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Dependable Flow Analysis for Evaluating Raw Water Availability in the Drinking Water Supply System at Curug Weir and Walahar Weir, Karawang, Indonesia

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ABSTRACT

The Curug–Walahar weir system plays a strategic role in raw water allocation in Karawang Regency because it supports drinking water supply, irrigation, and industrial activities. This study evaluates dependable flow availability to assess the reliability of raw water supply for the drinking water supply system. Daily discharge data from 2015 to 2025 were analysed for five main flow sections using descriptive statistics, monthly discharge patterns, and Flow Duration Curve (FDC) analysis. Dependable flows were determined using Q80 and Q90 and were compared with raw water demand under two scenarios: existing water treatment plant operational capacity and projected raw water demand based on service areas up to 2044. The results show that Citarum River flow from Curug Weir (NTC-CUR) and Citarum overflow (CIT-O) have high discharge variability. In contrast, West Tarum Canal (WTC), East Tarum Canal (ETC), and North Tarum Canal (NTC-WAL) show relatively stable flow characteristics due to regulated canal operation. The existing dependable flow remains sufficient to meet the operational capacity of water treatment plants in all analysed canal sections. Future demand projections also indicate that raw water demand up to 2044 remains below the available Q80 and Q90 values. These findings suggest that the FDC-based dependable flow approach can provide an initial basis for evaluating raw water reliability in multi-use regulated canal systems, particularly for supporting water allocation planning under low-flow conditions.

Keywords: Citarum River, Curug–Walahar weirs, Flow Duration Curve, Raw water availability, & Reliable Flow

1. Introduction

Densely populated regions often face increasing challenges in securing water availability because domestic water demand continues to grow while competing with other sectoral needs. In multifunctional water resource systems, a single river or canal network may simultaneously support agricultural irrigation, industrial activities, fisheries, livestock, urban water use, and raw water supply for drinking water systems (Chaki et al., 2012; Maganga et al., 2002; Maxwell et al., 2026; Ngene et al., 2021; Patel & Ramachandran, 2018; Setiadi et al., 2022). Such conditions may increase pressure on water allocation and reduce the reliability of raw water supply, particularly when multiple sectors require water during the same period.

Karawang Regency is one of the administrative regions traversed by the Citarum River, one of West Java's most important multifunctional rivers. The Citarum River supports various water uses, including industry, fisheries, livestock, irrigation, urban activities, and raw water supply for drinking water systems (Keputusan Menteri Pekerjaan Umum dan Perumahan Nomor 606/KPTS/M/2023, 2023; Septiansyah et al., 2024).

Agriculture is one of the dominant water users in Karawang Regency. In 2021, the regency had approximately 95,018.5 ha of paddy fields and produced 1,319,011 tons of rice (Dinas Komunikasi dan Informatika Kabupaten Karawang Provinsi Jawa Barat, 2022). In addition to irrigation demand, pressure on surface water resources is also increasing due to the expansion of drinking water services.

Population growth further intensifies the need for reliable raw water supply. The population of Karawang Regency increased by approximately 12% over the last decade, reaching 2,468,576 people in 2021 (Badan Pusat Statistik Kabupaten Karawang, 2022). This demographic growth has direct implications for increasing domestic water and clean water demand. As of 2022, Perumdam Tirta Tarum Karawang served 518,116 people through 102,246 household connections, with a service coverage of 39.66% of the population within the service area (Badan Perencanaan Pembangunan Daerah Kab. Karawang, 2023). This coverage indicates substantial potential for drinking water service expansion. However, drinking water expansion occurs within a water system that also supports high irrigation demand, which may increase pressure on the same surface water sources used as raw water. Therefore, an evaluation of raw water availability in Karawang Regency is required, particularly under low-flow conditions.

Assessing water source reliability based only on average discharge may be insufficient because mean values can obscure daily flow variability, especially during dry periods. Using average discharge as the sole basis for planning may therefore lead to an overestimation of available water. To address this limitation, dependable flow indicators such as Q80 and Q90 are commonly used to represent discharge values that are equalled or exceeded for a specified percentage of time (Saragi et al., 2023). One widely applied method for estimating dependable flow is the Flow Duration Curve (FDC), which describes the relationship between discharge magnitude and the percentage of time that a given discharge is equalled or exceeded (Permana et al., 2022; Salim et al., 2024; Sharma et al., 2019).

Previous studies have examined dependable flow analysis in natural rivers (Permana et al., 2022; Rahman et al., 2024; Salim et al., 2024) and reservoirs (Agastya et al., 2024). However, studies focusing on weir-regulated canal systems remain limited. This type of system requires specific attention because its discharge is influenced not only by hydrological variability but also by operational regulation and intersectoral water allocation. Therefore, dependable flow analysis in regulated canal systems is important for understanding the reliability of raw water supply under actual water management conditions. This study aims to evaluate the discharge characteristics and dependable flow availability of the Curug-Walahar weir system, which regulates flow from the Citarum River and Tarum canal network in relation to raw water supply for the drinking water system in Karawang Regency. The evaluation was conducted through daily discharge characterisation, monthly discharge pattern analysis, Flow Duration Curve analysis, and dependable flow estimation using Q80 and Q90. The results are expected to provide an initial basis for assessing the reliability of surface water sources in a multi-use regulated canal and to support raw water allocation planning, particularly under low-flow conditions.

