboats	662.0
Herb Park	9.3
Orchid Park	3.4
Butterfly Park	7.8
Tropical Park	2.0
Kenyir Water Park	34.5
Kenyir Elephant Conservation Village (KECV)	12.0
Kelah Sanctuary Park	10.6
National Park	4.1
Camping Sites	1.9
Offices of KETENGAH and Tourist Information Centre	5.4
Public Toilets at Pengkalan Gawi	291.0
Prayer Rooms at Pengkalan Gawi	10.0
Food Stalls at Pengkalan Gawi	7.7
Aquaculture sites at Como River	12.2
Total Water Demand (per day)	1249.8

It was found that the camping site has the lowest daily water demand at Kenyir Lake. This is because no appropriate facilities or toilets were built at the camping site area. In addition, most of the camping sites are in the National Park where complete facilities are provided there. Campers also prefer to use lake and stream water over water from public toilets for their camping activity. In Spain, water use per guest in tourist accommodation is only 84 litres for campsites compared to the hotel [38]. It is proven that camping sites have the lowest water demand compared to other tourist accommodations. The downside of the camping sites that they have an off-season (wet season) where they are closed and out of reach [43].

Houseboats showed the highest water demand in contrast to other premises. Of late, it becomes more challenging for houseboat operators and local authorities in meeting the growing visitor's demand and ensuring convenient service for them [44]. Houseboats have become a famous mode of water transportation among tourists. Furthermore, in Amsterdam, the surface waters are broadly used as accommodation for houseboats and other floating buildings [45]. The major ecotourism business at Kenyir Lake goes to houseboat operators (74%) followed by speedboat operators (24%) and resorts (2%) [46]. Usually, tourists and local communities are attracted to complete equipment installed in the houseboats and exclusive package activities prepared by the houseboat operators [44]. Eventually, water demand for houseboats keeps rising each day if the houseboat operators fulfil customer's preferences and satisfaction.

4.2. National Water Services Commission (SPAN) Guidelines

Water demand at Kenyir Lake applied SPAN Guidelines by using average daily water demand multiplied by multiplying factors as shown in Equation (3). For instance, water demand value using SPAN Guidelines at Lawit Lodge is obtained from average daily water demand for hotel x multiplying

factor for Lawit Lodge at 1500 litres/room x 10 room = 15000 litres/ 15.0 m^3 per day. Procedures for forecasting water demand using SPAN Guidelines for other premises at Kenyir Lake are alike. The values of average daily water demand and multiplying factors are chosen according to the type of premise.

Table 6 presents daily water demand accessed using SPAN Guidelines for all buildings at Kenyir Lake. The range of water demand values is from 0.8 to 810.0m^3. The highest and lowest water demand recorded are houseboats at 810.0 m^3 and Tropical Park at 0.8 m^3 respectively. Both estimation techniques showed highest water demand at Kenyir Lake is houseboats. Tropical Park recorded as the lowest water demand when calculated using SPAN Guidelines. The reason for this may cause by its short service of operation which is from the year 2015 to 2017 only. Therefore, only a few tourists have the chance to explore the park.

Table 6. Daily water demand estimated using SPAN Guidelines at Kenyir Lake.

Type of Buildings/Premises	Daily Water Consumption (m^3)
Lake Land Resort	22.5
Musang Kenyir Resort	19.5
Surya Rakit Resort	16.5
Kenyir Eco Resort	25.5
Petang Island Resort	37.5
Tanjung Mentong Resort	25.5
Rumah Rehat Persekutuan	49.5
Lawit Lodge	15.0
Houseboats	810.0
Herb Park	8.1
Orchid Park	1.4
Butterfly Park	6.6
Tropical Park	0.8
Kenyir Water Park	9.2
Kenyir Elephant Conservation Village (KECV)	10.0
Kelah Sanctuary Park	3.4
National Park	8.3
Camping Sites	2.0
Offices of KETENGAH and Tourist Information Centre	6.9
Public Toilets at Pengkalan Gawi	121.8
Prayer Rooms at Pengkalan Gawi	27.7
Food Stalls at Pengkalan Gawi	16.5
Aquaculture sites at Como River	10.0
Total Water Demand (per day)	1254.1

The value of calculated water demand implementing the National Water Services Commission (SPAN) Guidelines is 1254.1 m^3 (Table 6), with a small disparity to the calculated water demand using MCA which is 1249.8 m^3 (Table 5). Water demand estimation using MCA is more accurate because it considers all water appliances used as well as the water activity and the number of tourists. As indicated by Parker and Wilby [47], the micro-component data let water used to be accessed at its microscale. The variation is due to a slight disparity in multiplying factor values and parameters.

