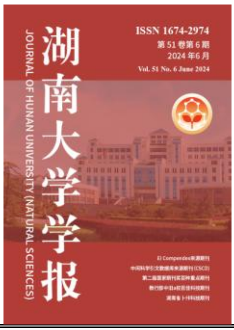

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Water Allocation Model Due to Non-Technical (Economic, Social, and Environmental) Factors

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Abstract: Currently, the existing model in the research location (Balikpapan City) considers only the technical aspects, and there is subjective allocation due to the manager's vision. This study simulated water allocation, taking into account nontechnical (economic, social, and environmental) factors. The research methodology consists of literature review, analysis of land use change based on the satellite Citra in 2014, 2015, and 2021, analysis of flood routing and flood maps based on LiDAR 2021, and analysis of flood vulnerability. The research location is the Karangmumus watershed, Talangsari sub-watershed in Samarinda City. The results indicate that the rainfall depth is 70 mm, and the area inundated with water to a depth greater than 0.7 m is 4.6 ha. Additionally, the area inundated to a depth greater than 0.5 m is 7.54 ha, and the area inundated to a depth greater than 0.3 m is 21.56 ha. Change in the inundation area impacts the level of flood vulnerability. It is expected that through a detailed examination of the land use change analysis in the Talangsari sub-watershed, it will be feasible to determine the susceptibility of areas in flood-prone regions in other watersheds. The extent of flood intensity can be assessed by considering land use transformations; therefore, the change in flood vulnerability impact can also be estimated. The outcomes of this study can serve as a useful guide for formulating area utilization policies in a watershed, thereby minimizing the potential impact of escalating flood vulnerability in the future.

Keywords: water allocation, economic factors, social factors, environmental factors.

非技术（经济、社会和环境）因素导致的水资源分配模型

摘要：目前，研究地点（巴厘巴板市）现有的模型仅考虑技术方面，并且由于管理者的愿景而存在主观分配。本研究模拟了水分配，考虑了非技术（经济、社会和环境）因素。研究方法包括文献综述、基于卫星西特拉对 2014 年、2015 年和 2021 年土地利用变化的分析、基于激光雷达 2021 对洪水路线和洪水地图的分析以及洪水脆弱性分析。研究地点是三马林达市的卡朗穆穆斯流域、塔朗萨里子流域。结果表明，降雨深度为 70 毫米，水深大于 0.7 米的面积为 4.6 公顷。此外，水深大于 0.5 米的面积为 7.54 公顷，水深大于 0.3 米的面积为 21.56 公顷。淹没区的变化会影响洪水脆弱性水平。通过详细研究塔朗萨里子流域的土地利用变化分析，预计可以确定其他流域洪水易发地区的易发性。可以通过考虑土地利用变化来

评估洪水强度的程度；因此，也可以估计洪水脆弱性影响的变化。本研究的结果可以作为制定流域区域利用政策的有用指南，从而最大限度地减少未来洪水脆弱性升级的潜在影响。

关键词：水资源分配，经济因素，社会因素，环境因素。

1. Introduction

Water is a fundamental requirement for human life, provided by the Almighty. The availability of this vital resource is influenced by both spatial constraints and the passage of time, both of which become increasingly scarce. Despite this, the demand for water continues to rise [1, 2]. A challenge in water resource management is the allocation of water for various user sectors, such as raw water, irrigation, industry, fisheries, and energy. In situations where water availability exceeds overall water demand, conflicts or issues are unlikely to arise. Nevertheless, achieving ideal circumstances is not easily attainable due to the alterations in water resources resulting from spatial and temporal functions [3, 4]. According to the Indonesian Water Resources Law No. 17 of 2019, to address the imbalance between decreasing water availability and increasing water demand [5, 6], it is necessary to manage water resources by taking into account the social, environmental, and economic functions in harmony to implement synergy and integration between different regions, sectors, and generations to meet human needs for water. Therefore, there is a water allocation model that can help water resource managers accommodate social, environmental, and economic functions in harmony.

Balikpapan, as one of the major cities in East Borneo Province, boasts significant economic progress and is poised to serve as the nation's new capital gateway. Balikpapan, which is on the coast of the Makasar Strait, does not have big rivers that can be depended on for raw water supply. Nowadays, Balikpapan depends on some big reservoirs like Manggar Dam and Teritip Dam and some depth wells. Throughout its history, Balikpapan has grappled with instances of drought. One such instance occurred in 2014 when the Manggar reservoir, which supplied 61.4% of the city's raw water, experienced a landslide, necessitating a reduction in the water level elevation to the minimum level. Another instance was brought on by climate factors such as El Nino in 2015-2017 and 2023-2024.

Babel et al. [7] indicated that certain conditions in an integrated water allocation model (IWAM) that has been developed are such that, if the availability of water is less than the normal demand [8], the allocation of water is based on normal demand. If water availability is below the minimum demand, water allocation can use a condition that is based on equality or emergency and priority. Wenlan [9] implemented a dynamic model to apply Integrated Water Resources Management (IWRM) in the mining sector. The model was utilized to manage the production of sustainable water quantity and quality, while also considering economic factors. Additionally, regional development plans were formulated to support the sustainable management of water resources. The first model used was socio-economic, while the second model focused on water supply, demand, and quality.

Most water allocation procedures carried out by the Balikpapan Regional Drinking Water Company (PDAM) are based on subjective policies, which have led to public dissatisfaction. The allocation of water tends to be conducted on a rotating basis and prioritizes the economic center region. As a result, the water allocation model is intended to assist policymakers in addressing water scarcity by considering the social, economic, and environmental factors that influence societal satisfaction.

2. Materials and Methods

2.1. Materials

In this study, various maps and data were utilized in the following manner:

1. Rainfall data from stations in Balikpapan, the location of the research, were collected. Due to the limited availability of rainfall stations with 20 years of data, GPM satellite data were used to supplement the data, which were then adjusted using data from the BMKG rainfall station at Sepinggan airport in Balikpapan.
2. Data on the water level of the Maggar reservoir were gathered over a period of 19 years (2005 to 2021), while data on the Teritip reservoir water level were collected over 8 years (2016 to 2024).
3. Information on the water intake of the Manggar reservoir over 19 years (2005 to 2024) and the Teritip reservoir over 8 years (2016 to 2024) was analyzed.
4. The operational patterns of the Manggar and Teritip reservoirs were studied and analyzed.
5. The water allocation zones in Balikpapan and the allocation strategies were examined through interviews with the PDAM in Balikpapan.
6. Population data were obtained from the Statistic Center Institution (BPS).

2.2. Research Location

The study site was situated in Balikpapan, encompassing eight service zones within the PDAM of

Balikpapan. Balikpapan is divided into six districts and eight water service zones. The main raw water sources in Balikpapan are the Manggar reservoir with the collection of about 940 l/s (61.4% of water avilability in Balikpapan) and the Teritip reservoir with the collection of about 200 l/s. Fig. 1 presents the water service zones in Balikpapan, and Fig. 2 presents the administrative region.