2. Methods

2.1 Study Location

This study was conducted in the flow system of the Citarum River and Tarum Canals in Karawang Regency, particularly at Curug Weir (-6°26'50.40"S, 107°22'43.10"E) and Walahar Weir (-6°23'0.40"S, 107°21'39.13"E) (shown in Figure 1). The flow at Curug Weir originates from the Citarum River, with Jatiluhur Dam located upstream. At Curug Weir, the flow is diverted into three main components: the West Tarum Canal (WTC), the East Tarum Canal (ETC), and the Citarum River reach flowing toward Walahar Weir. At Walahar Weir, the flow is further divided into two components: the North Tarum Canal (NTC-WAL) and the Citarum River overflow (CIT-O). In this study, the Citarum River flow from Curug Weir to Walahar Weir is denoted as NTC-CUR, while the available discharge at Walahar Weir is denoted as Qavail-WAL. The available discharge represents the flow distributed to the North Tarum Canal and the Citarum River overflow, as described in Equation (1). The relationship between this flow system and drinking water supply is indicated by several Perumdam Tirta Tarum Karawang intake points that withdraw raw water from the Citarum River and the Tarum Canals. Perumdam Tirta Tarum provides piped drinking water services through nine branch units and twelve Ibu Kota Kecamatan (IKK) service units distributed across several subdistricts under a centralised system. In this study, the branch and IKK units selected as study objects were limited to those withdrawing raw water from canals included in the flow system regulated by Curug Weir and Walahar Weir. These consisted of nine branch units and four IKK units. Table 1 summarises the raw water sources, system codes, and intake locations of the selected service units.

$$Q_{avail-WAL} \approx Q_{NTC-WAL} + Q_{CIT-O} \quad (1)$$

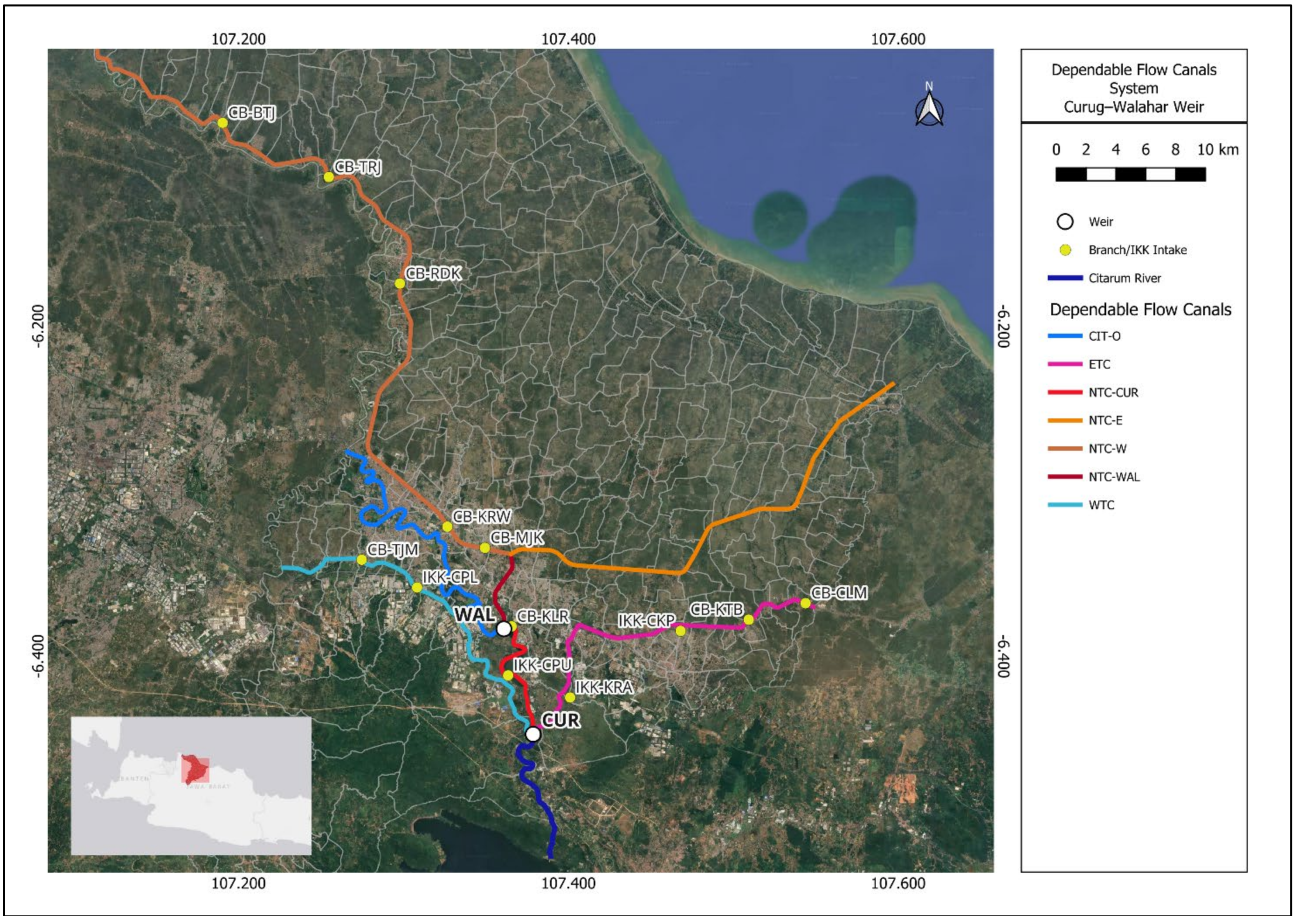

Figure 1. Curug–Walahar Weir Canal System and Drinking Water Supply Intake Points in Karawang

Table 1. Raw water sources of branch and IKK units of the drinking water supply system in Karawang within the Curug-Walahar Weir flow system

