Article

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Posted Date: 18 May 2026

doi: 10.20944/preprints202605.1097.v1

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Abstract

Traditional reservoir flood control operations in China have long relied on a fixed Flood Limited Water Level (FLWL), which frequently results in the underutilization of water resources during flood seasons. Dynamic FLWL regulation and joint reservoir operation have emerged as core strategies to optimize floodwater resource utilization while ensuring flood control safety. However, these approaches typically treat the flood control storage capacity of individual reservoirs as fixed constraints, failing to consider the potential for reallocating this capacity within a cascade reservoir system. This study explores the concept of "equivalent utilization of flood control storage capacity" among cascade reservoirs. Focusing on the four major reservoirs (Wudongde, Baihetan, Xiluodu, and Xiangjiaba) in the lower reaches of the Jinsha River, a methodology for analyzing the equivalent index of their flood control storage capacity is established. The core of this methodology involves a two-round scheduling simulation under various design flood scenarios. The first round of simulation adheres to standard operating rules, while the second round allows upstream reservoirs to retain additional flood volume—with downstream reservoirs correspondingly reducing their outflow—on the premise that downstream safety targets are satisfied. The equivalent index is defined as the ratio of the reduced storage capacity utilized downstream to the additional storage capacity utilized upstream. Nine design flood scenarios (covering three typical years with 1%, 2%, and 5% exceedance probabilities) for flood control in the Sichuan-Chongqing reach were analyzed, with the tightly coupled Wudongde-Baihetan and Xiluodu-Xiangjiaba reservoir pairs treated as two integrated units. The results indicate that the equivalent indices between these two reservoir groups range from 0.96 to 0.999, demonstrating near-perfect functional interchangeability of their flood control storage capacities for the specified research objective. For practical engineering application, a value of 0.96 is recommended as the lower-bound equivalent index. This study provides a methodological framework and specific index to support the dynamic, coordinated, and more efficient utilization of flood control storage capacity in large-scale cascade reservoir systems.

Keywords: flood control storage capacity; equivalent index; cascade reservoirs; joint operation; lower Jinsha river cascade reservoirs

1. Introduction

As the central element of river basin flood control systems, reservoirs fulfill a critical function by impounding floodwaters, attenuating peak discharges, and ensuring the safety of downstream regions.

The conventional operational model in China relies on maintaining a fixed Flood Limited Water Level (FLWL). This strategy guarantees the dedicated reservation of storage for flood prevention. However, its static nature fails to respond to dynamic hydrological variability, often resulting in significant underutilization of potential hydraulic head during flood seasons and creating a pronounced conflict between flood control security and multi-purpose conservation benefits [1]. To address this limitation, the concept of dynamic control of the FLWL has been introduced and developed. This paradigm proposes allowing reservoir levels to fluctuate within a predetermined, risk-assessed range above the standard FLWL, guided by real-time hydrological and meteorological forecasts. The objective is to enhance the utilization efficiency of floodwater resources and optimize hydropower generation, while rigorously maintaining flood risk within acceptable thresholds [2–4]. Empirical research demonstrates the efficacy of this approach. For instance, Zhou Y et al. [5] employed the NSGA-II algorithm to optimize flood-season operating levels for three major reservoirs in the Yangtze River basin. Similarly, Zhou YL et al. [6] established a cooperative floating operation model for a four-reservoir cascade in the lower Jinsha River, formulating dynamic operational rules. Furthermore, Zhu D et al. [7] developed an optimization model for the flood control levels of a six-reservoir cascade (encompassing the middle-lower Jinsha River and the Three Gorges Reservoir) that incorporates tiered flood prevention objectives. These studies have significantly improved flood resource utilization. Subsequent research has expanded these models to integrate factors such as antecedent reservoir storage [8] and inherent forecast uncertainties [9,10].

The sequential construction of cascaded reservoir systems has shifted research emphasis from single-reservoir optimization to the coordinated operation of reservoir groups. This systemic approach, known as joint flood control operation, is now recognized as pivotal for maximizing a basin’s overall flood risk reduction capability [11–13]. Illustrative studies include the work of Li Y et al. [14], who analyzed inflow patterns during the refill period of the Three Gorges Reservoir to derive refill rules balancing risk and benefit. Zhou Y et al. [15] formulated comprehensive refill rules for the integrated Jinsha River and Three Gorges Reservoir cascade, while Zhang R et al. [16] optimized joint operation schemes for the lower Jinsha River cascade. These studies collectively demonstrate the enhanced protection for critical downstream areas achievable through coordinated upstream-downstream operations. The application of advanced computational techniques, including genetic algorithms [17] and hybrid models coupling improved genetic algorithms with support vector machines [18], has further refined the search for optimal joint operation strategies, leading to increased hydropower yields.

Notably, both dynamic FLWL control and joint operation studies typically treat the flood control storage capacity of individual reservoirs as a predefined, fixed constraint within optimization models. This perspective does not interrogate the potential for reconfiguring the system-level allocation of flood control storage within a reservoir group. This gap has motivated research into the “interchangeability of flood control storage capacity”[19]. The core hypothesis posits that within a cascade system tasked with a common downstream flood control objective, the designated flood control capacities of individual reservoirs possess functional equivalence and can be partially substituted or compensated for by one another. Preliminary assessments have explored this potential for systems comprising the Xiluodu, Xiangjiaba, and Three Gorges reservoirs [20], and later, the Yalong River cascade combined with these three [21]. The recent commissioning of the Wudongde and Baihetan reservoirs on the lower Jinsha River has substantially expanded the available flood control storage in this region, necessitating the integrated operation of the Wudongde, Baihetan, Xiluodu, and Xiangjiaba reservoirs as a unified hydraulic unit within the upper Yangtze River flood control system. Consequently, this study focuses on developing methodologies for the equivalent allocation and coordinated operation of the flood control storage capacity of these four key reservoirs, aiming to provide a methodological framework and practical insights for analogous challenges in large-scale cascade reservoir system management.