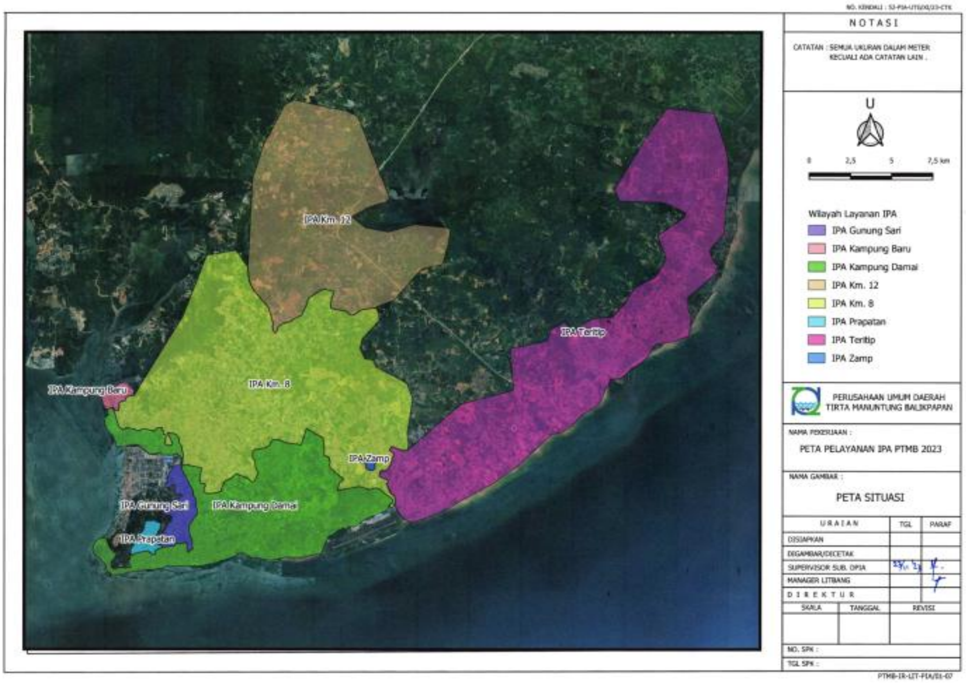


Fig. 1 Water service zones in Balikpapan (Own study)

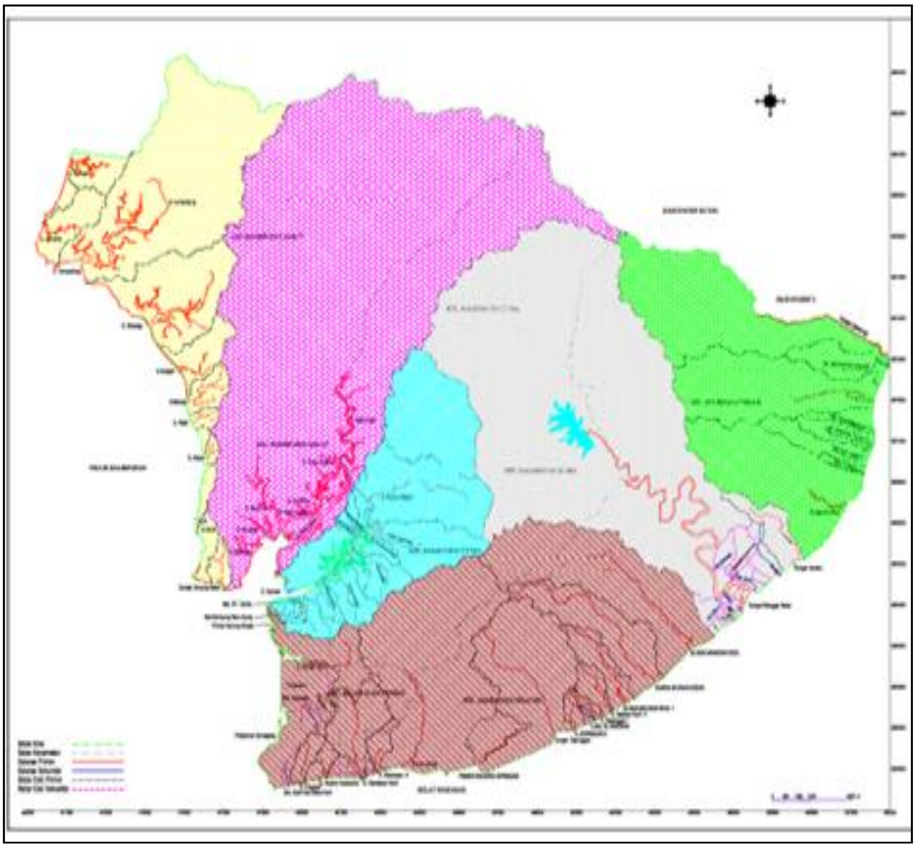


Fig. 2 Administrative region (Own study)

2.3. Methodology

2.3.1. Model

A model is representation of a real form; however, a system is an inter-relation [10] between developed elements of a unity. A model is generally developed to achieve a certain objective. The objective of modeling is to analyze and provide predictions that can approach reality before the system is applied in the field [8]. Modeling is a form of representation that uses logic to depict a complex reality in a sequential manner. In this research, we developed a water allocation model that takes into account the needs of the water manager, water operator, and water user, with the aim of achieving a balanced outcome that satisfies all parties involved. The existing water allocation model is shown in Fig. 3.