No.	Branch	Code	Raw Water Source System	Intake
1	Karawang Branch	CB-KRW	North Tarum Main Canal	West Branch B. Tub. 2-3 No. 1 (reservoir)
2	Rengasdengklok Branch	CB-RDK	North Tarum Main Canal	West Branch B. Tub. 12-13
3	Klari Branch	CB-KLR	Citarum River downstream of Curug Weir	Walahar Village, Klari District
4	Teluk Jambe Branch	CB-TJM	West Tarum Canal	B. Tb. 18-B.Tb. 19
5	Cilamaya Branch	CB-CLM	East Tarum Canal	B. Tt. 21
6	Kotabaru Branch	CB-KTB	East Tarum Canal	B. Tt. 18
7	Tirtajaya Branch	CB-TRJ	North Tarum Main Canal	West Branch B. Tub. 17-18
8	Batujaya Branch	CB-BTJ	North Tarum Main Canal	West Branch B. Tub. 23
9	Majalaya & Kartim Branch	CB-MJK	North Tarum Main Canal	West Branch B. Tub. 1-2
10	Ciampel IKK Unit	IKK-CPL	West Tarum Canal	B. Tb. 11
11	Cipule IKK Unit	IKK-CPU	Citarum River downstream of Curug Weir	-

No.	Branch	Code	Raw Water Source System	Intake
12	Karang Anyar IKK Unit	IKK-KRA	East Tarum Canal	B. Tt. 4a-5
13	Cikampek IKK Unit	IKK-CKP	East Tarum Canal	B. Tt. 21

Source: Perumdam Tirta Tarum Karawang, 2026, processed by the authors. The authors assigned the branch/unit codes for mapping and analysis purposes.

2.2 Data Sources and Pre-processing

The main data used in this study were daily discharge data for six flow components within the Curug and Walahar Weir system, namely ETC, WTC, NTC-CUR, NTC-WAL, CIT-O, and Qavail-WAL. These data were obtained from Perum Jasa Tirta II for the period 2015-2025, comprising a total of 24,108 observations. The 2015–2025 period was selected because it represents the most recent complete discharge record available and provides an 11-year daily dataset. This period satisfies the minimum 10-year data length recommended for direct Flow Duration Curve analysis using observed daily or monthly discharge data (Udjianto & Yusuf, 2019). Therefore, the dataset was considered adequate for estimating dependable flow without rainfall-runoff models such as Mock or NRECA to extend the discharge series.

Coordinate data for the weirs and flow points were also obtained from Perum Jasa Tirta II and used to develop the study location map. The daily discharge dataset contained 30 missing values, representing 0.12% of the total observations. Because the proportion of missing data was relatively small, the missing values were filled using linear interpolation before analysing discharge characteristics, monthly discharge patterns, the Flow Duration Curve (FDC), and dependable flow.

Data related to the drinking water supply system were obtained from Perumdam Tirta Tarum Karawang. These data included production design capacity, installed intake capacity, and operational capacity of water treatment plants in 2025. In addition, the coordinates of the selected branch and IKK units were used to map the relationship between intake locations and the analysed flow system.

2.3 Flow Duration Curve and Dependable Flow Analysis

The Flow Duration Curve (FDC) is a cumulative frequency curve that describes the relationship between discharge and exceedance probability (Chaki et al., 2012; Rahman et al., 2024; Sharma et al., 2019). Exceedance probability refers to the percentage of time during which a certain discharge value is equalled or exceeded over the observation period. A low exceedance probability, such as Q10, represents a high discharge that occurs only during a relatively small portion of the observation period and therefore reflects high-flow conditions. Conversely, a high exceedance probability, such as Q80 or Q90, indicates a discharge that occurs more frequently because it can be equalled or exceeded for 80% or 90% of the observation period. Therefore, discharge values at high exceedance probabilities are commonly used to represent low-flow conditions or dependable flow, which is often associated with dry-season water availability (Dhakal & Wu, 2025). In this study, the FDC was used to evaluate discharge availability and reliability in the analysed canals. The FDC was constructed by arranging the daily discharge data in descending order, from highest to lowest, and assigning each discharge value to its corresponding exceedance probability (Adhikary et al., 2013; Salim et al., 2024; Udjianto & Yusuf, 2019). The exceedance probability was calculated using the Weibull plotting position equation as follows Equation 2).

$$P = \frac{m}{n+1} \tag{2}$$

where P is the exceedance probability, m is the rank number of each discharge value from 1 to n, and n is the total number of discharge observations. Based on this approach, dependable flow is the minimum canal discharge that can be equalled or exceeded at a specific probability level (Udjianto & Yusuf, 2019). The probability level used to define dependable flow may vary depending on water use. For example, an 80% exceedance probability is commonly applied for paddy irrigation, whereas drinking water and industrial water supply may require a higher reliability level, ranging from 90% to 95% (Salim et al., 2024).

2.4 Evaluation of Dependable Flow Adequacy for PDAM Raw Water Demand

The evaluation of discharge adequacy assessed the capacity of dependable flow in each canal to meet PDAM raw water demand under both existing and future demand scenarios. This evaluation used dependable flow values of Q80 and Q90. Q80 represented general dependable flow conditions, while Q90 served as a more conservative indicator for assessing water availability under low-flow conditions. The discharge data used in this analysis consisted of ETC, WTC, NTC-CUR, NTC-WAL, CIT-O, and Qavail-WAL for the period 2015-2025. In the North Tarum system, the available discharge data were represented by NTC-WAL, which indicates the discharge entering the North Tarum Canal after Walahar Weir. Although the downstream section of this canal branches into NTC-W and NTC-E, discharge data and gate-opening records for each branch were not available. Therefore, the discharge availability evaluation for intake points located within the North Tarum system was conducted using NTC-WAL as a representative discharge entering the North Tarum Canal. The evaluation was performed under two scenarios. The first scenario represents the existing condition by comparing the dependable flow of each canal with the total operational capacity of water treatment plants (WTPs) that withdraw raw water from the respective canal. WTP operational capacity was expressed in L/s and converted to m^3/s to match the dependable flow unit. For each canal, WTP operational capacities were summed by corresponding raw water source group and then compared with Q80 and Q90. The utilisation ratio under the existing condition was calculated using Equation (3).

$$R_{existing,i,p} = \frac{C_i}{Q_{i,p}} \times 100 \tag{3}$$

where $R_{existing,\,i,p}$ is the discharge utilisation ratio of canal i relative to dependable flow at exceedance probability p, Ci is the total WTP operational capacity in canal i in m^3/s, and Qi,p is the dependable flow of canal i at 80% or 90% exceedance probability. A canal was classified as surplus when the WTP operational capacity was lower than the available dependable flow.

