Optimizing the Citra Raya Conservation Lake as Raw Material for Clean Water Treatment in the Citra Raya Residential Area, Tangerang

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Abstract. In Tangerang Indonesia, the Citra Raya residential area, three Citra Raya Conservation Lakes function as sources of clean water production. The area is flooded when the lake overflows during the rainy season. Community access to clean water is disrupted throughout the dry season due to a decrease in clean water discharge. So an effort is needed to increase the sustainability of its availability in achieving sustainable development goals (SDGs). This research was conducted to determine the water balance and improve water management in the three lakes. The water demand study was carried out based on the number of active consumers in 2020 and predictions until 2025. Flow characteristics and a basic planning-month approach were used to analyze water availability. Water balance analysis is used to compare the availability of reliable discharge and its needs as a basis for optimization. Optimization using linear programming. Optimization results show that the availability of raw water in the conservation lake is sufficient to meet the clean water demand of the Citra Raya area every month. However, in reality, there are problems such as pipe leaks and legal violations. This requires further research.

1 INTRODUCTION

Decent clean water is a basic human need, so increasing the sustainability of its availability must be supported in achieving sustainable development goals (SDGs) point 6, clean water and sanitation [1,2]. Good water resource management is very necessary to meet the daily needs of clean water for the community [3-7]. Along with the rapid growth rate of the urban population, this has an impact on the increasing need for clean water as well as domestic wastewater. The development of water resources engineering technology means that wastewater is used as raw material to be processed and reused [8-11], for example, the conservation lake in the Citra Raya area of Tangerang, Indonesia.

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Citra Raya Conservation Lake is a source of raw water to provide clean water for residents in the Citra Raya housing complex. The conservation lake consists of three lakes, namely Lake Chimanceuri, Lake Kusuma Dwipa, and Lake WoW (Water of Wonder). The water in these three lakes is processed at Water Treatment Plant 2 (WTP 2) into clean water, then distributed to customers, where the number of customers increases every year depending on the increase in residential areas. In the rainy season, the lake water is abundant so it must be drained out so that the lake can accommodate rainwater and water flow from the drainage channel in the form of domestic wastewater. As a result, during the dry season, clean water production is reduced, causing harm to customers. To meet the need for clean water, the volume of water managed must be following needs at all times. Optimization techniques are needed in managing raw water and clean water [12-16]. This study aims to carry out water balance analysis and optimization in managing water sources from the three conservation lakes.

This study carries out analyses and calculations of the need for clean water that must be available; the availability of water in the lake originating from rainwater and domestic wastewater; the mainstay discharge of lake water which will be processed into clean water; and the volume of reservoir water availability to optimize clean water. We hope that the results of this study can provide alternative solutions in managing available water resources so that the clean water needs of residents of the Citra Raya housing community are met on an ongoing basis.

2 Materials And Method

This research uses a case study approach, with quantitative descriptive, analytical, and optimization methods that aim to evaluate conditions in a certain period as a basis for future predictions [17] in meeting the community's clean water needs. The research stages include determining the study location, data collection, data processing and analysis, optimization with linear programming, and comparative evaluation of the results of the optimization model to conditions in the field.

2.1 Studi location

The study location is in the Citra Raya Tangerang residential area covering an area of 2760 ha. The clean water needs of residential residents come from raw water from three conservation lakes, namely Chimanceuri, Kusuma Dwipa, and WoW lakes. This raw water is processed into clean water at the water treatment plant sector 2 (WTP 2) and supplied to 51 clusters. A map of the study location along with three lakes and WTP 2, is presented in Figure 1. Chimanceuri Lake is a new lake development in 2020.