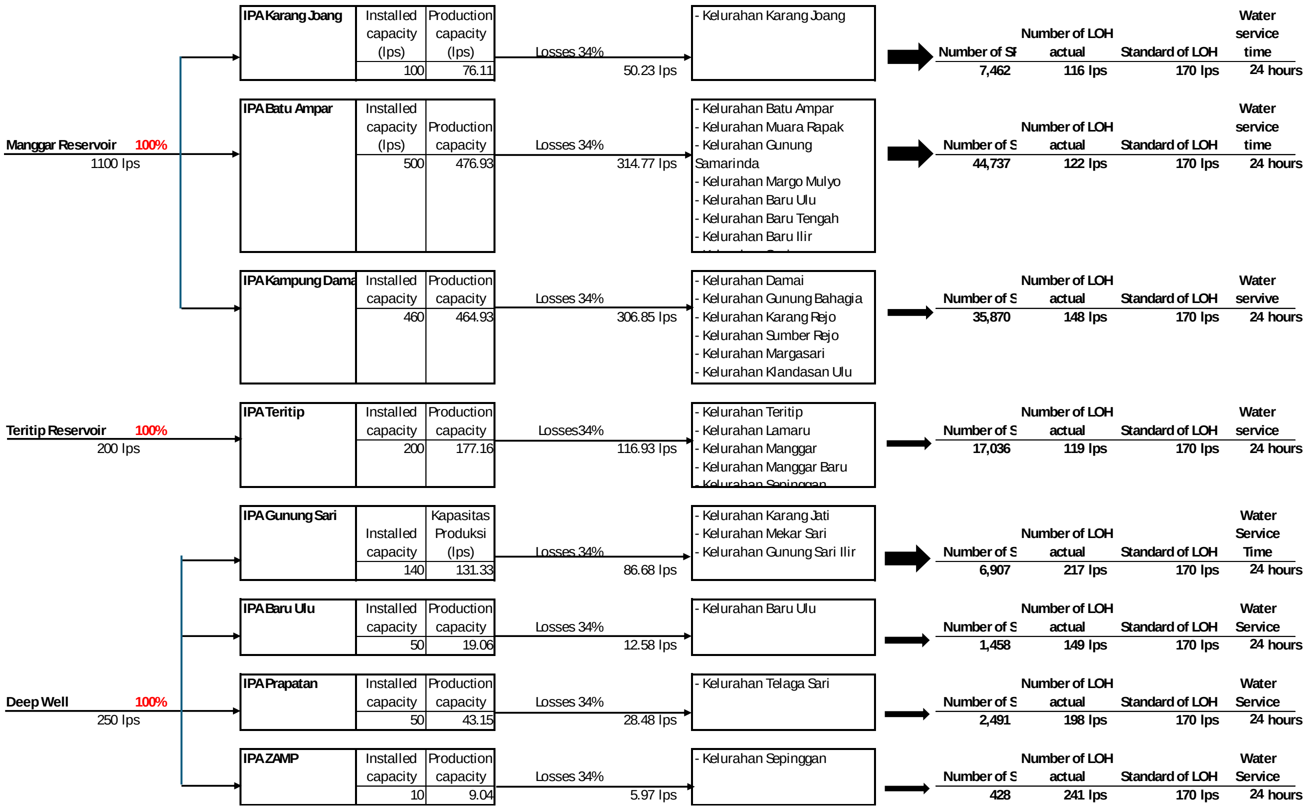


Fig. 3 Model of existing water allocation in Balikpapan (Own study)

This model elucidates the water allocation from water sources that is distributed across 8 service zones and the alterations in water allocation for each period of water supply. In this study, the model was developed using a dynamic approach, with water availability being the primary factor, and the interests of managers, operators, and customer satisfaction being considered as factors that can be influenced.

2.3.2. Water Availability Analysis

In this research, it is essential to consider the availability of water when constructing a water allocation model [12]. There are two main raw water sources in Balikpapan: surface water and groundwater. The surface water supply was derived from the Manggar and Teritip reservoirs, which exhibit variable availability that aligns with the rainfall pattern. Analysis of water availability is conducted at the surface water source [13]; however, the groundwater source is assumed to be constant.

Water availability in a reservoir is contingent upon the equilibrium simulation of reservoir storage. This scenario is assessed in accordance with the drafting guidelines for reservoir operation patterns established by the Ministry of General Work and Housing (PUPR) [11] (Fig. 4), using the following equation:

The basic equation [14]:

$$I - O = \frac{ds}{dt} \tag{1}$$

where:
I - inflow
O - outflow
ds/dt - ΔS storage change

In addition, it can be expressed as follows:

$$St+1 = St + It + Rt - Et - Lt - Ot - Ost \tag{2}$$

where:
St - reservoir storage in period *t*
St+1 - reservoir storage in period *t+1*
It - inflow in period *t*
Rt - rainfall on the reservoir surface during the *t* period
Et - water loss caused by evaporation in period *t*
Lt - water loss caused by seepage and leakage
Ot - total water demand
OSt - outflow from the spillway

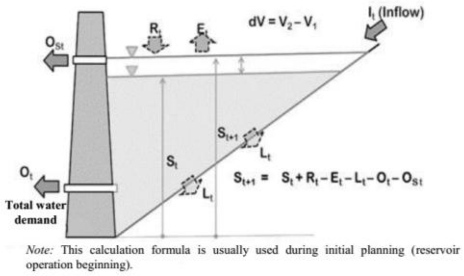


Fig. 4 Simulation of reservoir storage equality [16]

The examination of water availability commences by obtaining rainfall data. In this instance, we utilize satellite rainfall data [10, 15] corrected with data from the BMKG rainfall station situated at Sepinggan airport (Fig. 5). The calibration results for satellite rainfall data are presented in Fig. 6, followed by an analysis of discharge using the F.J. Mock method and then analyzing the reliable discharge [16].

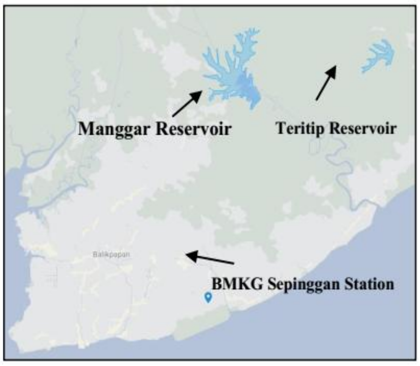


Fig. 5 BMKG rainfall station (Own study)

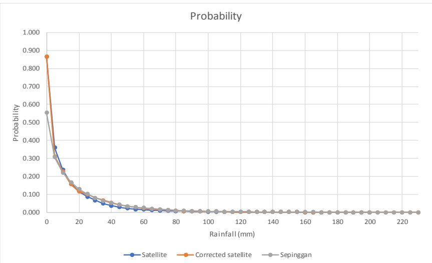


Fig. 6 Calibration and correction of satellite rainfall data (Own study)

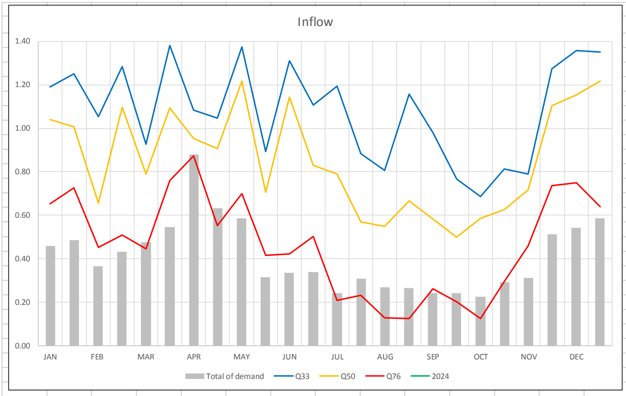
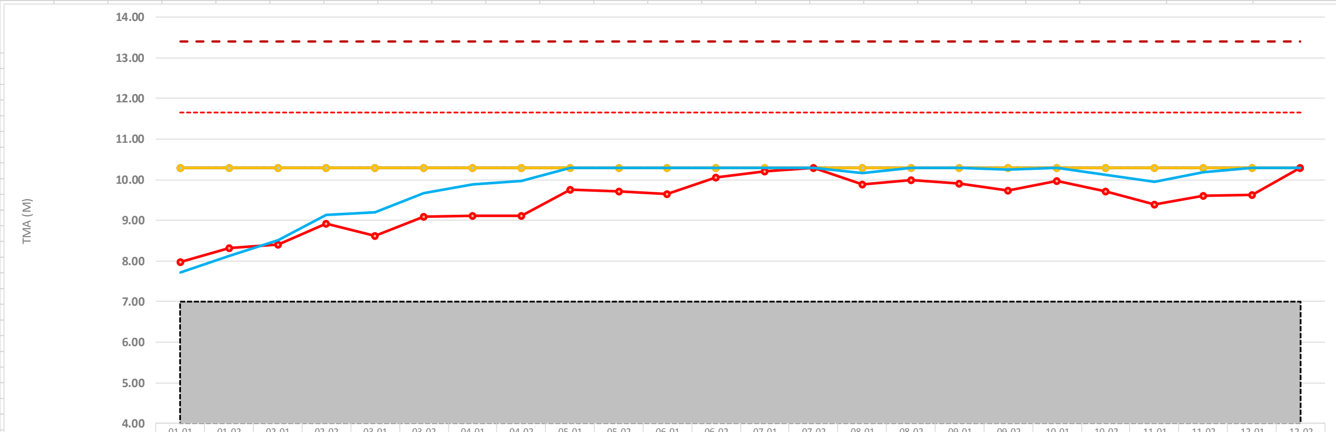


Fig. 7 Discharge analysis by F.J. Mock (Own study)

Simulation and optimization are conducted to ascertain the water availability, which serves as the foundation for the reservoir's annual operational pattern [17-19]. Based on the guidance provided by the PUPR on reservoir operation practices, the operation patterns for Manggar and Teritip reservoirs are presented in Fig. 8 and 9.