The second scenario evaluated the adequacy of canal discharge for future raw water demand. The projected total water demand of Karawang Regency for 2024-2044 was obtained from Hasan et al. (2025), which included domestic demand, non-domestic demand, and water losses. Because the projected water demand data were available at the regency scale, the raw water demand for each canal was estimated using the population proportion of the WTP service areas. Each branch or WTP unit was grouped according to its raw water source canal, and the administrative population within the corresponding service areas was then summed. The population proportion of each canal was calculated relative to the total administrative population of Karawang Regency based on the RISPAM document. The population proportion for each canal was calculated using the following Equation (4).

$$\alpha_i = \frac{P_i}{P_{total}} \tag{4}$$

where αi is the population proportion of the service area in canal i, P_i is the administrative population within the WTP service area that withdraws raw water from canal i, and P_{total} is the total administrative population of Karawang Regency. The projected raw water demand was then calculated as follows Equation (5).

$$D_{i,t} = \alpha_i \times D_{total,t} \tag{5}$$

where $D_{i,t}$ is the estimated raw water demand in canal i in year t, and Dtotal,t is the total water demand of Karawang Regency in year t. The water demand values in L/s were then converted into m^3/s. For certain service units, differences existed between the population-based service area classification and the technical classification of raw water sources. One example is the Batujaya/Telagajaya system. In this study, Batujaya Branch was included as a study object because it withdraws water from the North Tarum Main Canal.

In contrast, Telagajaya IKK uses a pontoon intake that is not part of the Curug-Walahar weir canal system. Therefore, Telagajaya IKK was not treated as a separate study object. However, because the service area data were presented as a combined system, an adjustment was required to allocate the population to Batujaya

Branch. Accordingly, the population allocation for Batujaya Branch was determined based on the proportion of utilised capacity from raw water sources originating from the North Tarum Main Canal. The utilisation ratio of future raw water demand relative to dependable flow was calculated using the following Equation (6).

$$R_{projected,i,t,p} = \frac{D_{i,t}}{Q_{i,p}} \times 100 \quad (6)$$

where $R_{projected,\ i,t,p}$ is the utilisation ratio of projected raw water demand in canal i and year t relative to dependable flow at exceedance probability p. The evaluation was conducted for both Q80 and Q90, with greater emphasis on Q90 as the more conservative low-flow condition. In this study, the projection was applied only to water demand, while water availability was represented by historical dependable flow. This approach was used because discharge in the analysed canal system is regulated by weir operation and intersectoral water allocation; therefore, projecting future discharge would require additional assumptions beyond the scope of this study.

3. Results and Discussion

3.1 Daily Discharge Characteristics of the Curug-Walahar Weir Flow System

Daily discharge statistics provide an initial basis for understanding the hydrological behaviour of each component in the Curug-Walahar weir system before interpreting dependable flow availability. As shown in Table 2, ETC, WTC, and NTC-WAL had mean discharges of 44.08, 45.39, and 62.33 m³/s, respectively. Their median values were relatively close to the mean values, particularly for ETC and WTC, indicating that daily discharge in these regulated canals was distributed within a more stable range during the 2015-2025 observation period. The coefficient of variation also supports this pattern. WTC had the lowest coefficient of variation (0.14), followed by ETC and NTC-WAL (0.28). These values indicate lower relative variability compared with the main river and overflow components. The interquartile range also supports this interpretation because WTC, ETC had narrower IQR values of 9.86 and 20.00 m³/s. These statistics matter because mean discharge alone may not capture the stability of a water source; monthly flow behaviour and flow-duration characteristics are useful for identifying streamflow systems affected by both hydrological processes and operational regulation. Previous studies have emphasised discharge variability, low-flow conditions, and water availability patterns in river and canal systems (Langat et al., 2019; Burgan & Aksoy, 2020; Ghotbi et al., 2020).

Table 2. Daily discharge characteristics of canals in the Curug-Walahar Weir flow system

Parameter	ETC	WTC	NTC-CUR	Qavail-WAL	NTC-WAL	CIT-O
Mean	44.08	45.39	104.87	117.80	62.33	55.47
Median	45.00	45.83	79.31	91.08	64.25	19.47
Minimum	0.42	13.53	22.83	0.00	0.00	0.00
Maximum	62.50	57.89	581.01	629.72	198.55	602.11
Standard deviation	12.30	6.58	70.45	82.08	17.43	83.35
Coefficient of variation	0.28	0.14	0.67	0.70	0.28	1.50
IQR	20.00	9.86	62.50	70.94	25.56	76.37
Unit	m³/s	m³/s	m³/s	m³/s	m³/s	m³/s