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2. Methodology

The methodological framework employed in this study is illustrated in Figure 1.

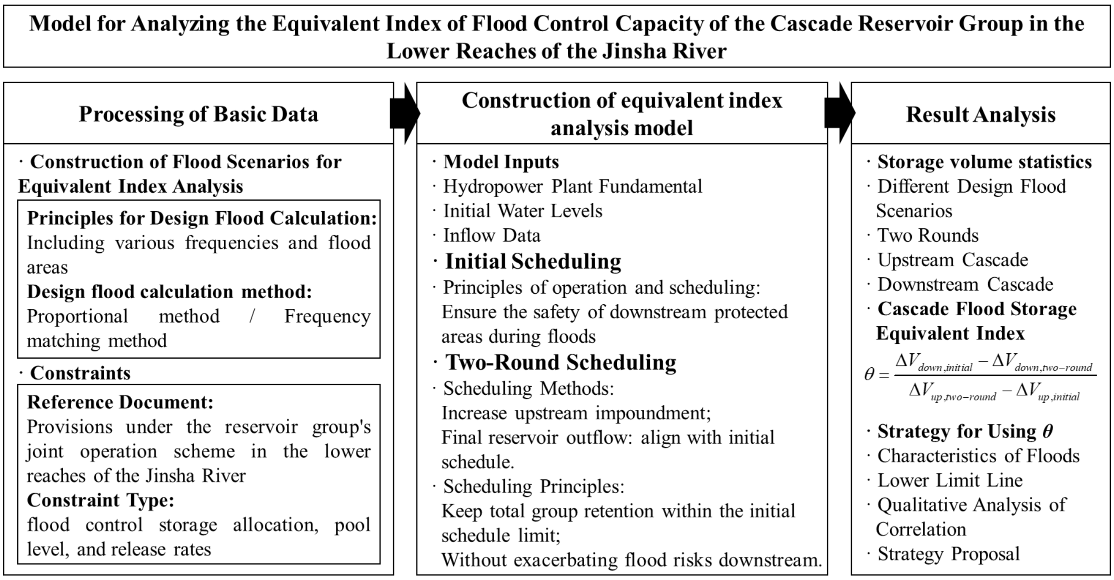

Figure 1. Methodological framework.

2.1. Processing of Basic Data

2.1.1. Construction of Flood Scenarios for Equivalent Utilization Analysis

Based on the regional composition and magnitude of historical floods affecting the flood control protected objects in the downstream, typical flood hydrographs are selected, and the inflow hydrographs at each upstream section are extracted correspondingly according to the flood propagation time. The typical flood hydrographs are then amplified using the same magnification ratio method or same frequency method to derive the overall design flood, thus completing the construction of flood scenarios for the analysis of equivalent regulation of flood control storage capacity of the reservoir group in the basin.

2.1.2. Extraction of Constraint Conditions

In accordance with the requirements of plans, regulations and procedures such as the operation and dispatching plans for reservoir cascades and the joint optimal dispatching schemes, the upper limits of utilizable equivalent storage capacity of the reservoir cascades in the study area during different periods are analyzed, and the flood control dispatching modes of the reservoir cascades for the downstream flood control protected targets are clarified. Subsequently, the water level-storage capacity curves and water level-discharge curves of each reservoir within the reservoir cascades are collected. Based on the above data, the dispatching constraint conditions for the joint dispatching of reservoir cascades, including the water level control ranges, the upper limits of flood control storage capacity utilization and the outflow discharge control modes, are extracted, which provides a basis for the subsequent development of the joint dispatching model.

2.2. Analytical Model for Equivalent Allocation of Flood Control Storage Capacity in a Reservoir Cascade

2.2.1. Construction of a Joint Operation Model for Reservoir Cascades

Based on the water level-capacity relationship curve and the water level-discharge capacity curve obtained in Section 2.1.2, as well as the constraints on reservoir capacity, water level, and outflow flow rate derived through systematic analysis, a joint scheduling model for the reservoir group is constructed, taking into account the flood propagation time within the reservoir group.

2.2.2. Quantitative Index of Equivalent Flood Control Storage Utilization for Reservoir Groups

For two cascade reservoir groups that have the same or related flood protection objects, under the condition of ensuring the flood safety of the flood protection objects and not lowering the original flood protection standard of the river section, the flood storage capacity can be dynamically utilized through the “upward” and “downward” movement of the flood storage capacity. The specific proportion of the “upward” and “downward” movement of the flood storage capacity is the quantitative index for the equivalent utilization of the flood storage capacity of the reservoir group. There are mainly two methods for calculating this index.

Reference [22,23] discretized the available flood control capacity of the upstream reservoir. By conducting simulations and optimization solutions after reserving different flood control capacities for the upstream reservoir, the equivalent conversion ratio of the flood control capacity of the upstream reservoir relative to the downstream reservoir was obtained.