	01-01	01-02	02-01	02-02	03-01	03-02	04-01	04-02	05-01	05-02	06-01
Standby of drought	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Elevation of dam bed	1	1	1	1	1	1	1	1	1	1	1
NWL	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30
HWL	11.65	11.65	11.65	11.65	11.65	11.65	11.65	11.65	11.65	11.65	11.65
RTOW-wet year	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30
RTOW-normal year	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30
RTOW-dry year	7.98	8.33	8.40	8.91	8.61	9.10	9.11	9.12	9.76	9.71	9.66
Elevation of dam peak	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4
RTOW-forcast	7.71	8.13	8.50	9.13	9.20	9.66	9.87	9.97	10.30	10.30	10.30

	06-02	07-01	07-02	08-01	08-02	09-01	09-02	10-01	10-02	11-01	11-02	12-01	12-02
Standby of drought	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
Elevation of dam bed	1	1	1	1	1	1	1	1	1	1	1	1	1
NWL	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30
HWL	11.65	11.65	11.65	11.65	11.65	11.65	11.65	11.65	11.65	11.65	11.65	11.65	11.65
RTOW-wet year	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30
RTOW-normal year	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30	10.30
RTOW-dry year	10.06	10.21	10.30	9.89	9.99	9.91	9.73	9.97	9.71	9.40	9.60	9.62	10.30
Elevation of dam peak	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4
RTOW-forcast	10.30	10.30	10.30	10.16	10.30	10.30	10.24	10.30	10.12	9.94	10.19	10.29	10.30

Fig. 8 Manggar Reservoir operation pattern (Own study)

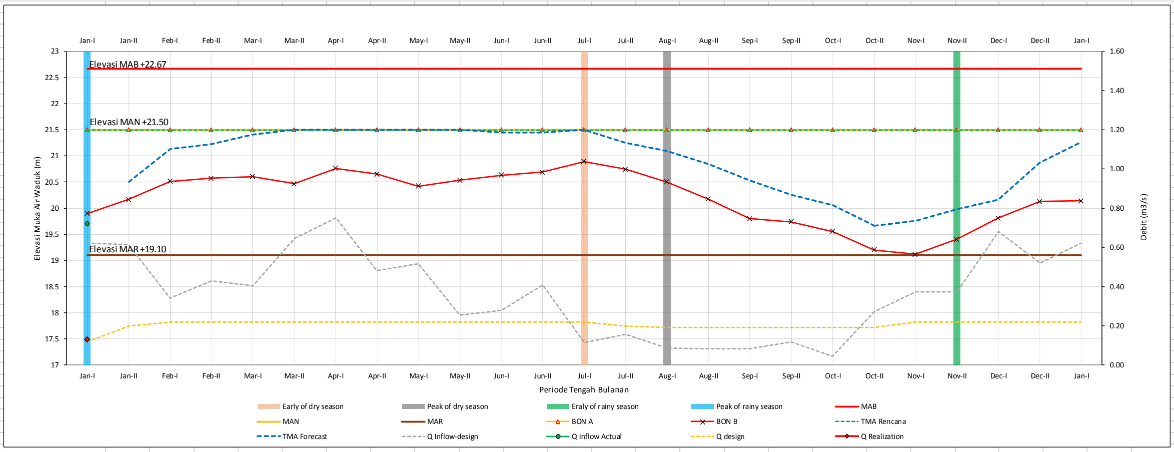


Table of RTOW Teritip Dam	Jan		Feb		Mar		Apr		Mei		Jun	
	Jan-I	Jan-II	Feb-I	Feb-II	Mar-I	Mar-II	Apr-I	Apr-II	Mei-I	Mei-II	Jun-I	Jun-II
MA Flood (m)	22.67	22.67	22.67	22.67	22.67	22.67	22.67	22.67	22.67	22.67	22.67	22.67
MA Normal (m)	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50
MA Low (m)	19.10	19.10	19.10	19.10	19.10	19.10	19.10	19.10	19.10	19.10	19.10	19.10
BONA (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BONB (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TMA Design (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TMA Realization (m)	19.2	20.5	20.53	20.41	20.19	20.22	20.51	0	0	0	0	0
Q Inflow Actual (m3/s)	0.720	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Q Out design (m^3/s)	0.120	0.200	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220
Q Out Realization (m^3/s)	0.129	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

Table of RTOW Teritip Dam	Jul		Agu		Sep		Okt		Nov		Des	
	Jul-I	Jul-II	Agu-I	Agu-II	Sep-I	Sep-II	Okt-I	Okt-II	Nov-I	Nov-II	Des-I	Des-II
MA Flood (m)	22.67	22.67	22.67	22.67	22.67	22.67	22.67	22.67	22.67	22.67	22.67	22.67
MA Normal (m)	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50
MA Low (m)	19.10	19.10	19.10	19.10	19.10	19.10	19.10	19.10	19.10	19.10	19.10	19.10
BONA (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BONB (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TMA Design (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TMA Realization (m)	0	0	0	0	0	0	0	0	0	0	0	0
Q Inflow Actual (m3/s)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Q Out design (m^3/s)	0.220	0.200	0.190	0.190	0.190	0.190	0.190	0.190	0.220	0.220	0.220	0.220
Q Out Realization (m^3/s)	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

Fig. 9 Teritip Reservoir operation pattern (Own study)

3. Results and Discussion

3.1. Water Allocation Model for Normal and Wet Years

According to the PDAM data for Balikpapan in 2024, the city currently utilizes both surface water from Manggar and Teririp reservoirs as its primary raw water sources and groundwater from several deep wells located throughout the area. To treat this water, the Balikpapan PDAM has nine active water treatment installations, including IPA Batu Ampar with a capacity of 500 l/s, IPA Kampung Damai with a capacity of 460 l/s, IPA Gunung Sari with a capacity of 140 l/s, IPA Teritip with a capacity of 200 l/s, IPA Prapatan with a capacity of 50 l/s, IPA Gunung Tembak with a capacity of 10 l/s, IPA ZAMP Korpri with a capacity of 10 l/s, and IPA Kampung Baru with a capacity of 50 l/s. These installations are able to meet the clean water demand of Balikpapan in 2024, which is estimated to be 1,510 l/s. The Balikpapan PDAM is capable of meeting the water requirements of the city's population to an extent of approximately 66% corresponding to 116,389 residential connections.

Based on the secondary data obtained from the PDAM in Balikpapan and River Region Institution of Kalimantan IV in 2014, a model of existing water allocation in normal and wet years was obtained (Fig. 10).