It is also supported by Carragher et al. [48] that the MCA method provides strong fundamentals in investigating the usefulness of water demand methods. Implementation of water end-use data has become a basis for water demand evaluations across the world [49]. MCA or End-Use studies aid water demand estimations by including the design of water service infrastructure and reticulation [50].

The findings of this study will help Terengganu improve its water security. The definition of water security is enough quantities and good quality of water for living, non-living things as well as its surrounding [51]. Water security also refers to the ability to meet long-term water demand while stabilising human and environmental existence. The projected water demand value in this study expresses the definition of water security to yield sustainable water demand.

Aside from that, water consumption at Kenyir can improve its efficiencies by the detailed calculations of water demand and increase water prices to allow consumers to reduce their water consumption. Ways of conserving water resources include rainwater harvesting, greywater recycling, and the use of water-efficient fixtures. Also, the adoption of high-efficiency water fixtures in residential households or premises is one of the pertinent strategies for water demand management [48].

5. Conclusion

The summation of daily water demand for Kenyir Lake is estimated to be within 1250 m^3 with a small difference between the two forecasting techniques. Both low and high levels of water demand at some premises at Kenyir Lake should get attention from the authorities. This is because immediate action can be taken by the authorities to balance the water demand at each premise within Kenyir Lake. Communities should receive the right amount of water supply to ensure continuous water resources for the future generation.

Estimating water demand at Kenyir Lake, Terengganu is a good example for other countries to also identify the water supply and demand at their lakes, to ensure balance needs of water for human and the ecosystem there. The Micro-Component Analysis method used in this study also showed that this method is applicable for other lakes that have limited data of water supply. This study is one important way in making sure the sustainability of water in lakes and its surrounding.

This research can be expanded by exploring the forecasted water demand using appropriate analysis including fuzzy logic or statistical analysis. The exploration can be focused on the connection between the variables of water consumption. Besides that, the application of fuzzy logic is suggested to classify water demand into low, medium, and high to ensure straightforward decision making in water management. Water protection for houseboat users should also be addressed by the authorities to ensure long-term tourism in Kenyir Lake. Although there is no shortage of water at Kenyir Lake, the users' and tourists' health should be a top focus. This will ensure that the tourist sector remains Terengganu's and Malaysia's primary source of revenue.

References

[1] Veisi K, Bijani M and Abbasi E 2020 A human ecological analysis of water conflict in rural areas: evidence from Iran. *Global Ecology and Conservation* ***23*** e01050

[2] Valizadeh N, Bijani M, Hayati D and Fallah Haghighi N 2019 Social-cognitive conceptualization of Iranian farmers' water conservation behavior *Hydrogeol. J.* ***27***(4) 1131–1142 doi: 10.1007/s10040-018-01915-8

[3] Izadi N, Ataei P, Karimi-Gougheri H and Norouzi A 2019 Environmental Impact Assessment of Construction of Water Pumping Station in Bacheh Bazar Plain: A Case from Iran *EQA - Int. J. Environ. Qual.* ***35***(0) 13–32 doi: 10.6092/issn.2281-4485/8890

[4] Shahid M, Cong Z and Zhang D 2018 Understanding the impacts of climate change and human activities on streamflow: a case study of the Soan River basin, Pakistan *Theor. Appl. Climatol.* ***134***(1–2) 205–219 doi: 10.1007/s00704-017-2269-4

[5] Ataei P, Khatir A, Izadi N and Frost K J 2018 Environmental Impact Assessment of Artificial Feeding Plans: the Hammami Plain in Iran *Eqa-International J. Environ. Qual.* ***27*** 19–38, doi: 10.6092/issn.2281-4485/7345

[6] Aliabadi V, Gholamrezai S and Ataei P 2020 Rural people's intention to adopt sustainable water management by rainwater harvesting practices: application of TPB & HBM models *Water Supply* 1–15 doi: 10.2166/ws.2020.094

[7] Adams E A 2014 Behavioral Attitudes towards Water Conservation and Re-use among the