References [24–26] conducted an initial simulation-based dispatching for the design flood based on the actual dispatching rules of the reservoir group. In the second round, while the outflow of the downstream terminal reservoir remained as much as possible unchanged, the upstream reservoirs intercepted a certain amount of water. They analyzed the changes in the interception volumes of the upstream and downstream reservoirs in the two rounds of dispatching, and obtained the equivalent index.

In consideration of practical application requirements, this paper adopts the second method to conduct the analysis on the equivalent allocation of flood control storage capacity for reservoir cascades, with the specific details presented as follows.

(1) Initial Scheduling in Accordance with Operating Rules

The constructed design flood scenarios are input into the joint operation model for reservoir cascades, and flood operation is conducted in accordance with the operation rules specified in the relevant codes and schemes. The water volumes intercepted and stored by the upstream and downstream cascade reservoirs, denoted as $\Delta V_{up,initial}$ and $\Delta V_{down,initial}$ respectively, and the time period ΔT for flood interception and storage by the downstream cascade reservoirs are recorded.

$$f(Z_0, Q_{design}) \Rightarrow \{\Delta V_{up,initial}, \Delta V_{down,initial}, \Delta T\} \tag{1}$$

where: f —— Joint operation model of reservoir groups by rules;

Z_0 —— Initial water level, the same below;

Q_{design} —— Overall design flood at Lizhuang station, the same below.

(2) Two-Round Scheduling

Considering the equivalent operation of upstream and downstream reservoirs, during the ΔT period, the upstream reservoir group operates based on the initial discharge, using the “head-cutting” method, that is, controlling the discharge according to a certain flow q (the initial discharge is greater than q, and the water is released at q, otherwise it is released according to the initial discharge). Compared with the initial scheduling, it stores an additional flood storage volume ($\leq \Delta V_{down,initial}$). The downstream cascade will adjust the outflow based on the new incoming water conditions, starting from the first round of outflow. The second round of operation must follow the following three principles:

① Do not increase the water volume released downstream;

② The maximum discharge from the dam shall not exceed the initial scheduling process;

③ Ensure the flood safety of the downstream flood control targets, and the peak flood flow of the flood protection objects shall not exceed the initial scheduling process.

Statistics of the total flood volume retained by the upstream and downstream cascade units in the second round of scheduling: $\Delta V_{up,two\text{-}round}$, $\Delta V_{down,two\text{-}round}$.

$$g(Z_0, Q_{design}, \Delta V_{down,initial}) \Rightarrow \{\Delta V_{up,two-round}, \Delta V_{down,two-round}\} \tag{2}$$

where: g —— Joint operation model of upstream reservoir groups for impoundment increment based on downstream cascade impoundment under initial operation;

2.2.3. Calculation of Indexs for the Utilization of Equivalent Flood Control Capacity of Reservoir Groups

Compared with the two-round scheduling, the ratio of the additional flood control reservoir capacity used by the upstream cascade to the reduced flood control reservoir capacity used by the downstream cascade is the equivalent index of the flood control reservoir capacity between the upstream and downstream cascades. The calculation formula is as follows:

$$\theta = \frac{\Delta V_{down,initial} - \Delta V_{down,two-round}}{\Delta V_{up,two-round} - \Delta V_{up,initial}} \tag{3}$$

where: θ —— the Equivalent index of reserved flood control storage capacity.

2.3. Result Analysis

Based on the analysis results of the equivalent utilization of flood control storage capacity of upstream and downstream reservoirs under different design flood scenarios, a summary table of mutual utilization coefficients was obtained. Combined with the composition of floods, the rules for the equivalent utilization of flood control storage capacity of the reservoir group in different inflow scenarios were summarized. Furthermore, consider setting the lower limit of quantitative index of equivalent flood control storage utilization for reservoir groups or establishing a relationship between the index and other characteristics such as floods, and propose an index application strategy to provide a reference for the joint operation of the reservoir groups in the basin.

3. Case Study

3.1. Data and Background

The cascade reservoirs on the lower Jinsha River jointly provide flood control services for multiple regions—including the Sichuan–Chongqing reach—and coordinate with the Three Gorges Reservoir to safeguard the middle and lower reaches of the Yangtze River. Consequently, the equivalent allocation of flood control storage capacity among these cascade reservoirs must be evaluated separately, in accordance with their actual operational conditions and distinct flood control responsibilities.

(1) Equivalent index of reserved flood control storage capacity for the middle and lower Yangtze River (in coordination with the Three Gorges Reservoir)

Flood propagation analysis along the Jinsha River indicates that the average travel time of flood waves from the Wudongde Reservoir to the Three Gorges Reservoir is approximately 44 hours. Given this substantial lag and the practical constraints of real-time dispatching, precise temporal control of outflow hydrographs from the lower Jinsha River cascade is infeasible. Instead, synchronous flood detention—i.e., coordinated retention across reservoirs—is prioritized to attenuate peak inflows into the Three Gorges Reservoir. Considering both the regulation capability of the Three Gorges Reservoir and the inherent flood wave propagation characteristics of the Jinsha River, the flood detention volumes contributed by the Wudongde, Baihetan, Xiluodu, and Xiangjiaba Reservoirs can be treated as functionally equivalent when jointly fulfilling the flood control mandate for the middle and lower Yangtze River.

(2) Equivalent index of reserved flood control storage capacity for the Sichuan–Chongqing reach

Flood detention operations targeting key urban centers—including Yibin, Luzhou, and Chongqing—require highly coordinated, timing-sensitive compensatory dispatching among the four cascade reservoirs. Accordingly, assessing the mutual substitutability (i.e., functional interchangeability) of their reserved flood control storage capacities is essential to inform rational capacity allocation and integrated operational strategies.