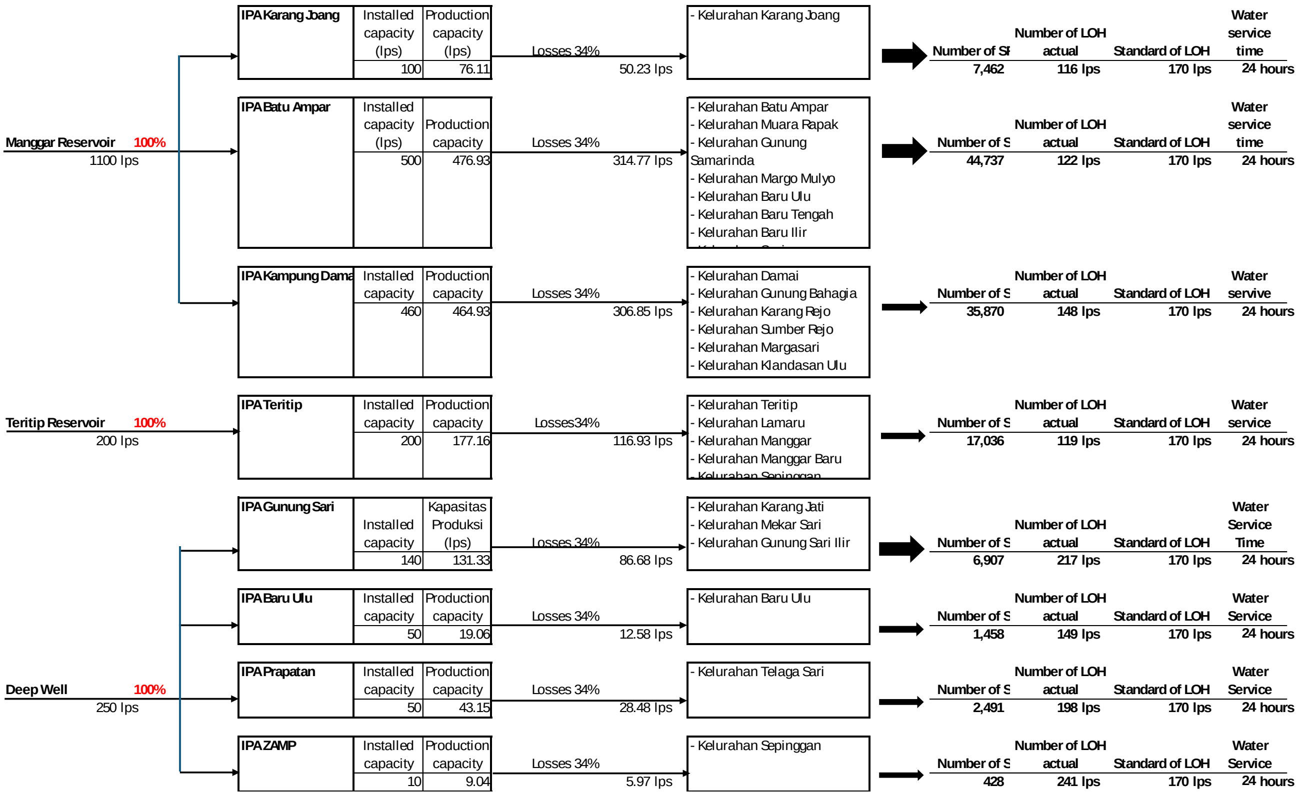


Fig. 10 Model of existing water allocation in normal and wet years (Own study)

The main water sources in Balikpapan are Manggar and Teritip reservoirs. For normal and wet years, water allocation analysis is based on the guidelines for reservoir operation patterns provided by the PUPR. This involves optimizing the reservoir storage for one year, taking into account the boundary of the reservoir's inflow, with a reliable discharge of over 33.33% for a normal year and over 66.67% for a wet year. However, the raw water supplies from groundwater sources (deep wells) are considered to be constant as there is no significant variation [20].

Based on the evaluation of the reservoir operation plan for Manggar and Teritip reservoirs, throughout wet and normal years, all eight units of the water treatment installations (IPA) can be supplied continuously for 24 hours. However, the distribution of discharged water does not entirely adhere to the recommended standards set by the PUPR for a big city with a population ranging from 500,000 to 1,000,000 individuals, which is 170 l/person/day (170 lps). The IPA zones that are still in compliance with the water demand standards are IPA Batu Ampar, IPA Karang Joang, and IPA Kampung Damai for the Manggar reservoir, IPA Teritip for the Teritip reservoir, and IPA Kampung Baru for the deep wells.

Based on 34% water loss and a daily water demand of 170 l per person, with approximately 116,389 house connections, a water source discharge capacity of 1,534 l/s is required (Fig. 11 and Table 1).

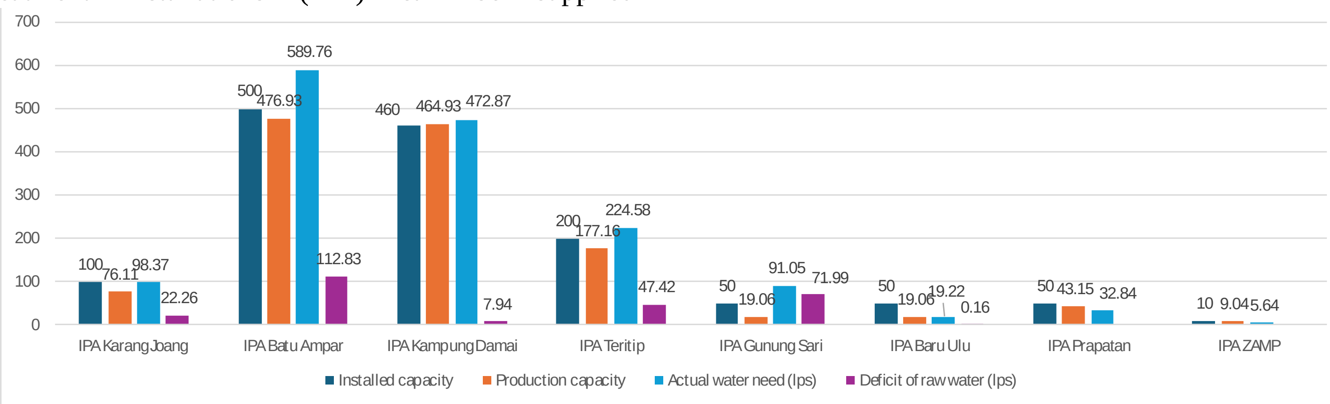


Fig. 11 Deficit of raw water under normal and wet year conditions (Own study)

Table 1 Deficit of raw water under normal and wet year conditions (Own study)

Zona	Installed capacity	Production capacity	Number of SF	Actual water need (lps)	Deficit of raw water (lps)
IPA Karang Joang	100	76.11	7,462	98.37	22.26
IPA Batu Ampar	500	476.93	44,737	589.76	112.83
IPA Kampung Damai	460	464.93	35,870	472.87	7.94
IPA Teritip	200	177.16	17,036	224.58	47.42
IPA Gunung Sari	50	19.06	6,907	91.05	71.99
IPA Baru Ulu	50	19.06	1,458	19.22	0.16
IPA Prapatan	50	43.15	2,491	32.84	
IPA ZAMP	10	9.04	428	5.64	
Total	1,420.00	1,285.44	116,389	1,534.34	262.61

3.2. Water Allocation Model for Emergency Conditions

During emergency situations, the allocation of water is crucial for ensuring the long-term survival of the population and the efficient utilization of available water resources. The occurrence of emergency circumstances is often triggered by the inability to access water sources for a specific period of time, as determined by the relevant regional authority.