A different pattern was observed for NTC-CUR, Qavail-WAL, and CIT-O. Table 2 shows that NTC-CUR and Qavail-WAL had higher mean discharges (104.87 and 117.80 m³/s), while their medians were lower (79.31 and 91.08 m³/s). This difference indicates a right-skewed distribution, where occasional high-flow events increased the mean values. CIT-O showed the most variable behaviour among all components. Its mean discharge was 55.47 m³/s, but its median was only 19.47 m³/s. The coefficient of variation reached 1.50, far higher than that of the other flow components. The IQR of CIT-O also reached 76.37 m³/s, indicating large differences between lower and upper daily discharge conditions. The maximum discharges of NTC-CUR, Qavail-WAL, and CIT-O exceeded 580 m³/s, suggesting that these components were strongly affected by high-flow pulses. The zero minimum values recorded in CIT-O, Qavail-WAL, and NTC-WAL should be interpreted carefully. In a regulated weir system, zero or near-zero discharge may reflect temporary gate closure, diversion, operational control, or the absence of overflow through a specific flow path. This interpretation is consistent with studies showing that dependable flow and water availability analysis must account for the operational and temporal characteristics of the flow system, not only the magnitude of discharge values (Permana et al., 2022; Sallim et al., 2024). Figure 2 supports this pattern because CIT-O increased sharply during wetter months and decreased markedly during lower-flow periods, indicating that it behaved more as an episodic overflow component than as a stable raw water supply canal.

3.2 Monthly Discharge Variability and Seasonal Flow Patterns

Monthly discharge patterns provide a clearer view of how the Curug-Walahar weir system responds to seasonal changes and flow regulation. Figure 2 shows that ETC, WTC, and NTC-WAL had relatively stable monthly patterns compared with NTC-CUR, Qavail-WAL, and CIT-O. The monthly curves of ETC and WTC remained within a narrower range throughout the year, while NTC-WAL showed moderate variation but still followed a controlled pattern. This behaviour reflects the function of regulated canals as distribution channels for irrigation and raw water supply. In regulated systems, monthly flow may not fully follow natural rainfall-runoff dynamics because gate operation and water allocation can modify the timing and magnitude of discharge. Similar interpretations have been reported in recent hydrological studies, where monthly streamflow patterns and flow duration characteristics were used to identify seasonal variability, water availability, and the influence of land use or regulation on river systems (Langat et al., 2019; Burgan & Aksoy, 2020; Ghotbi et al., 2020). In Figure 2, ETC and NTC-WAL also show an increase during the June-September period, when several other components decline. This pattern may indicate operational flow regulation to maintain water delivery during lower-flow months.

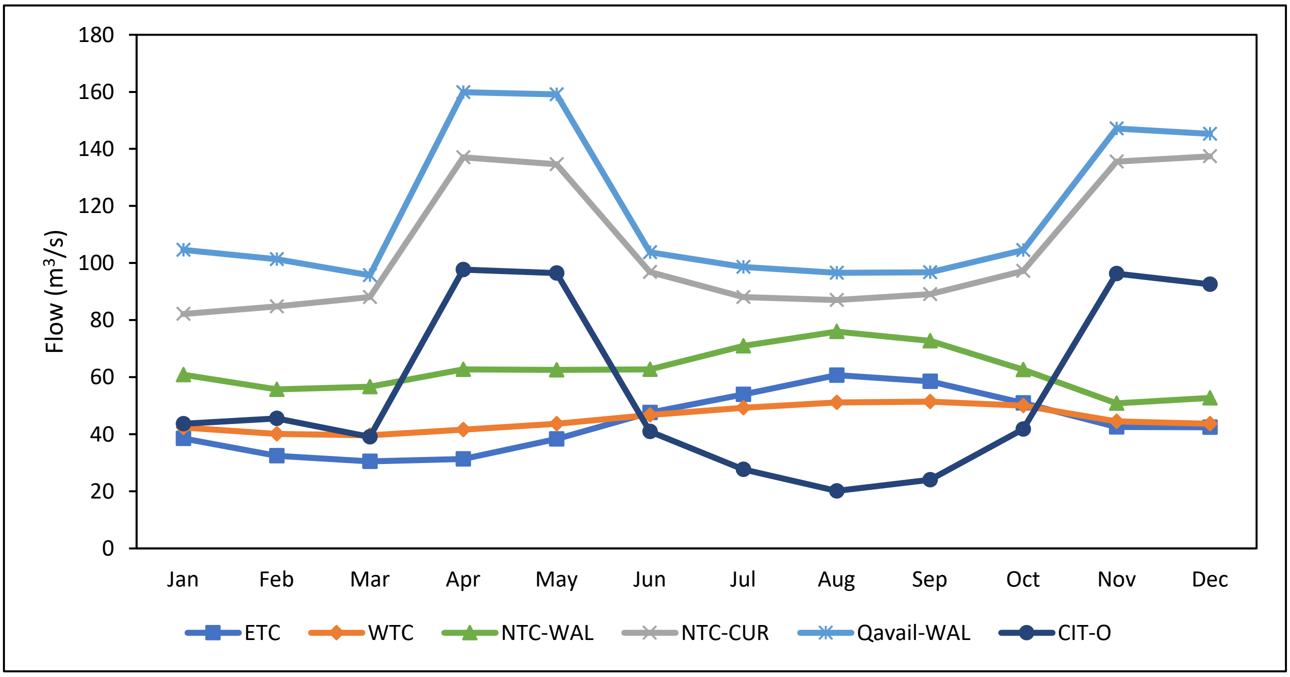

Figure 2 Monthly discharge patterns of canals in the Curug-Walahar Weir flow system

The seasonal pattern was more pronounced in NTC-CUR, Qavail-WAL, and CIT-O. Figure 2 shows clear discharge increases during April-May and again during November-December. These months likely represent periods with stronger wet-season influence and higher upstream flow availability. CIT-O showed the strongest seasonal contrast because its monthly flow increased sharply during wetter periods and decreased strongly during lower-flow months. In a weir-regulated system, this condition can occur when overflow is absent or when flow is directed to other canal branches. Recent studies on regulated rivers show that dams, weirs, and water diversion systems can alter seasonal flow magnitude, shift monthly discharge timing, and create flow patterns that differ from natural hydrological regimes (Chalise et al., 2021; Mostafazadeh et al., 2024). The contrast between the stable canals and the episodic overflow component in Figure 2 indicates that both seasonal hydrology and operational water allocation shape monthly discharge variability in the Curug-Walahar system.