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Given the tight hydraulic coupling between the Wudongde and Baihetan Reservoirs—whereoutflow adjustments at Wudongde directly regulate inflow to Baihetan—their flood control storage capacities are operationally integrated and thus modeled as a unified unit. Similarly, regulatory guidelines and multi-year operational experience confirm that the Xiluodu and Xiangjiaba Reservoirs are routinely managed as a coordinated pair for flood control in the Sichuan–Chongqing reach. Therefore, the equivalent allocation analysis for this reach focuses exclusively on evaluating the feasibility of interchangeability between the integrated Wudongde–Baihetan storage unit and the integrated Xiluodu–Xiangjiaba storage unit.

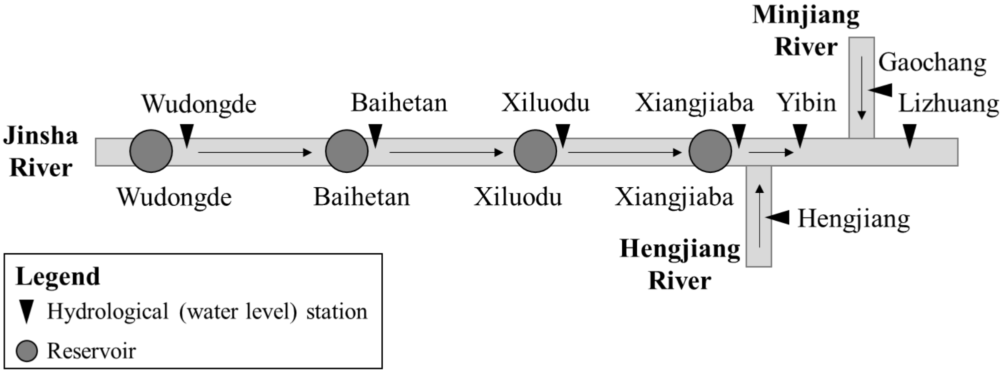


Figure 2. Topological Map of Water System Flow & Engineering Nodes (Wudongde Reservoir—Lizhuang Station).

3.2. Analysis of the Equivalence Index of Flood Control Storage Capacity Between Wudongde-Baoheshan and Xiluodu-Xiangjiaba

3.2.1. Construction and Analysis of Calculation Scenarios

Since the flood control storage capacities of the reservoir group in the lower reaches of the Jinsha River are basically equivalent when conducting flood control scheduling for the middle and lower reaches of the Yangtze River, only the calculation scenarios for flood control scheduling in the Sichuan-Chongqing reach were constructed. The Lizhuang Hydrological Station was selected as the flood control control node, and representative typical flood events (1966, 1981 and 1982) were chosen, with the design frequencies including 1%, 2% and 5%. The inflow discharges of the four reservoirs under each design frequency were reconstructed, as shown in the Table 1.

Table 1. Flood Scenarios for Equivalent Index Analysis.

Typical Year	Design Frequency (%)	Maximum Inflow of Wudongde	Peak of Lizhuang Station	Proportion of Inflow to Lizhuang Station (%, calculation period: 1 d)			
				Wudongde	Wudongde-Xiangjiaba Interval	Xiangjiaba	Xiangjiaba-Lizhuang Interval
1996	1	26200	56600	46.4	6.0	52.4	47.6
	2	24200	52100				
	5	21100	45500				
1981	1	28400	62300	26.3	3.3	29.6	70.4
	2	26200	57600				
	5	22900	50400				
1982	1	28900	52000	55.1	7.0	62.1	37.9

2	26600	47900
5	23400	42100

3.2.2. Construction of an Analytical Framework for Assessing the Equivalent Index of Flood Control Capacity Across the Downstream Reservoir Cascade on the Jinsha River

An analytical model was constructed to enable coordinated flood storage capacity utilization between the Wudongde–Baihetan and Xiluodu–Xiangjiaba reservoir systems. The model integrates reservoir characteristic curves, flood control operation rules, and inter-reservoir flood propagation times. Its structural framework is illustrated in the figure below.