Balikpapan encountered an emergency situation in 2014-2015 due to the landslide at the Manggar Dam, which necessitated a decrease in the reservoir water level. This change in water level impacted the dam's operational pattern, specifically by halting the collection of raw water and altering the distribution of water. The mayor of Balikpapan declared the emergency condition at the Manggar Dam from June 2014 to August 2015. Prior to the operation of the Teritip Dam in 2016, the Manggar Dam served as the primary source of raw water for Balikpapan.

The water distribution implemented by the water user operator, the PDAM in Balikpapan and Water Management in River Region Institution of Kalimantan III (renamed to River Region Institution of Kalimantan IV in 2019), is subject to change. Specifically, the operator maintains a 3-day schedule at IPA Kampung Damai and a 4-day schedule at Batu Ampar. However, as depicted in Fig. 12, there were periods during which the operator's emergency actions were not consistent in collecting raw water. During the period from October 12, 2014, to December 1, 2014, and certain days in April and May of 2015, the planned volume of raw water collection was not achieved. The rotation pattern, which is determined by the PDAM in Balikpapan without considering the needs of the Balikpapan population, will be a focal point in developing future water allocation models.

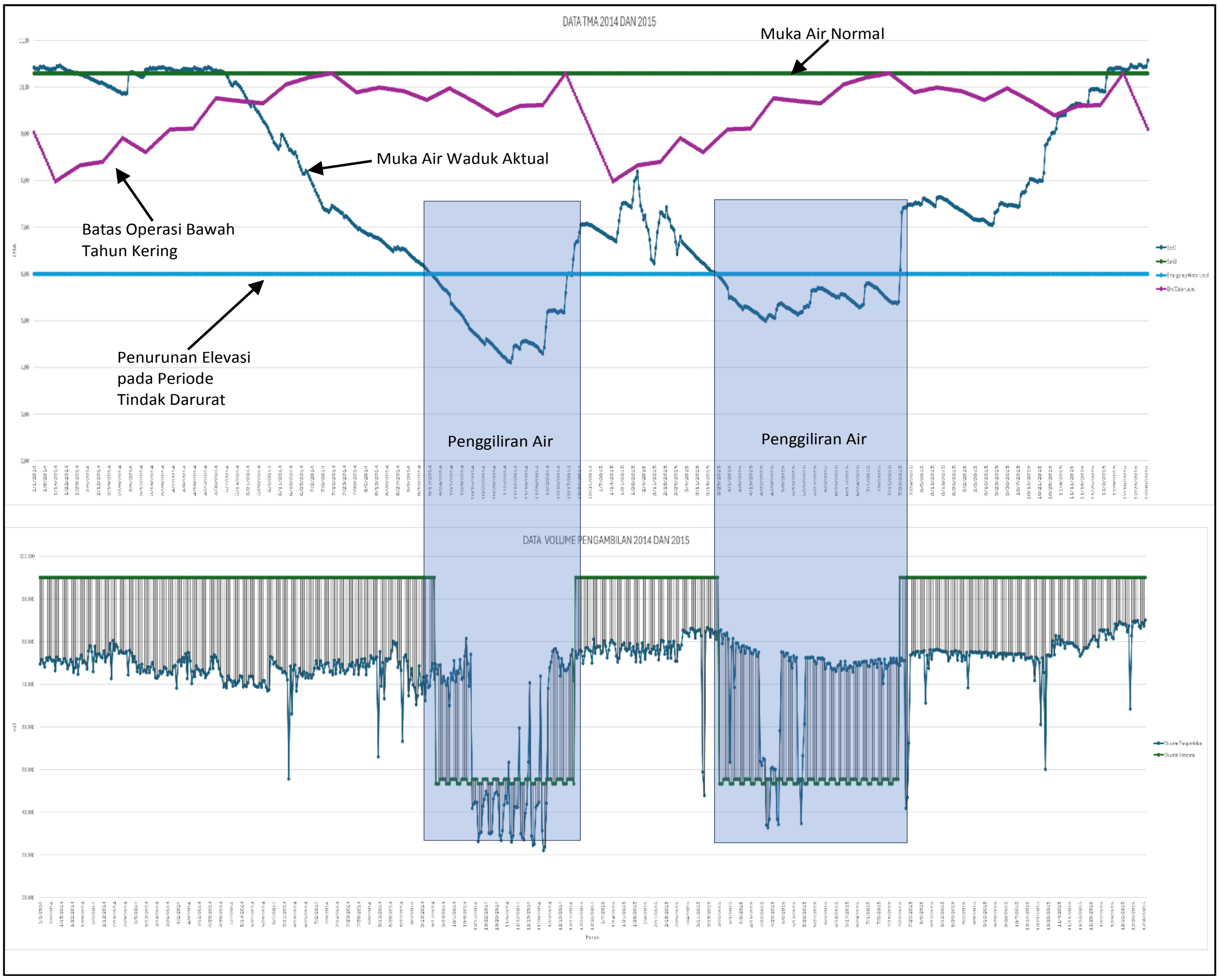


Fig. 12 Operation of the Manggar reservoir during the emergency response in 2014 and 2015 (Own study)

Based on the operation data from the Manggar reservoir during the emergency period, it can be observed that water allocations were carried out as presented in Fig. 13 and 14.