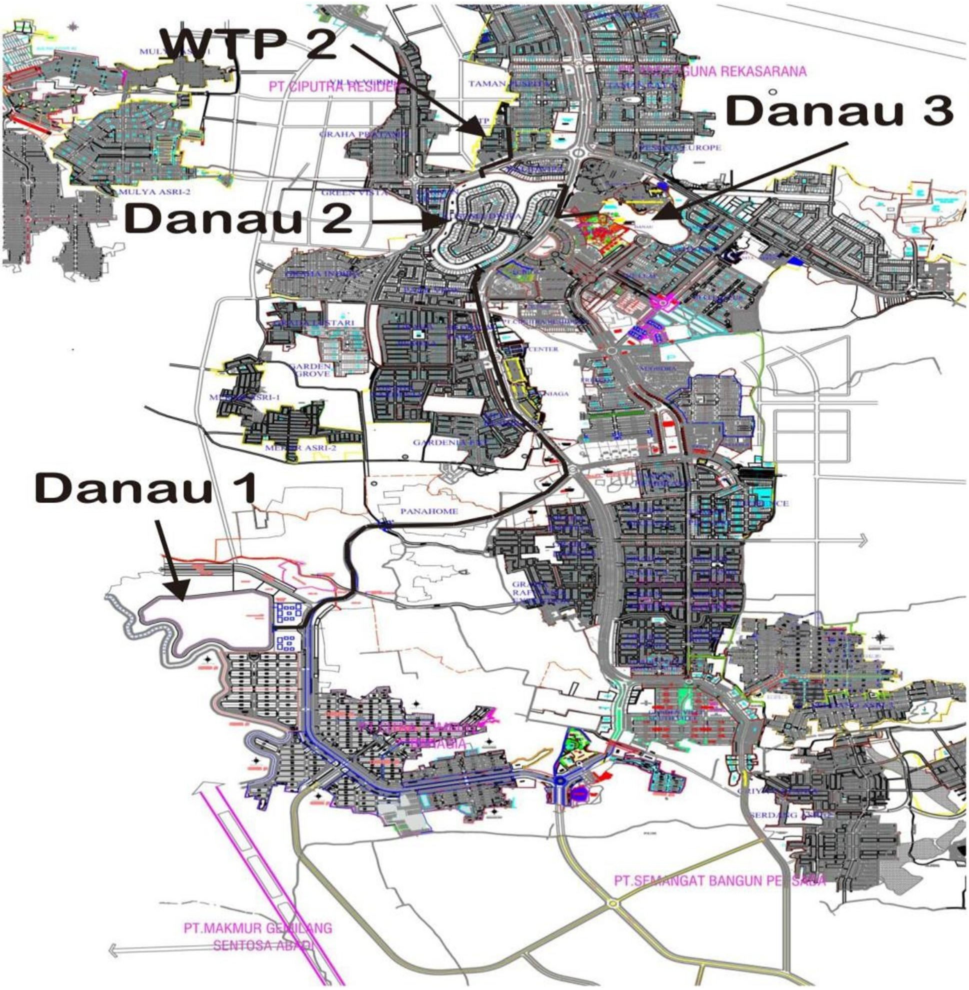

Figure 1. Study location

2.2 Data collection

Research data includes rainfall data, existing drainage channel dimension data, WTP 2 clean water production data, and clean water customer data in the Citra Raya Tangerang residential area. Rainfall data was obtained from mapping the distribution of rain station locations around the study location using the ArcGis software application, see Figure 2. Figure 2 shows that only one rainfall station represents the study location, namely the Budiarto Curug rain station. Rainfall data was obtained from BMKG (Meteorology, Climatology and Geophysics Agency), 2010-2019 as seen in Table 1.

Table 1. Rainfall data of Budiarto Curug station (BMKG, 2020)

No.	Year	Rainfall (mm)
1	2010	70.80
2	2011	83.40
3	2012	120.00
4	2013	103.40
5	2014	86.00
6	2015	121.97
7	2016	103.50
8	2017	85.50
9	2018	78.00
10	2019	127.00

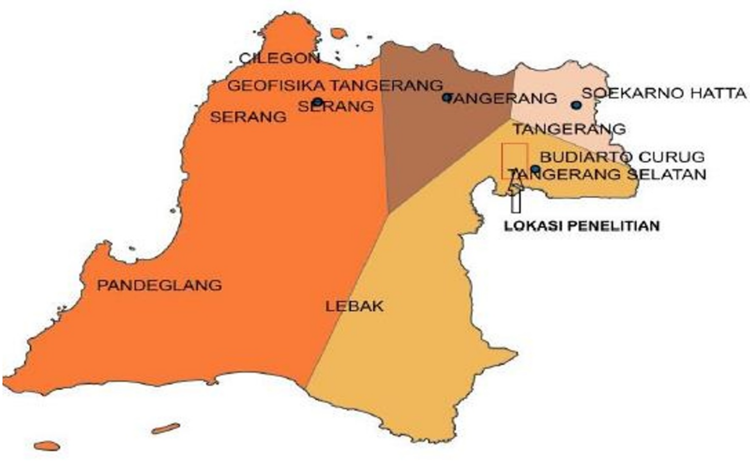

Figure 2. Rainfall station map

2.3 Data processing stages

The calculation and analysis stages are as follows:

- Calculate the number of active clean water customers at WTP 2 (data from Citra Raya Management).
- Calculate the total clean water needs of each customer (Qd), $Qd = Hc * Wc$ (1) where Qd is the total need for clean water, Hc is a home connection (assumed = 6 people) and Wc is water consumption = 130 l/s.
- Frequency distribution analysis and suitability tests (Chi-Square and Smirnov Kolmogorof), followed by calculation of planned return period rainfall. Because the Cittra Raya residential area is 2760 ha (more than 500 ha) and is located in a metropolitan city, the planned rainfall calculation uses a return period of 25 years.

- Calculate rain intensity using the Mononobe method (I), $I = (R_{24} / 24) * (24 / t)^{(2/3)}$ (2) where I is rainfall intensity (mm/hour), is R_{24} maximum rainfall in 24 hours and t is the duration (hours).
- Calculate the rainwater runoff discharge, usually called the planned flood discharge (Q), using the rational method formula because the area of the study location is less than 300 km², $Q = 0.278 * C * I * A$ (3) where Q is the planned flood discharge (l/s), C is the runoff coefficient depending on the type of soil or land use, I is the rainfall intensity (mm/hour) and A is the catchment area (ha).
- Calculate the volume of wastewater (Qr), $Qr = 80\% * Qd$ (4) where Qr is domestic wastewater discharge (l/s), Qd is clean water demand discharge (l/s).
- Calculate the mainstay discharge for water availability in the three lakes.
- Calculate the total need for clean water in the Citra Raya residential area.
- Water balance analysis, namely comparing available discharge with water demand discharge.
- Optimization with linear programming (using the solver application in Ms. Excel).
- Evaluate the results of the optimization model compared to events in the field.

3 Results and Discussion

3.1 Number of customers and clean water needs

Data on the number of customers was obtained from Citra Raya management. The calculation of clean water needs uses 2020 conditions as a calculation reference (Table 2). Based on Table 2, the total need for clean water in the Citra Raya residential area is 0.099 m³/s.

Table 2. Number of customers and clean water needs (Qd).

No.	Customer type	Hc (Year 2020)	Wc (l/day)	Qd (l/s)	Customer type	Qd (l/s)	Qd (m³/s)
1	General Social	18	3000	0.625	Social	0.688	0.001
2	Special social	3	1800	0.063	Domestic	66.518	0.067
3	Household-1	4675	600	32.465	Non-domestic	8.046	0.008
4	Household-2	1576	780	14.228	Water loses	23.520	0.024
5	Household-3	1373	780	12.395			
6	Household-4	823	780	7.430	Total	98.772	0.099
7	Medium commerce	968	600	6.722			
8	Large commerce	22	5200	1.324			

3.2 Analysis of frequency distribution and planned rainfall

Frequency distribution analysis uses the Normal, Gumbel, Log Normal, and Log Pearson III distribution methods with rain data from the Budiarto Curug rain station (see Table 1). As a result of the analysis, only the Log Pearson III distribution meets the requirements (Table 3). Next, a suitability test was carried out using the Chi-Square method (Table 4) and Smirnov Kolmogorof (Table 5). Table 4. Chi-Square test, for DK = 2 and α = 5%, obtained X^2cr = 5,991 and X^2 test = 4,00. Due to X^2 test < $X2\ cr$, so the Log Pearson III distribution is acceptable. In the Smirnov Kolmogorof test (Table 5), the value obtained Δ Max = 0.12 and Δ Max = 0.409, due to Δ Max < Δ Max so the Log Pearson III distribution is accepted.

Table 3. Result of frequency distribution analysis.