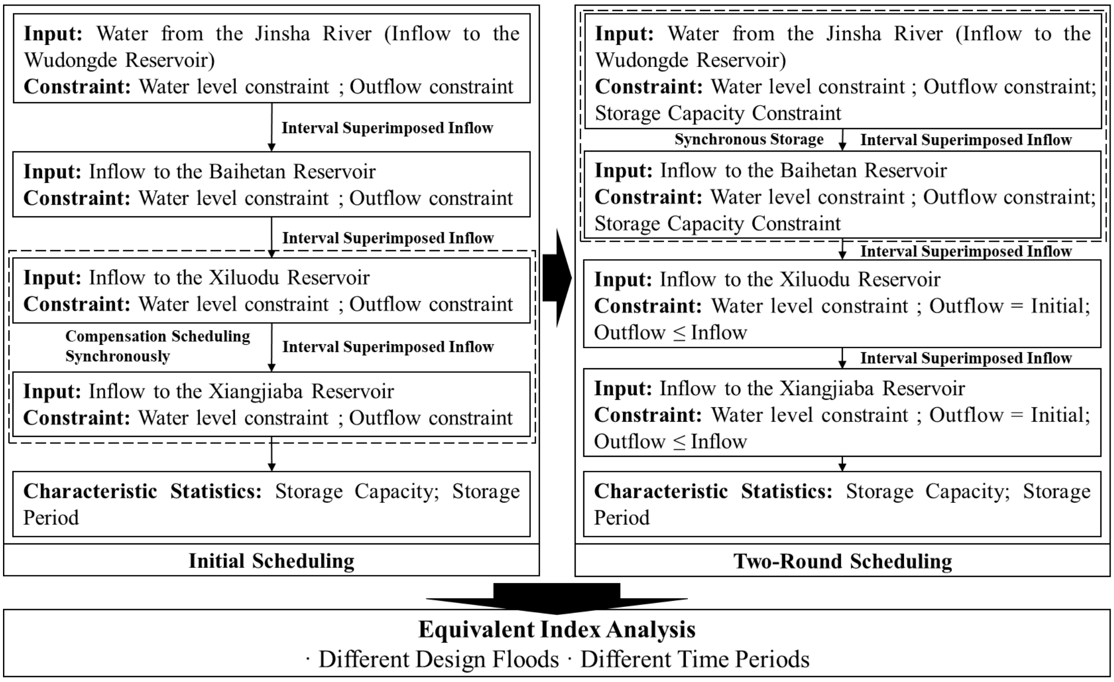
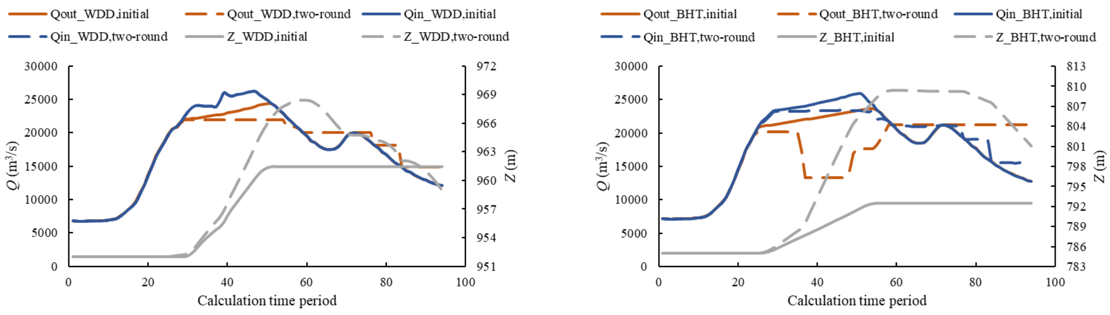


Figure 3. Equivalent Index Analysis Model Schematic.

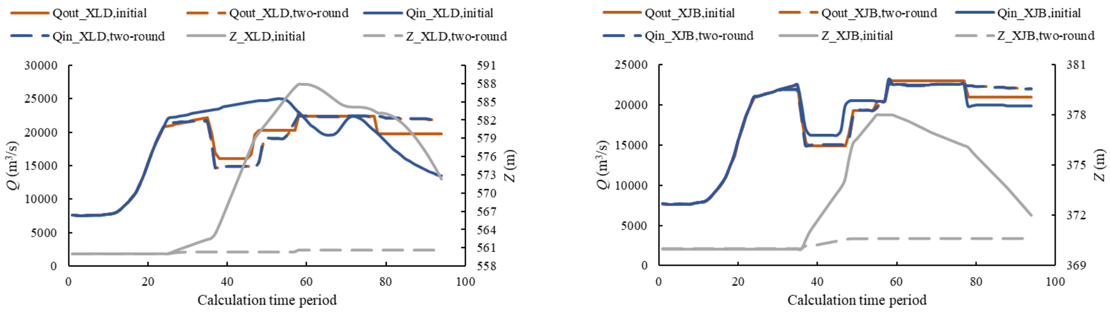
3.3. Results Analysis

3.3.1. Results of Equivalent Index Analysis

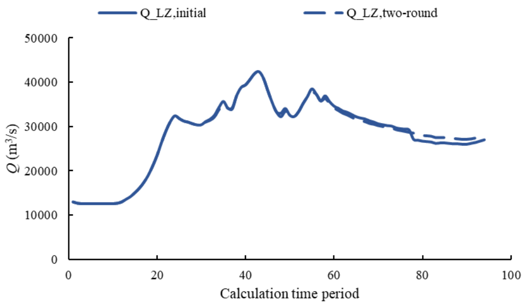
Nine design flood hydrographs corresponding to three hydrological frequencies across three typical years were input into the equivalent index analysis model, with all four reservoirs initially operated at their respective flood limited water levels (Wudongde: 952 m, Baihetan: 785 m, Xiluodu: 560 m, Xiangjiaba: 370 m). In the initial scheduling, the flood control storage capacities of the Wudongde and Baihetan Reservoirs were not directly utilized for flood detention, and the two reservoirs discharged water in accordance with their respective discharge rating curves. For the Xiluodu and Xiangjiaba Reservoirs, synchronous flood detention was implemented in accordance with the specific flood control requirements of downstream protected objects, and the flood detention volumes of the two reservoirs were allocated based on the remaining water volume of their flood control storage capacities while taking their actual discharge capacities into account. In the second-round scheduling, the Wudongde and Baihetan Reservoirs conducted synchronous flood detention with reference to the flood detention volumes and detention durations of the Xiluodu and Xiangjiaba Reservoirs during the initial scheduling. For the Xiluodu and Xiangjiaba Reservoirs, on the basis of the outflow processes from the initial scheduling, their outflow discharges were reduced accordingly when the outflow discharges exceeded the inflow discharges.