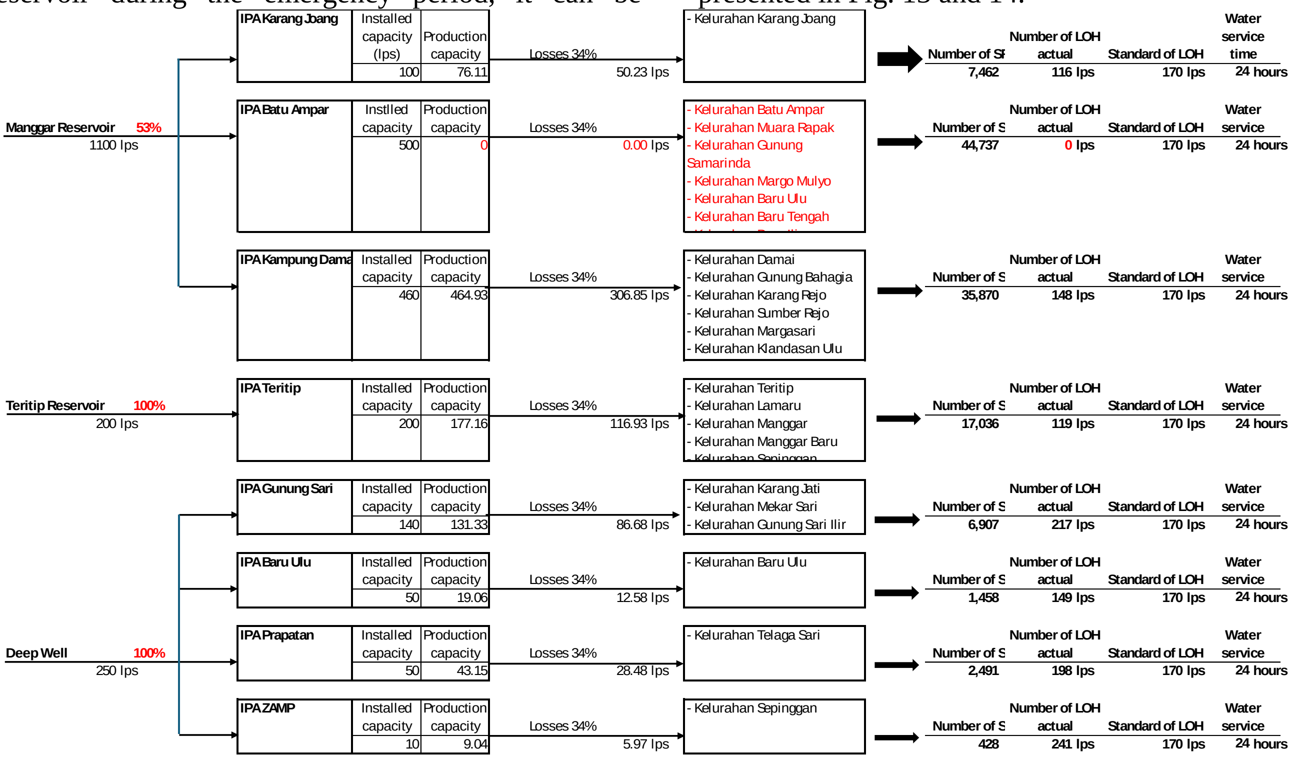


Fig. 13 Water Allocation Rotation 1 (Own study)

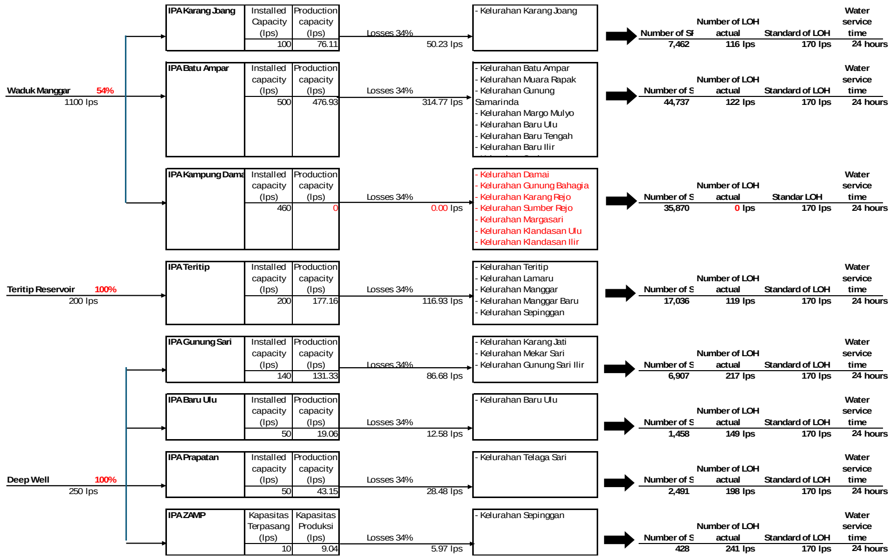


Fig. 14 Water Allocation Rotation 2 (Own study)

3.3. Water Allocation Model for Extremely Dry Years

Reorganizing the allocation of water involves three operational patterns: wet, normal, and dry years. However, there may be instances where water availability is lower than anticipated during dry years, such as during an El Niño event. Balikpapan experienced an El Niño event from the end of 2023 to the beginning of 2024.

Revised text with a formal tone:During an El-Nino condition, there is a decrease in the volume of surface water sources, which necessitates a reduction in the collection of water from these sources. The dam manager has allotted two days for the complete collection of water from the allowed capacity and two days for the collection of 50% of the allowed capacity. This compromise was agreed upon by the manager and the operator of drinking water (the PDAM in Balikpapan).

According to Fig. 15 and 16, the water level or reservoir capacity falls below the down-normal-operation-boundary/dry year threshold, suggesting a significant decrease in reservoir storage during El-Nino events. Despite the operator's continued water collection beyond recommended levels, the reliability of water availability in each period of distribution cannot be guaranteed. The production of potable water follows the water collection pattern in the source, with the extreme condition representing the minimal limit that society hopes to achieve to carry out the essential activities required for constructing the next water allocation model. Fig. 17 displays the rotation of water allocation in extremely dry years.

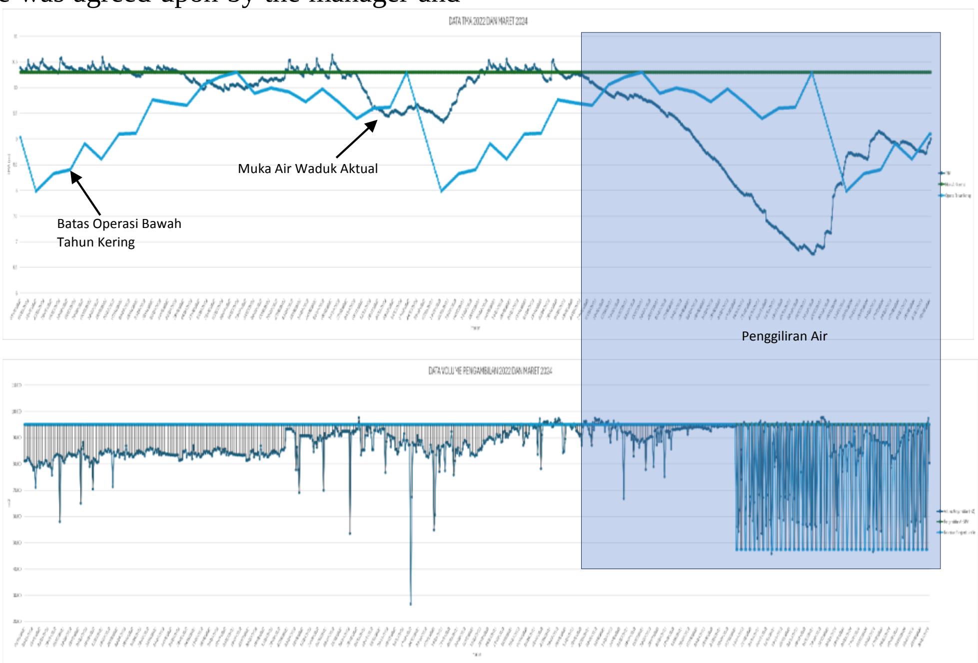


Fig. 15 Operation of the Manggar reservoir from 2022 to March 2024, influenced by El Niño (Own study)