Distribution method	Requirement	Result	Conclusion
Normal	Cs=0	0.33	not ok
Gumbel	Cs≈1.14	0.33	not ok
	Ck≈5.40	33.17	not ok
Log Normal	Cs=3Cv	0.14	not ok
Log Pearson III	-	-0.83	ok

Table 4. Result of Chi Square test

Class	Fe	Ft	Fe - Ft	(Fe-Ft)² /Ft
< 76.645	3	2	1	0.50
76.645-81.887	1	2	-1	0.50
81.887-104.037	4	2	2	2.00
104.037-109.761	1	2	-1	0.50
> 109.76	1	2	-1	0.50

Table 5. Smirnov-Kolmogorov distribution fit test

No.	Year	P(X)	X	Log X	G	Pr (%)	Pt(X)	P(X) – Pt(X)
1	2014	0.091	65.70	1.818	-1.378	90.427	0.096	-0.005
2	2018	0.182	69.10	1.839	-1.149	86.663	0.133	0.049
3	2010	0.273	70.80	1.850	-1.038	84.691	0.153	0.12
4	2017	0.364	81.80	1.913	-0.382	58.454	0.415	-0.051
5	2011	0.455	83.40	1.921	-0.294	56.989	0.430	0.025
6	2012	0.546	99.00	1.996	0.484	42.625	0.574	-0.028
7	2016	0.636	103.50	2.015	0.686	34.26	0.657	-0.021
8	2013	0.727	103.40	2.015	0.682	33.898	0.661	0.066
9	2015	0.818	105.50	2.023	0.773	26.751	0.732	0.086
10	2019	0.909	127.00	2.104	1.615	1.734	0.983	-0.074

Based on the results of the frequency distribution analysis and suitability test, the planned return period rainfall calculation uses the Log Pearson III distribution method. Because the Citra Raya area is more than 500 ha (PU PLP Cipta Karya, 2012) a return period of 25 years was chosen. Determine the planned rainfall for a 25-year return period (R25), with n = 10, the average rainfall = Rr = 90.2 mm, Sd = 19.86, Yt = 3.1985, Yn = 0.4952 and Sn = 0.9496:

$$Kt = \frac{Yt - Yn}{Sn} = \frac{3.1985 - 0.4952}{0.9496} = 2.88$$

$$Rt = Rr + (Kt * Sd) \Leftrightarrow R25 = 90.92 + (2.88 * 19.86) = 147 \text{ mm}$$

The study location is a residential area, so the runoff coefficient value, C = 0.4, means the amount of rain is effective (Reff) is:

$$\mathrm{Re}\,ff = C * R25 = 0.4 * 147 = 59\ mm.$$

3.3 Planned flood discharge

The water storage in the three conservation lakes comes from rainwater and domestic and non-domestic wastewater flows. Calculation of the volume of rainwater entering the lake by determining the planned flood discharge that will occur based on frequency analysis of rain data [18-19]. The planned flood discharge is calculated based on the maximum daily rainfall that occurs in the 25-year return period using the Rational method. The results of the planned flood discharge calculations for the three lakes are shown in Table 6. Table 6 shows that the planned flood discharge for Lake Chimanceuri is 6.59 m³/s, Lake Kusuma Dwipa is 2.30 m³/s, and Lake WoW is 6.40 m³/s.

Table 6. Flood discharge plan for Chimanceuri, Kusuma Dwipa, and WoW lakes

Lake	A (km²)	S	G	Tr (%)	K	Log R24	R24	C	I	Q (m³/s)
Chimanceuri	3.04	0.096	0.04	4	1.75	2.150	141.35	0.4	19.45	6.59
Kusuma Dwipa	1.07	0.096	0.04	4	1.75	2.150	141.35	0.4	19.45	2.30
WoW	2.96	0.096	0.04	4	1.75	2.150	141.35	0.4	19.45	6.40
Total										15.29

3.4 Calculation of household waste as lake inflow discharge

Domestic and non-domestic wastewater from the Citra Raya residential area is directly channeled into the drainage channel to the Citra Raya Conservation Lake. The amount of wastewater is 80% of clean water needs. Calculations of wastewater flowing into each lake can be seen in Table 7.