(a) Wudongde Reservoir (b) Baihetan Reservoir

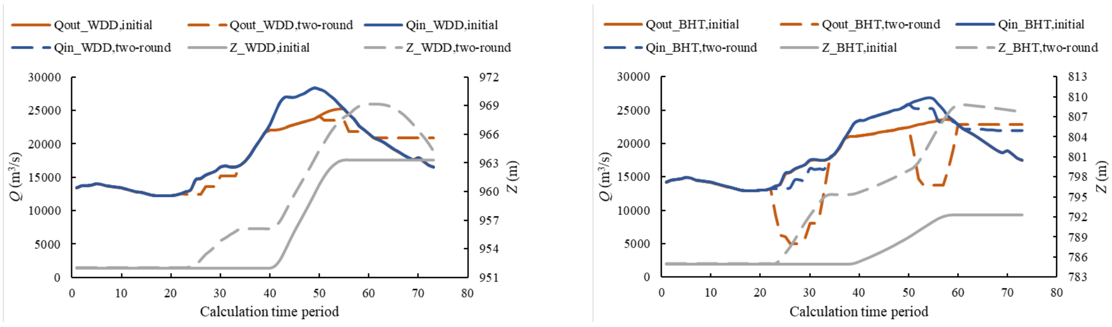


(c) Xiluodu Reservoir (d) Xiangjiaba Reservoir

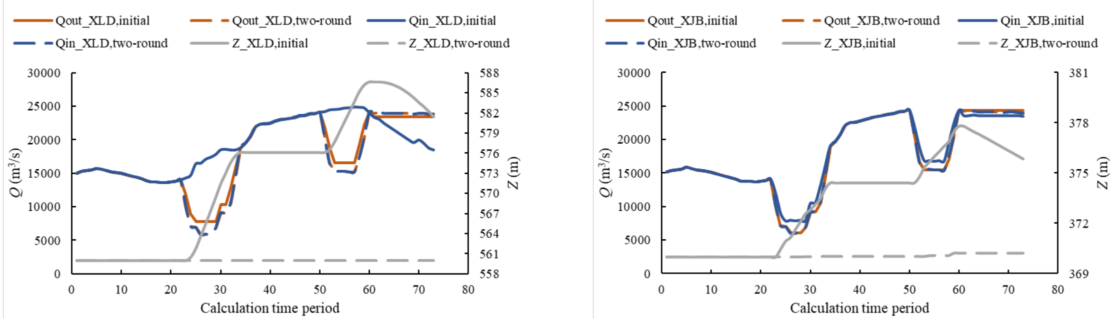


(e) Lizhuang Station

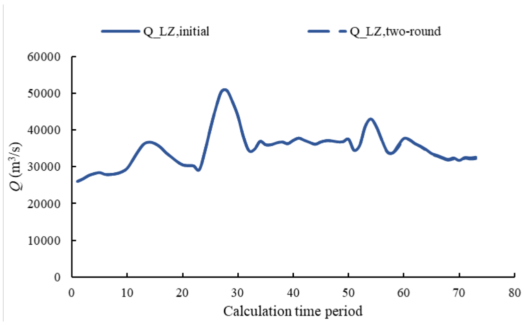
Figure 4. Schematic Diagram of Two Rounds of Scheduling for Cascade Reservoirs in the Lower Jinsha River and Lizhuang Station (1966, 1%).