3.3 Flow Duration Curve Characteristics of Regulated and High-Flow Components

The Flow Duration Curve (FDC) provides a useful basis for distinguishing the behaviour of high-flow components and regulated canal components in the Curug-Walahar weir system. Figure 3 shows that NTC-CUR, Qavail-WAL, and CIT-O had much wider discharge ranges than the regulated canals. The upper part of the curve shows high discharges approaching 600-700 m³/s, especially for Qavail-WAL and CIT-O. The steep slopes in Figure 3 indicate strong flow variability across exceedance probabilities. This condition reflects the presence of high-flow pulses and episodic flow components. Ghotbi et al. (2020) explained that the shape of an FDC can be interpreted through fast and slow flow components, which helps identify whether a river system is dominated by short-term high-flow response or more persistent flow supply. Langat et al. (2019) also used FDC behaviour to interpret hydromorphological changes and flow variability in a river system affected by land use and climatic conditions. In this study, CIT-O showed the sharpest decline among the high-flow components. Its discharge dropped toward nearly zero at higher exceedance probabilities. This suggests that CIT-O behaves more as an overflow pathway than as a stable canal for continuous water distribution.

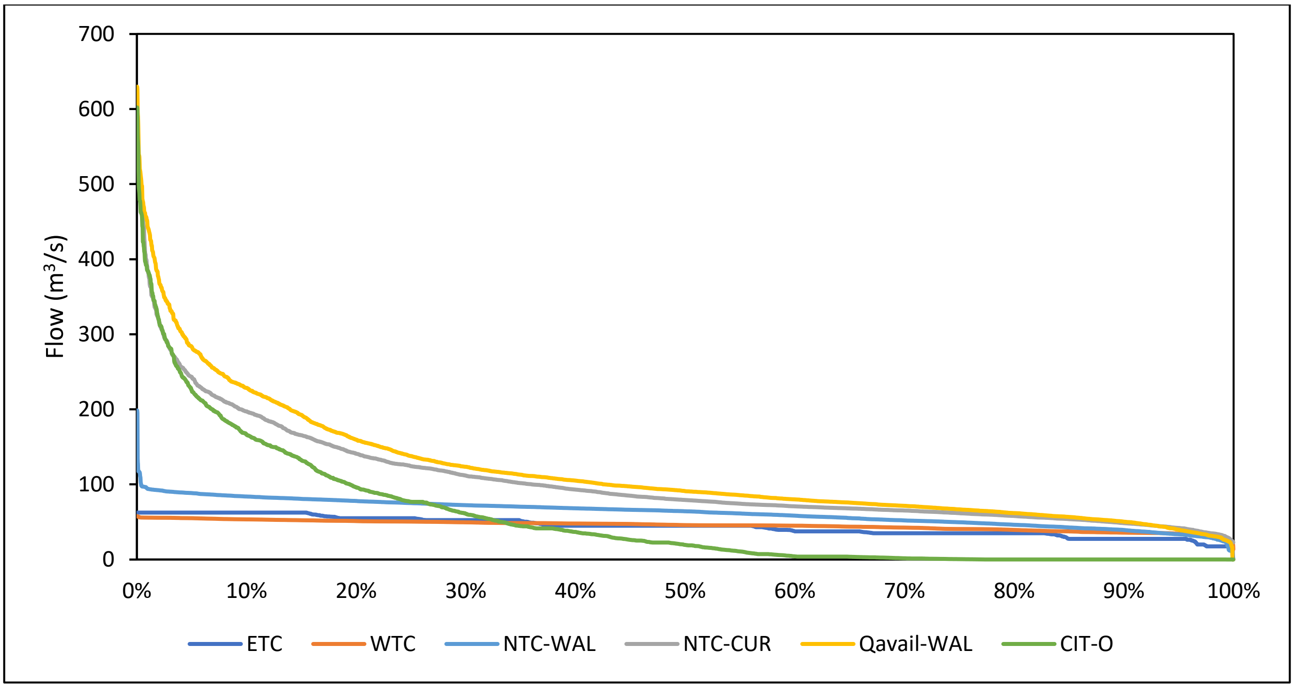

Figure 3. Flow duration curve in the Curug-Walahar Weir flow system

A different FDC pattern was observed for ETC, WTC, and NTC-WAL. These components had lower discharge magnitudes and flatter curves than the high-flow group. Their discharge values were mostly below 100 m³/s, with relatively limited changes across a wide range of exceedance probabilities. The flatter FDC slopes indicate more stable flow conditions, which are typical of regulated canals used for water allocation and distribution. Burgan and Aksoy (2020) emphasised that monthly and longer-term FDCs are useful for evaluating water availability because they describe the proportion of time specific discharge levels can be maintained. The regulated canal behaviour also indicates that canal operation may reduce natural discharge variability and maintain more consistent flow delivery. This interpretation agrees with recent studies showing that dams, weirs, and flow regulation can modify flow magnitude, timing, and seasonal variability in river systems (Chalise et al., 2021; Mostafazadeh et al., 2024).