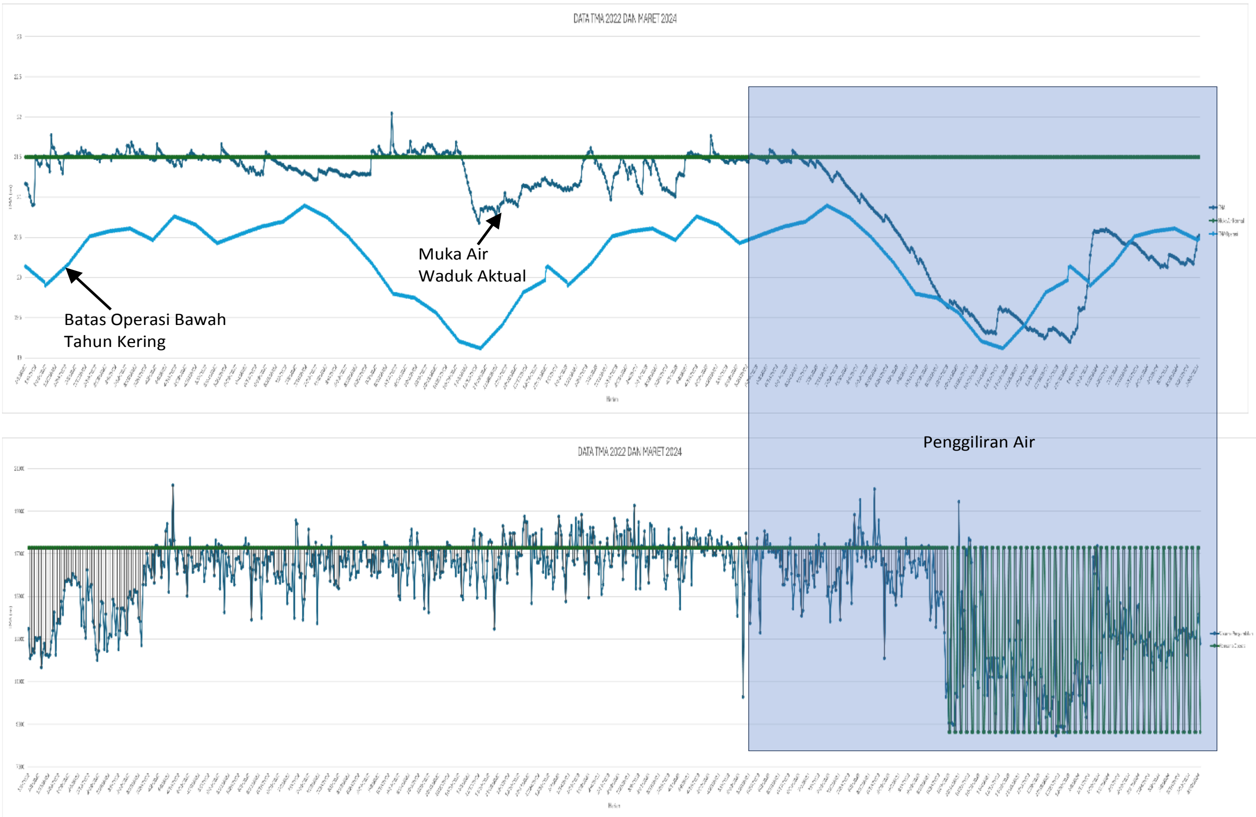


Fig. 16 Operation of the Teririp reservoir from 2022 to March 2024, influenced by El Nino (Own study)

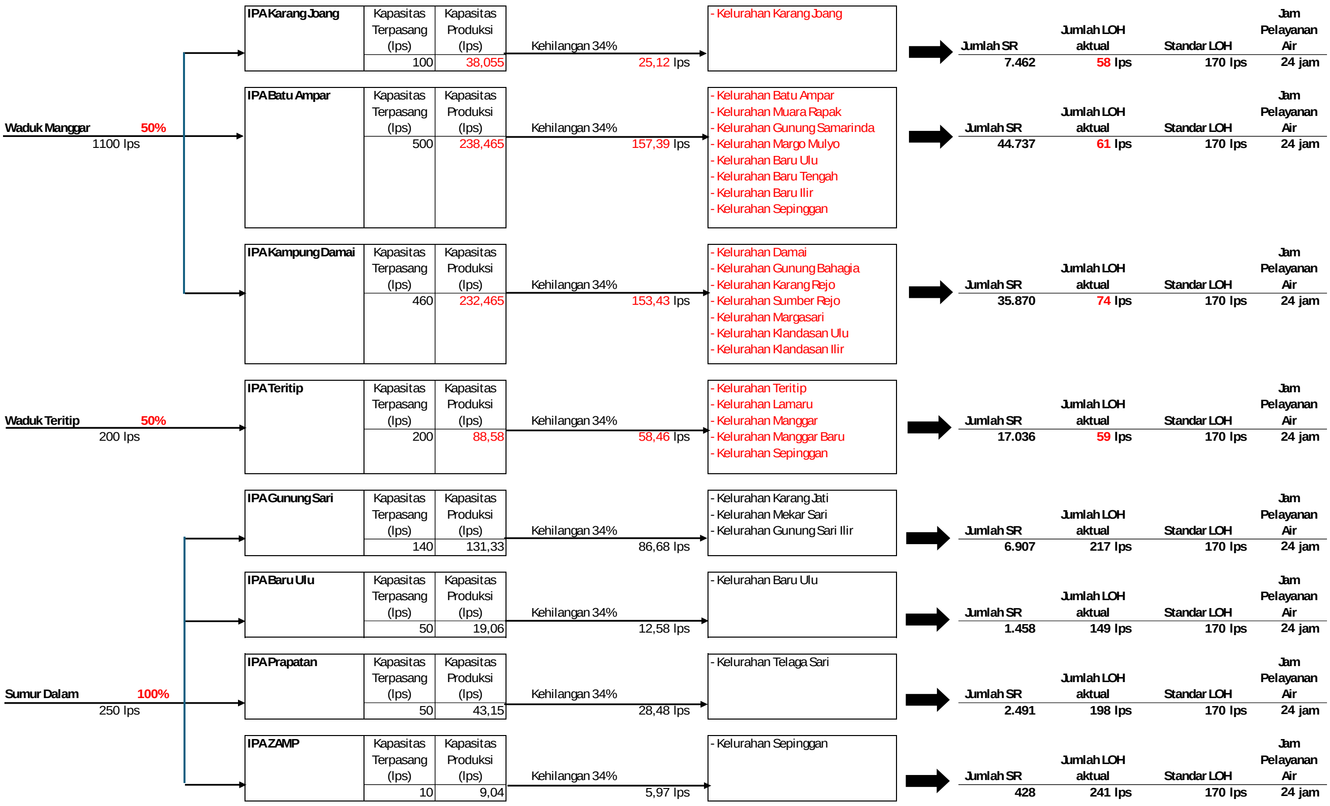


Fig. 17 Rotation of water allocation during an extremely dry year (Own study)

4. Conclusions

The current model in Balikpapan focuses exclusively on technical factors, resulting in subjective allocation, which reflects the manager's vision. This research aimed to simulate water allocation by taking into account non-technical factors: economic, social, and environmental.

As per the simulation results using data from 2014 to 2024, in normal and wet years, with the existing infrastructure for raw and drinking water in 2024, the water supply is 262.6 l/s. Additionally, the water fulfillment in five water service zones still adheres to the fixed standard of 170 l/person/day. In emergency conditions, represented by the period in 2014-2015, two water service zones are stopped from operating. In extremely dry conditions, four water service zones experience a 50% decrease in water supply through rotation.

Based on several scenarios of water scarcity and the amount of water collected from different sources over a specific period, we can estimate the level of water supply per person per day in each scarcity scenario, as illustrated in Fig. 18. The minimum water supply that can be provided to the community is 58 l/person/day, which falls below the standard set by the PUPR for semi-urban areas, which is 60 l/person/day.

To ensure the sustainability of the water supply, it is essential for the operator and manager to determine whether the reservoir operation pattern can be implemented. This involves balancing water user demand and minimizing the number of users, while considering the different social and economic characteristics of the served areas. Further research could be conducted to develop a dynamic model that takes into account availability and demand and adapts to different scenarios of water scarcity.

Fig. 18 Water sufficiency for each person in conditions of water scarcity (existing data) (Own study)

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