(a) Wudongde Reservoir (b) Baihetan Reservoir

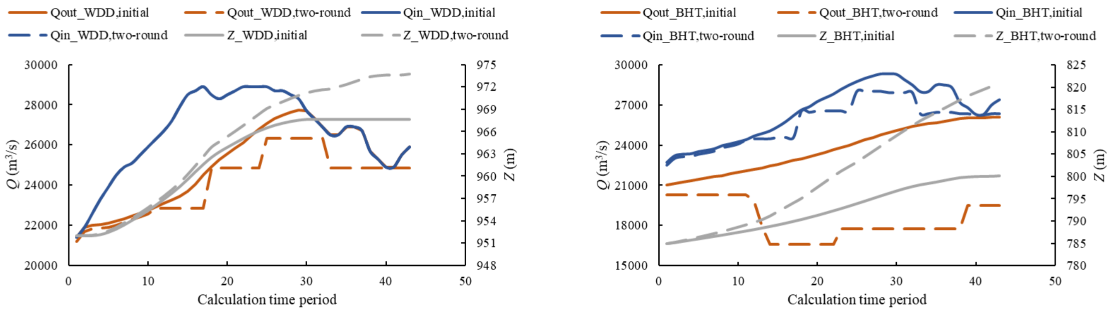


(c) Xiluodu Reservoir (d) Xiangjiaba Reservoir

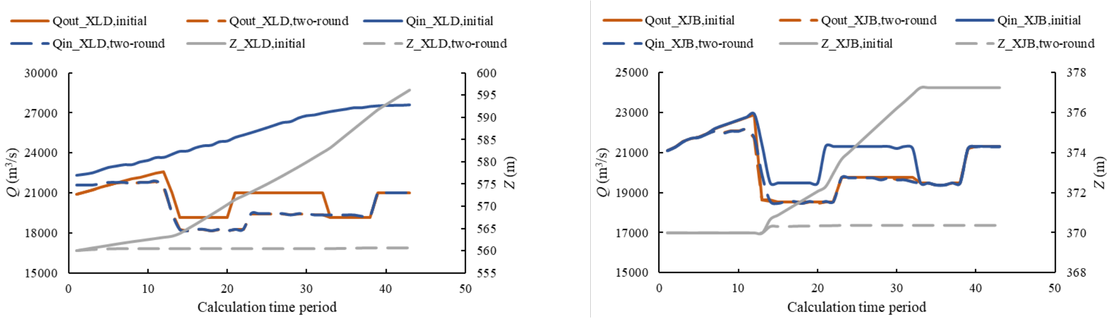


(e) Lizhuang Station

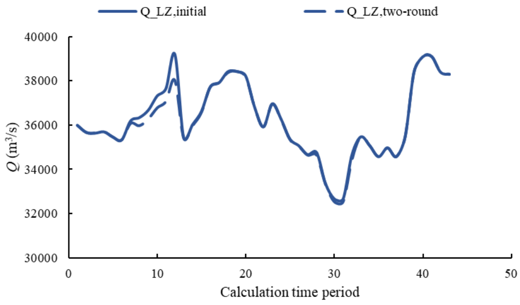
Figure 5. Schematic Diagram of Two Rounds of Scheduling for Cascade Reservoirs in the Lower Jinsha River and Lizhuang Station (1981, 1%).



(a) Wudongde Reservoir (b) Baihetan Reservoir



(c) Xiluodu Reservoir (d) Xiangjiaba Reservoir



(e) Lizhuang Station

Figure 6. Schematic Diagram of Two Rounds of Scheduling for Cascade Reservoirs in the Lower Jinsha River and Lizhuang Station (1982, 1%).

It can be seen from the Table 2 to Table 6 that the equivalent indices of flood control storage capacity for Wudongde and Baihetan Reservoirs versus Xiluodu and Xiangjiaba Reservoirs range from 0.96 to 0.999, which can be basically regarded as equivalent. In addition, for the same typical design flood, the smaller the hydrological frequency and the larger the total flood volume of the hydrograph, the closer the equivalent index is to 1. For different typical design floods with the same hydrological frequency, the smaller the difference in the total detention volumes during the two rounds of scheduling, the larger the equivalent index.

Table 2. Scheduling Characteristics of Wudongde Reservoir in Two Rounds.

Typical Year	Design Frequency (%)	Maximum Inflow (m³/s)	Maximum Outflow (m³/s)	Maximum Water Level (m)
1966	1	26200①	24400	961.42
		26200②	21900	968.41
	2	24200	22800	955.87
		24200	22500	961.76
	5	21100	21100	952.00
		21100	21000	956.57
1981	1	28400	25300	963.34
		28400	24100	969.15
	2	26200	23600	959.34
		26200	23200	965.26
	5	22900	22100	952.74
		22900	22100	958.31
1982	1	28900	27700	967.62
		28900	26300	973.95
	2	26600	25300	963.32
		26600	24600	971.12
	5	23400	22700	955.09
		23400	22500	956.45

Note: ① refers to the results of the initial scheduling; ② to those of the second-round scheduling; the same applies hereinafter.

Table 3. Scheduling Characteristics of Baihetan Reservoir in Two Rounds.

Typical Year	Design Frequency (%)	Maximum Inflow (m³/s)	Maximum Outflow (m³/s)	Maximum Water Level (m)
1966	1	25900	23700	792.55
		23500	21200	809.38
	2	24200	22900	790.10
		23900	22800	800.67
	5	22400	21500	786.14
		22300	21500	793.64
1981	1	26900	23600	792.27
		25800	22800	808.82
	2	25000	22900	790.24
		24700	22100	803.36
	5	23500	22000	787.77
		23500	21800	796.82
1982	1	29300	26100	800.31
		28000	20300	821.60
	2	26800	24600	795.26

		26200	23500	815.13
	5	24100	22800	789.99
		23900	22500	792.26

Table 4. Scheduling Characteristics of Xiluodu Reservoir in Two Rounds.

Typical Year	Design Frequency (%)	Maximum Inflow (m³/s)	Maximum Outflow (m³/s)	Maximum Water Level (m)
1966	1	25100	23000	587.86
		22400	22400	560.59
	2	24200	24200	578.75
		24100	24100	560.18
	5	22700	22700	572.87
		22700	22700	560.06
1981	1	24900	24200	586.61
		24200	24200	560.00
	2	24300	23800	581.69
		23700	23700	560.09
	5	23300	23200	575.07
		23200	23200	560.00
1982	1	27600	22600	597.25
		21900	21900	560.62
	2	26000	25600	594.85
		25000	25000	560.54
	5	24100	23800	565.15
		23800	23800	560.22

Table 5. Scheduling Characteristics of Xiangjiaba Reservoir in Two Rounds.

Typical Year	Design Frequency (%)	Maximum Inflow (m³/s)	Maximum Outflow (m³/s)	Maximum Water Level (m)
1966	1	23200	23200	378.00
		22600	22600	370.62
	2	24500	24500	374.70
		24300	24300	371.00
	5	22900	22900	373.63
		22900	22900	370.41
1981	1	24500	24500	377.78
		24500	24500	370.22
	2	24100	24100	376.58
		23900	23900	370.60
	5	23400	23400	375.29
		23400	23400	370.04
1982	1	22900	22900	377.25

		22200	22200	370.36
	2	25800	25700	377.29
		25300	25300	370.75
	5	24100	24100	370.00
		24000	24000	370.00

Table 6. Storage Capacity for Flood Control of Cascade Reservoirs, Flood Peak at Downstream Lizhuang Station in Two-Round Scheduling and Equivalent Index.