United States Public *Resour. Environ.* ***4***(3) 162–167 doi: 10.5923/j.re.20140403.04
[8] Saurí D 2013 Water conservation: Theory and evidence in urban areas of the developed world," *Annu. Rev. Environ. Resour.* ***38*** 227–248 doi: 10.1146/annurev-environ-013113-142651
[9] Gilbertson M, Hurlimann A and Dolnicar S 2011 Does water context influence behaviour and attitudes to water conservation? *Australas. J. Environ. Manag.* ***18***(1) 47–60 doi: 10.1080/14486563.2011.566160
[10] World Bank 2019 *World Rural Population, World Bank Group* retrieved from https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?most_recent_year_desc=false on Jun. 07, 2021
[11] Rashid M F, Ngah I and Misnan S H 2019 Revitalizing Rural Areas in Malaysia: A Framework for Economic Revitalization *IOP Conf. Ser. Earth Environ. Sci.* ***385***(1) doi: 10.1088/1755-1315/385/1/012004
[12] Ngah I 2015 Rural Transformations Development : a review on Malaysia ' s transformation program *Int. Conf. Soc. Sci. Humanit. UKM 2012 (ICOSH- UKM 2012) 12-13 December 2012* (August) 0–11
[13] Nigam A K and Rahi P D C 2016 Estimating Water Demand and Foecasting Water Demand for Year 2041 Jabalpur City *Int. J. Innov. Eng. Technol. 7*(2) 14–21
[14] Mohamad N D, Hanan Z, Izzati N and Kamal A 2020 Water Demand Estimation Based On Land Use In Urban City *Int. J. Sci. Technol. Res.* ***9***(6) 545–550
[15] Bata M, Carriveau R, and Ting D S K 2020 Short-term water demand forecasting using hybrid supervised and unsupervised machine learning model *Smart Water* ***5***(1) 1-11 doi: 10.1186/s40713-020-00020-y
[16] Jamieson D G, Shamir U, Martinez F and Franchini M 2007 Conceptual design of a generic, real-time, near-optimal control system for water-distribution networks *J. Hydroinformatics*, ***9***(1) 3–14 doi: 10.2166/hydro.2006.013
[17] Kozłowski E, Kowalska B, Kowalski D and Mazurkiewicz D 2018 Water demand forecasting by trend and harmonic analysis *Arch. Civ. Mech. Eng.* ***18***(1) 140–148 doi: 10.1016/j.acme.2017.05.006
[18] Donkor E A, Mazzuchi T A, Soyer R and Roberson J A 2014 Urban Water Demand Forecasting: Review of Methods and Models *J. Water Resour. Plan. Manag.* ***140***(2) 146–159 doi: 10.1061/(asce)wr.1943-5452.0000314
[19] House-Peters L A and Chang H 2011 Urban water demand modeling: Review of concepts, methods, and organizing principles *Water Resour. Res.* ***47***(5) doi: 10.1029/2010WR009624
[20] Anderson B, Manouseli D and Nagarajan M 2018 Estimating scenarios for domestic water demand under drought conditions in England and Wales *Water Sci. Technol. Water Supply*, no. September 2100–2107 doi: 10.2166/ws.2018.035
[21] Tanton R, Vidyattama Y, McNamara J, Vu Q N and Harding A 2009 Old, Single and Poor: Using Microsimulation and Microdata to Analyse Poverty and the Impact of Policy Change among Older Australians *Econ. Pap.* ***28***(2) 102–120 doi: 10.1111/j.1759-3441.2009.00022.x
[22] Díaz S and González J 2020 Analytical Stochastic Microcomponent Modeling Approach to Assess Network Spatial Scale Effects in Water Supply Systems *J. Water Resour. Plan. Manag.* ***146***(8) p. 04020065 doi: 10.1061/(asce)wr.1943-5452.0001237
[23] Blokker M, Agudelo-Vera C, Moerman A, Thienen P V and Pieterse-Quirijns I 2017 Review of applications for SIMDEUM, a stochastic drinking water demand model with a small temporal and spatial scale *Drink. Water Eng. Sci.* ***10***(1) 1–12 doi: 10.5194/dwes-10-1-2017
[24] Rinaudo J 2015 Long-Term Water Demand Forecasting in *Understanding and Managing Urban Water in Transition* 239–268
[25] UKWIR U W I R 2015 *Wrmp19 Methods – Household Consumption Forecasting: Guidance Manual* (London, UK)
[26] Herrington P 1996 *Climate change and the demand for water* (England: The Stationery Office Book)
[27] SPAN S P A N 2018 *Uniform Technical Guidelines Water Reticulation and Plumbing* retrieved from https://www.span.gov.my/article/view/guidelines-for-water on Aug. 05, 2020