Table 7. Water demand and wastewater at Kusuma Dwipa and WoW Lake

No.	Customer type	Kusuma Dwipa Lake		WoW Lake	
		Water demand (l/s)	Wastewater (m³/s)	Water demand (l/s)	Wastewater (m³/s)
1	General-social	0.625	0.00050	0.000	0.00000
2	Special-social	0.063	0.00005	0.003	0.00003
3	Domestic	28.443	0.02275	37.180	0.02974
4	Non-domestic	2.058	0.00165	5.963	0.00477
5	Large commerce	0.120	0.00009	1.940	0.00009
	Total	31.309	0.025	45.086	0.035

Table 7 shows that the waste water flowing into Lake Kusuma Dwipa is 0.025 m³/s and into Lake WoW is 0.035 m³/s. This calculation was made based on 2020 data, so there has been no wastewater flow into Lake Chimanceuri because Lake Chimanceuri is still under construction.

3.5 Reliable discharge in the lake

The reliability of water discharge in the lake is analyzed to determine its level of ability as raw material for clean water processing. Limantara [20,21], states that there are four methods for calculating reliable discharge, namely the minimum average discharge method, flow characteristics, basic planning year, and basic month-planning. In this study, we use the basic month-planning method by dividing discharge reliability into four conditions, namely:

- Dry season water discharge, reliability is (355/365) x 100% = 97,3%.
- Low water flow, reliability is (275/365) x 100% = 75.3%.
- Normal water flow, reliability is (185/365) x 100% = 50.7%.
- Water flow is sufficient, and reliability is (95/365) x 100% = 26%.

To determine the reliability of raw water availability every month, we carried out calculations using the four reliability conditions mentioned above applied to the three conservation lakes. The results of calculating the mainstay discharge for each lake are shown in Table 8, while the total mainstay discharge can be seen in Table 9.

Table 8. Reliability of discharge (Q reliable) at Chimanceuri, Kusuma Dwipa, and WoW Lake.

Qreliable	Chimanceuri Lake				Kusuma Dwipa Lake				WoW Lake			
	97.3 %	75.3 %	50.7 %	26.0 %	97.3 %	75.3 %	50.7 %	26.0 %	97.3 %	75.3 %	50.7 %	26.0 %
January	0.76	1.69	2.36	3.11	0.29	0.62	0.85	1.11	0.77	1.68	2.33	3.06
February	1.20	1.63	2.39	3.34	0.44	0.60	0.86	1.19	1.20	1.62	2.36	3.28
March	1.10	1.77	2.28	2.97	0.41	0.64	0.82	3.00	1.11	1.76	2.25	2.93
April	0.17	0.92	1.81	3.15	0.08	0.35	0.66	1.13	0.20	0.93	1.80	3.10
May	0.47	1.53	2.46	3.63	0.19	0.56	0.89	1.29	0.49	1.52	2.43	3.56
June	0.66	1.33	1.85	2.61	0.26	0.49	0.67	0.94	0.68	1.33	1.84	2.58
July	0.01	0.33	1.24	2.97	0.03	0.14	0.46	1.07	0.04	0.36	1.24	2.93
August	0.04	0.37	0.91	1.92	0.04	0.15	0.34	0.70	0.08	0.39	0.92	1.90
September	0.01	0.43	1.32	2.55	0.03	0.18	0.49	0.92	0.05	0.45	1.32	2.52
October	0.01	0.11	0.87	1.73	0.03	0.13	0.33	0.63	0.05	0.34	0.89	1.71
November	0.08	1.32	3.51	6.72	0.05	0.49	1.25	2.37	0.12	1.32	3.45	6.57
December	0.12	0.36	2.14	3.49	0.07	0.38	0.77	1.25	0.15	1.03	2.12	3.43

Table 9. Calculation results of total reliable discharge (Qtot. reliable) for the three lakes.