Typical Year	Design Frequency (%)	Peak of Lizhuang Station (m^3/s)	Storage Capacity for Flood Control		Equivalence Index
			Wudongde and Baihetan (10^8m^3)	Xiluodu and Xiangjiaba (10^8m^3)	
1966	1	42400	21.27	38.06	0.97
		42400	59.33	1.12	
	2	39900	11.62	24.19	0.96
		39900	35.81	1.03	
	5	37600	1.81	16.59	0.98
		36800	18.40	0.41	
1981	1	50800	22.78	36.34	0.99
		50800	59.12	0.19	
	2	46700	15.18	29.32	0.98
		46700	44.50	0.60	
	5	40700	5.06	20.53	0.999
		40700	25.58	0.03	
1982	1	39200	41.43	49.30	0.98
		39100	90.74	0.92	
	2	39200	27.95	46.21	0.98
		39000	73.99	1.18	
	5	38900	10.70	5.20	0.96
		38900	15.89	0.22	

3.3.2. Strategy for Using Equivalent Indices

The mean values of the equivalent indices under the design flood scenarios with three hydrological frequencies for each typical year were calculated, and the response plot of the mean values against flood compositions was plotted, as shown in Figure 3. It can be seen from the figure that there is no obvious correlation between flood composition and the equivalent index. Therefore, in the application of the equivalent coefficient, the lower limit of the analysis results from the nine design flood scenarios is adopted, with 0.96 designated as the flood control storage capacity equivalent index for Wudongde and Baihetan Reservoirs relative to Xiluodu and Xiangjiaba Reservoirs.

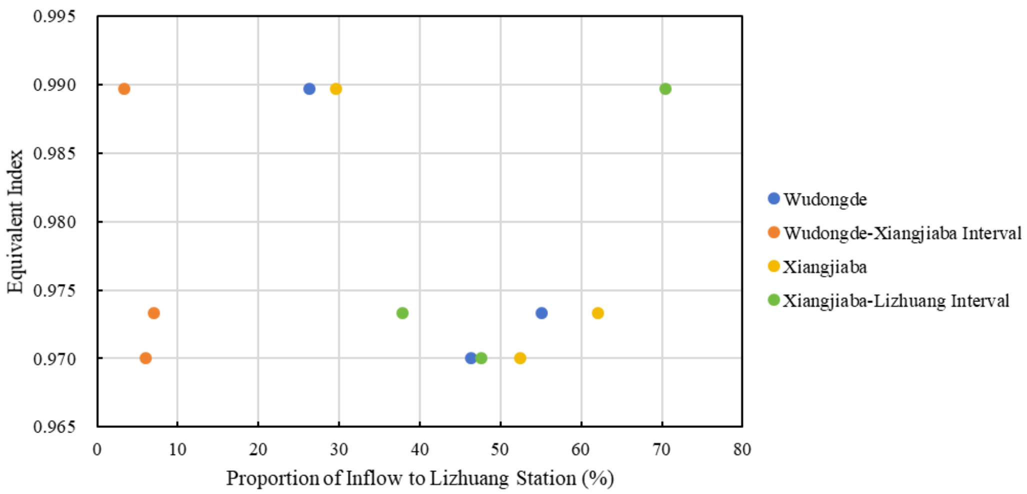


Figure 7. Equivalent Index-Flood Composition Ratio Response Plot.

4. Discussion

The equivalent utilization of flood control storage capacity in cascade reservoir groups serves as a scientific concept and critical approach for guiding flood control and water resource utilization, with rational analysis results of equivalent relationships providing robust technical support for the collaborative optimal operation of cascade reservoir groups. Based on the integrated utilization of flood control storage capacity in cascade reservoir groups, this study investigates the equivalent relationships of flood control storage capacity for the cascade reservoir group in the lower reaches of the Jinsha River. Nevertheless, the equivalent relationships between the flood control storage capacity of an individual reservoir and that of its upstream and downstream counterparts within the same group, as well as those of reservoir groups nested in a series-parallel configuration, remain to be further explored in depth. Such in-depth research will enable a more scientific, refined and efficient allocation of reservoir storage capacity and optimal utilization of flood resources.

5. Conclusions

This paper, based on the cascade reservoir group in the lower reaches of the Jinsha River, constructed 9 design flood calculation scenarios for 3 typical years at 3 different frequencies. It analyzed the equivalent relationship of flood storage capacity among the Wudongde-Baihetan and Xiluodu-Xiangjiaba reservoirs. The results showed that the equivalent indices of the two groups ranged from 0.96 to 0.999. The composition of the floods had little relation to the equivalent index. In practical applications, the equivalent index could be taken as 0.96. The research results provide a reference for the dynamic application of flood storage capacity of the reservoir group in the lower reaches of the Jinsha River, and can to some extent improve the utilization rate of water resources.

Author Contributions: Conceptualization, X.G. & Z.W.; methodology, Y.C.; validation, Z.W.; investigation, Z.W. & Y.X. & X.W.; writing-original draft, X.G. & Z.W.; writing-review and editing, Y.C.; supervision, Y.C. All authors have read and agreed to the publication version of the manuscript.

Funding: This work was supported by the National Natural Science Foundation of China (Nos. 52441901, U2340213);Scientific Research Project of Huaneng Longkaikou Hydropower Co., Ltd. (Grant No. LKKDC2024/P09).

Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Conflicts of Interest: Xiangxing Wei were employed by the Huaneng Longkaikou Hydropower Co., Ltd.. The remaining author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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