The FDC pattern observed in this study is comparable with previous studies that used flow duration analysis to distinguish source reliability under different planning contexts. Udjianto and Yusuf (2019) applied FDC analysis to determine dependable discharge for hydropower planning and selected Q85 as the design discharge to balance flow reliability and energy production potential. In contrast, the present study emphasises Q80 and Q90 because the objective is to evaluate raw water availability under dependable and conservative low-flow conditions. Rahman et al. (2024) also showed that FDC characteristics can vary substantially among river locations within the same urban water system, with some rivers showing very low dependable flows and others retaining higher low-flow availability. This source-specific behaviour is also evident in the Curug–Walahar system, where ETC, WTC, and NTC-WAL showed flatter, more stable FDCs. At the same time, CIT-O declined toward nearly zero at high exceedance probabilities. This indicates that interpreting dependable flow should consider not only the numerical value of Q80 or Q90, but also the functional role of each flow component within the regulated system.

3.4 Dependable Flow Availability and Existing WTP Operational Demand

Dependable flow availability was evaluated using Q80 and Q90 to represent canal discharge that can be equalled or exceeded during most of the observation period. Figure 3 shows that the dependable flow range between 80% and 90% exceedance probability, where the curves of ETC, WTC, NTC-CUR, Qavail-WAL, and NTC-WAL remain above the very low-flow range. CIT-O behaves differently because its discharge approaches zero at high exceedance probabilities. This pattern indicates that CIT-O is less reliable as a continuous raw water source and is more likely associated with overflow conditions. Table 3 shows that the Q90 values of the canals used for WTP intake were 27.50 m³/s for ETC, 35.80 m³/s for WTC, 48.40 m³/s for NTC-CUR, and 39.35 m³/s for NTC-WAL. Using Q80 or Q90 for dependable flow assessment is consistent with recent studies that apply FDC-based analysis to describe water availability and low-flow reliability for raw water or clean water planning (Adhikary, 2013; Burgan & Aksoy, 2020; Afifah et al., 2019; Sarminingsih, 2023). In a regulated canal system, interpreting Q90 should consider both hydrological supply and operational control because discharge is affected by weir operation, flow diversion, and allocation among sectors.

Table 3. Evaluation of WTP Operational Capacity Against Canal Dependable Flow Under Existing Conditions

Canal	WTP Operational Capacity in 2025 (m³/s)	Q80 (m³/s)	Q90 (m³/s)	Ratio to Q90 (%)	Status
ETC	0.149	35.00	27.50	0.54	Surplus
WTC	0.169	39.40	35.80	0.47	Surplus
NTC-CUR	0.112	58.00	48.40	0.23	Surplus
NTC-WAL	0.576	46.26	39.35	1.46	Surplus

Table 4. Utilisation Ratio of Projected Demand to Dependable Flow

Canal	Demand in 2024 (m³/s)	Demand in 2044 (m³/s)	Ratio to Q80 in 2044 (%)	Ratio to Q90 in 2044 (%)
ETC	0.214	1.896	5.42	6.90
WTC	0.065	0.573	1.45	1.60
NTC-CUR	0.098	0.873	1.51	1.80
NTC-WAL	0.340	3.019	6.53	7.67

The comparison between dependable flow and existing WTP operational demand shows a large difference between available canal discharge and current raw water use. As presented in Table 3, the WTP operational capacity in 2025 was 0.149 m³/s for ETC, 0.169 m³/s for WTC, 0.112 m³/s for NTC-CUR, and 0.576 m³/s for NTC-WAL. These values were far below the corresponding Q90 values. The utilisation ratio to Q90 ranged from 0.23% to 1.46%, with the highest ratio observed in NTC-WAL. This result indicates that the existing WTP operational capacity only uses a small portion of the dependable discharge available at the canal scale. Similar approaches have been applied in clean water supply studies that compare dependable flow with projected or operational water demand to evaluate whether a river or intake location can support public water supply development (Permana et al., 2022; Permana & Susetyaningsih, 2024). This comparison helps screen raw water adequacy before more detailed intake-level analysis.

However, dependable flow in a regulated canal system should be interpreted differently from dependable flow in a natural river system. In natural rivers, the FDC mainly reflects rainfall, catchment response, baseflow contribution, and seasonal hydrological variability. In the Curug–Walahar system, the FDC also reflects operational regulation, including gate operation, diversion at weirs, irrigation scheduling, and intersectoral water allocation. Therefore, a high Q80 or Q90 value does not necessarily mean that the entire canal discharge is freely available for PDAM abstraction. Part of the flow may already be allocated to irrigation, industrial activities, downstream requirements, or other operational purposes. The surplus status in Table 3 should be interpreted as quantitative adequacy at the canal scale. It does not directly represent uninterrupted intake operation because technical factors such as intake capacity, pump operation, gate regulation, sedimentation, maintenance, and competing irrigation demand may still affect daily raw water abstraction. The Q90-based comparison therefore provides an initial reliability indicator for WTP planning in the Curug-Walahar system.

3.5 Projected Raw Water Demand and Future Dependable Flow Adequacy

Projected raw water demand provides an important basis for evaluating whether the Curug-Walahar system can support future drinking water service expansion. Figure 4 shows that projected raw water demand increased in all canal groups from 2024 to 2044. The highest projected demand was observed in NTC-WAL, increasing from 0.340 m^3/s in 2024 to 3.019 m^3/s in 2044. ETC also showed a large increase from 0.214 m^3/s to 1.896 m^3/s. Lower increases were observed in NTC-CUR and WTC, which reached 0.873 m^3/s and 0.573 m^3/s in 2044. This pattern reflects differences in the population proportion served by each canal group and the distribution of water treatment plant service areas. Similar approaches have been applied in raw water planning studies, where projected demand is compared with reliable discharge or available source capacity to assess future supply adequacy. Afifah et al. (2019) emphasised the need to identify dependable discharge for raw water supply, especially during dry periods. Yanidar et al. (2020) also showed that future water supply planning should consider interactions among raw water availability, service coverage, and population demand. In this study, the upward trend in Figure 4 indicates that pressure on each canal is expected to increase, although demand magnitudes remain different among the canal groups.