[28] Kamarudin M K A, Wahab N A, Jalil N A A, Sunardi S and Saad M H M 2020 Water Quality Issues in Water Resources Management at Kenyir Lake, Malaysia *J. Teknol.* ***82***(3) 1–11
[29] Azlan N N I M, Malek M A, Zolkepli M, Salim J M and Ahmed A N 2021 Sustainable management of water demand using fuzzy inference system : a case study of Kenyir Lake , Malaysia *Environmental Science and Pollution Research* ***28***(16) 20261-20272
[30] Kamarudin M K A *et al.* 2018 The potential impacts of anthropogenic and climate changes factors on surface water ecosystem deterioration at Kenyir Lake, Malaysia *Int. J. Eng. Technol.* ***7***(3) 67–74 doi: 10.14419/ijet.v7i3.14.16864
[31] Sharip Z and Zakaria S 2008 Lakes and Reservoir in Malaysia : Management and Research Challenges *12th World Lake Conf.* 1349–1355
[32] Dullah H, Malek M A, and Hanafiah M M 2020 Life cycle assessment of Nile Tilapia (oreochromis niloticus) farming in Kenyir Lake, Terengganu *Sustain.* ***12***(6) doi: 10.3390/su12062268
[33] Rauf M, Ullah S, Haseeb A, Shah H and Khan M 2015 Physiochemical Investigation of River Kabul at Michini, Khyber Pakhtunkhwa, Pakistan *Journal of Biodiversity and Environmental Sciences* ***7***(3) 280-291
[34] Zakaria R and Baharin H B 2018 *Pembangunan Tasik Kenyir lonjak sektor pelancongan* retrieved from https://www.bharian.com.my/berita/nasional/2018/04/407385/pembangunan-tasik-kenyir-lonjak-sektor-pelancongan on Aug. 04, 2020
[35] Kamaruddin I S, Kamal A S M, Christianus A, S. K. Daud, and L. Yu Abit, "Fish community in Pengkalan Gawi - Pulau Dula section of Kenyir Lake, Terengganu, Malaysia," *J. Sustain. Sci. Manag.*, vol. 6, no. 1, pp. 89–97, 2011.
[36] Environment Agency UK 1995 *Environment Act* retrieved from https://www.legislation.gov.uk/ukpga/1995/25/contents on Aug. 05, 2020
[37] Syarikat Air Terengganu 2020 *Tips Penjimatan Air* retrieved from http://www.satuwater.com.my/index.php/ms/tips-penjimatan-air on Aug. 05, 2020
[38] Gössling S *et al.* 2012 Tourism and water use: Supply, demand, and security. An international review *Tour. Manag. 33*(1) 1–15 doi: 10.1016/j.tourman.2011.03.015
[39] Butler D and Memon F A 2006 Water consumption trends and demand forecasting techniques in *Water Demand Management* 1–25
[40] Browne A L, Medd W and Anderson B 2013 Developing Novel Approaches to Tracking Domestic Water Demand Under Uncertainty-A Reflection on the 'Up Scaling' of Social Science Approaches in the United Kingdom *Water Resour. Manag.* ***27***(4) 1013–1035 doi: 10.1007/s11269-012-0117-y
[41] Butler D 2003 The Influence of Dwelling Occupancy and Day of the Week on Domestic Appliance Wastewater Discharges *Build. Environ.* ***28***(I) 73–79
[42] Kame'enui A E 2003 Water Demand Forecasting in the Puget Sound Region: Short and Long-term Models (University of Washington, US)
[43] Rice W L, Pan B and Newman P 2019 Forecasting campground demand in US national parks *Ann. Tour. Res.* ***75***(May) 424–438 doi: 10.1016/j.annals.2019.01.013
[44] Muhamad W N H W, Radam A and Yacob M R 2014 Using Choice Experiments to Understand Visitors Preferences for the Man-Made Lake Ecotourism Services in Terengganu *J. Mark. Consum. Res.* ***4***(September) 41–50
[45] Van Der Meulen E S, Sutton N B, Van De Ven F H M and Van Oel P R 2020 Trends in Demand of Urban Surface Water Extractions and in Situ Use Functions *Water Resour. Manag.* ***34*** 4943–4958
[46] Set K, Yaakop A Y, Zatul N, Hussin I and Mohd B 2015 Understanding Motivation Factors of Tourism Entrepreneurs in Tasik Kenyir *Int. Acad. Res. J. Soc. Sci.* ***1***(2) 248–254 [Online]. Available: http://www.iarjournal.com/wp-content/uploads/34-P248-254.pdf.
[47] Parker J M and Wilby R L 2013 Quantifying Household Water Demand: A Review of Theory and Practice in the UK *Water Resour. Manag.* ***27*** 981–1011 doi:10.1007/s11269-012-01902
[48] Carragher B J, Stewart R A and Beal C D 2012 Quantifying the influence of residential water appliance efficiency on average day diurnal demand patterns at an end use level: A precursor

to optimised water service infrastructure planning *Resour. Conserv. Recycl* ***62*** 81–90 doi: 10.1016/j.resconrec.2012.02.008
[49] Blokker E J M, Pieterse-Quirijins E J, Vreeburg J H G and Van Dijk J C 2011 Simulating Residential Water Demand with a Stochastic End-Use Model *J. Water Resour. Plan. Manag.* ***137***(6) 511–520 doi: 10.1061/(ASCE)WR.1943-5452.0000002
[50] Jacobs H E 2007 The first reported correlation between end-use estimates of residential water demand and measured use in South Africa *Water SA* ***33***(4) 549–558
[51] Malek M A, Nor M A M and Leong Y P 2013 Water security and its challenges for Malaysia," *IOP Conf. Ser. Earth Environ. Sci.* ***16***(1) 1–6 doi: 10.1088/1755-1315/16/1/012123

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