Q reliable	Q reliable total			
	97.3%	75.3%	50.7%	26.0%
January	1.82	3.99	5.54	7.28
February	2.84	3.85	5.61	7.81
March	2.62	4.17	5.35	8.90
April	0.45	2.20	4.27	7.38
May	1.15	3.61	5.78	8.48
June	1.60	3.15	4.36	6.13

Q reliable	Q reliable total			
	97.3%	75.3%	50.7%	26.0%
July	0.08	0.83	2.94	6.97
August	0.16	0.91	2.17	4.52
September	0.09	1.06	3.13	5.99
October	0.09	0.58	2.09	4.07
November	0.25	3.13	8.21	15.66
December	0.34	1.77	5.03	8.17

Based on the calculation data (see Table 9), if the discharge in the three lakes matches the dry season discharge (97.3% reliability), then water needs can be met. So that the water needs of the Citra Raya residential community can be met every month, we optimize the operations of the three lakes using a linear programming optimization model.

3.6 Analisis water balance

The water balance analysis in this study is to compare the amount of raw water available in the three conservation lakes with the clean water needs of the community in the Citra Raya residential area. In this analysis, we also predict the availability and demand for water until 2025 (Table 10) and water balance (Table 11).

Table 10. Results of debit calculations for availability and demand as well as predictions until 2025

% Reliability	Q availability (m^3/s)						Q demand (m^3/s)					
	2020	2021	2022	2023	2024	2025	2020	2021	2022	2023	2024	2025
97.3%	0.957	0.960	0.964	0.967	0.970	0.974	0.099	0.104	0.109	0.114	0.120	0.126
75.3%	2.436	2.439	2.442	2.446	2.449	2.453	0.099	0.104	0.109	0.114	0.120	0.126
50.7%	4.542	4.545	4.548	4.551	4.555	4.559	0.099	0.104	0.109	0.114	0.120	0.126
26.0%	7.611	7.614	7.617	7.620	7.624	7.628	0.099	0.104	0.109	0.114	0.120	0.126

Table 11. Water balance and predictions until 2025

% Reliability	Water balance (m^3/s)					
	2020	2021	2022	2023	2024	2025
97.3%	0.859	0.857	0.855	0.853	0.851	0.848
75.3%	2.337	2.336	2.334	2.332	2.329	2.327
50.7%	4.443	4.441	4.439	4.437	4.435	4.433
26.0%	7.512	7.510	7.508	7.506	7.504	7.502

Calculations of water availability and demand for all % reliability (see Table 10) from 2020 to 2025 state that water availability exceeds the demand discharge. This means that the water needs of residents in the Citra Raya housing complex are met. Table 11 shows the condition of the water balance in a surplus position, where water availability exceeds the amount of water needed.

3.7 Optimizing the demand and availability of clean water

Optimization is a process to achieve ideal results. In this study, we use a linear program optimization technique, namely the solver in Microsoft Excel. The condition of water demand problem that occurs in the Citra Raya Tangerang housing complex is that during the dry season, the water flow supplied to residents' houses decreases. The need for clean water in the Citra Raya area is 0.156 m^3/sec, and the total storage capacity of the three lakes is 917687 m^3, so it is necessary to determine the raw water requirement for each lake that will be produced into clean water every month.

As an illustration of optimization calculations, we use a reliability value of 97.3% and data on clean water needs in January 2020. The formulation of variable functions, objectives, and constraints is determined based on the results of previous calculations as follows:

- Variabel function: X1 = Chimanceuri Lake, X2 = Kusuma Dwipa Lake, X3 = WoW Lake

- The reliable discharge is 97.3% for each lake, namely: 0.76 m³/s, 0.29 m³/s, and 0.77 m³/s, the maximum capacity for each lake is 593793 m³, 147685 m³, and 176209 m³, while the need for clean water in January is 0.099 m³/s.
- Objective function: Max = (593793 x X1) + (147685 x X2) + (176209 x X3)
- Constraint: X1 + X2 + X3 = 0.99, X1 ≤ 0.76, X2 ≤ 0.29, X3 ≤ 0.77

Solving the values for variables X1, X2, and X3 is done using the solver program as follows:

January Qreliability= 97.3% Qdemand total
Constraint: X1 0.099 X2 0.000 X3 0.000
X1+X2+X3 = 0.0990.099<= 0.156
X1 <= 1.196 0.099
X2 <= 0.443 0.000
X3 <= 1.108 0.000

Maximum = 593793*X1+ 147685*X2+ 176209*X3 = 58647.46 → raw water requirements for clean water production (m³).