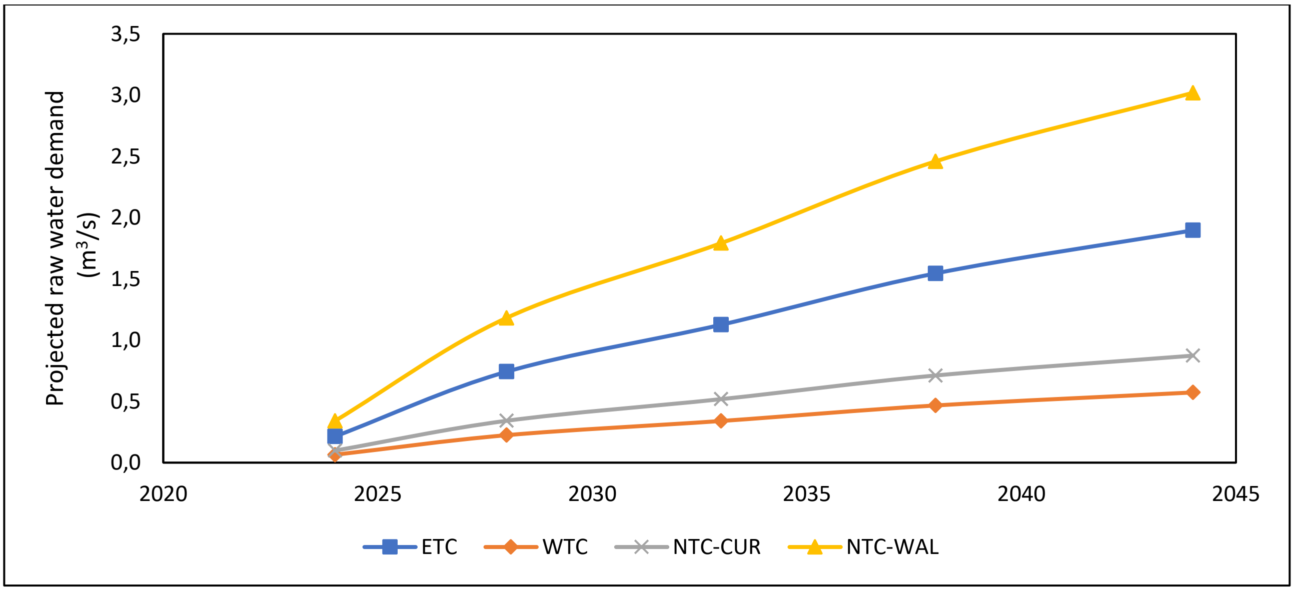

Figure 4 Projected Raw Water Demand by Canal

The future adequacy analysis in Table 4 shows that, under future conditions and projected service expansion and broader population growth trends, projected demand in 2044 remained lower than the available dependable flow in all analysed canals. The ratio to Q90 in 2044 was 6.90% for ETC, 1.60% for WTC, 1.80% for NTC-CUR, and 7.67% for NTC-WAL across the canals and service areas for long-term planning. These values indicate that projected raw water demand still uses less than 10% of Q90 when assessing future supply and source security. This comparison matters because Q90 represents a conservative low-flow condition and is often used to evaluate the reliability of raw water sources for planning and allocation decisions in water allocation studies. Sarminingsih (2023) used reliable discharge probabilities of 80%, 90%, and 95% to assess water availability for raw water purposes in similar assessments during dry periods, while Permana and Susetyaningsih (2024) compared Q90 water availability with future discharge requirements to identify possible shortages. Said et al. (2024) also demonstrated the importance of plotting projected raw water demand against source potential within planning horizons to identify the earlier timing of future surplus or deficit. The results in Table 4 suggest that the Curug-Walahar system still has sufficient canal-scale discharge for projected PDAM raw water demand up to 2044 at system scale under service expansion. This interpretation should remain limited to quantitative availability at the canal scale. Although projected PDAM raw water demand remains below Q90, actual intake performance may still be affected by gate operation, irrigation priority, pump capacity, sedimentation, water quality, maintenance activities, and seasonal operational constraints. Therefore, the projected surplus should be understood as an initial indication of canal-scale water quantity adequacy, rather than a complete guarantee of future raw water security under actual operating conditions.

4. Conclusions

This study evaluated dependable flow availability in the Curug-Walahar weir system to assess raw water reliability for the drinking water supply system in Karawang Regency. Analysis of daily discharge data from 2015 to 2025 showed that ETC, WTC, and NTC-WAL had relatively stable discharge characteristics because they function as regulated canals, while NTC-CUR, Qavail-WAL, and CIT-O showed higher variability, with CIT-O behaving more as an episodic overflow component than a continuous raw water supply source. The Flow Duration Curve analysis indicated that the Q80 and Q90 dependable flows in the main canal components remained much higher than the existing WTP operational capacity in 2025, with utilisation ratios to Q90 ranging from 0.23% to 1.46%. Future demand evaluation also showed that projected raw water demand up to 2044 remained below the available dependable flow, with Q90 utilisation ratios below 10% in all analysed canals. These findings indicate that, from a quantitative canal-scale perspective, the Curug-Walahar system still has sufficient dependable flow to support current and projected PDAM raw water demand. However, this study was limited to PDAM raw water demand. It did not fully include irrigation, industrial demand, environmental flow needs, future climate variability, land-use change, water quality, intake performance, gate operation, pumping capacity, and transmission constraints. Future studies should integrate multi-sector water demand, climate and land-use scenarios, intake-level hydraulic analysis, water quality assessment, and operational records to provide a more comprehensive decision-support basis for sustainable raw water allocation in the Curug-Walahar weir system.

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6. Conflict of Interest

The authors declare no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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