A recapitulation of optimization calculations is shown in Table 12 below:

Table 12. Results of optimizing raw water availability and clean water demand

Month	Q-Clean water demand	Q-Raw water availability			Q-Raw water production			Total raw water requirement	Lake capacity
		Chimanceuri	Kusuma Dwipa	WoW	Chimanceuri	Kusuma Dwipa	WoW		
	(m³/s)	(m³/s)	(m³/s)	(m³/s)	(m³/s)	(m³/s)	(m³/s)	(m³)	(m³)
Jan.	0.0988	1.1956	0.4433	1.1083	0.0988	0.0000	0.0000	58647.46	Ok
Feb.	0.0988	0.7571	0.2899	0.7720	0.0988	0.0000	0.0000	58647.46	Ok
Mar.	0.0988	1.1030	0.4109	1.1083	0.0988	0.0000	0.0000	58647.46	Ok
Apr.	0.0988	0.0841	0.2001	0.1687	0.0000	0.0000	0.0988	58647.46	Ok
May	0.0988	0.1888	0.4911	0.4681	0.0000	0.0000	0.0988	58647.46	Ok
June	0.0988	0.2560	0.6780	0.6603	0.0000	0.0000	0.0988	58647.46	Ok
July	0.0988	0.0439	0.0081	0.0279	0.0449	0.0081	0.0279	16834.80	Ok
Aug.	0.0988	0.0777	0.0428	0.0400	0.0560	0.0000	0.0000	35268.60	Ok
Sept.	0.0988	0.0496	0.0139	0.0299	0.0505	0.0139	0.0299	21569.39	Ok
Oct.	0.0988	0.0137	0.0298	0.0494	0.0137	0.0428	0.0504	21426.66	Ok
Nov.	0.0988	0.0846	0.0546	0.1183	0.0329	0.0329	0.0329	30212.54	Ok
Dec.	0.0988	0.1159	0.0656	0.1487	0.0988	0.0000	0.0000	58647.46	Ok

Table 12 shows that the availability of raw water in the conservation lake is sufficient to meet the clean water needs of the Citra Raya Tangerang area every month. However, several problems in the field result in a shortage of clean water, such as leaks in pipe networks, illegal connections, and unregistered usage. Below we present Table 13 which contains clean water usage reports from Citra Raya Tangerang management as analysis material for further research.

Table 13. WTP 2 report in January 2020

No	WTP 2 monthly report	Volume (m³)
1	Raw water production	299140
2	Water used for cleaning	74362
3	Water distribution recorded by the WTP 2 water meter	224778
4	Total water distributed to customers from WTP 2	224778
5	Water recorded on the customer's water meter	200000
6	Draining water for cleaning	2500
7	Water usage for company facilities	25350
8	Total water usage	227850

Table 13 shows that the raw water production of WTP 2 Citra Raya is 299,140 m³, the clean water distributed to customers is 224,778 m³, recorded in customer water meters is 200,000 m³, and the use of clean water for company facilities is 227,850 m³. If we look at the results of production and usage, there is a water shortage of 3072 m³, caused by a lack of clean water production. Apart from that, the Word of Wonder (WoW) lake cannot accommodate maximum capacity because in the area there are commercial areas whose activities will be disrupted if the lake water level is high.

4 Conclusion

Fulfilling the need for clean water in the Citra Raya housing complex in Tangerang experiences problems during the dry season. This research was conducted to determine the water balance and improve management. The problem of lack of clean water in the Citra Raya area during the dry season is not caused by a lack of raw water from conservation lakes but by other causal factors. Through this study, it has been proven through calculations and analysis as well as linear program optimization modeling (solver) that the raw water capacity in conservation lakes is sufficient to meet the need for clean water production every month. If the reality in the field is that there is a shortage of clean water during the dry season, then this is a special problem that requires further integrated research.

Acknowledgments

The authors would like to express their gratitude for the support from the leadership of the Faculty of Engineering and the Head of the UMB Civil Engineering Study Program and also thank the Menara Bakti Foundation for providing funds to participate in the SAFE2024 Conference and publication of this paper in Scopus-indexed Proceeding. Thank you to the management of Citra Raya Tangerang for providing data and allowing us to conduct research in the Citra Raya area. Thank you also to BMKG for providing rain data.

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