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Effect of Daily Regulation on Navigation Conditions in Deep Reservoirs

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ABSTRACT

The daily regulation and anti-regulation of upstream and downstream power stations, respectively, frequently alter the river flow regime, velocity, and surface gradient, thus resulting in unsteady flow characteristics of the river and hindering shipping, waterway maintenance, and wharf operations. This study investigated the influence of daily regulation on the navigation conditions in the deep reservoir by taking the rivers between the Three Gorges Dam and the Gezhouba Dam as the research object. Prototype observations and a depth-averaged 2-D model were used to determine the main factors affecting the propagation law of unsteady flow. The propagation pattern of unsteady flow and channel navigational conditions and measures of the power station were analyzed systematically. The results showed that the water level amplitude was affected primarily by the peak amplitude and duration of the peak shaving. Additionally, the base flow significantly influenced time spatial distributions of the water level amplitude. Impacted by the reservoir storage capacity, a threshold for the duration of peak shaving was noted; this may result in maximum water level variation. As the peak shaving duration increased, the amplitude of the water level decreased. The research results can provide theoretical support for the optimization of hub shipping.

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Water level amplitude

1. INTRODUCTION

Human activities have caused significant changes to the river ecosystem, especially dam establishment (Syvitski et al., 2005; Fang et al., 2012). Owing to the operation of large-scale hydropower projects, navigation conditions have been fundamentally improved in channelized rivers, especially in reservoir areas. However, the surface gradient and flow velocity of rivers vary frequently, which hinders shipping, ecosystems, waterway maintenance, and wharf operations (Ban et al., 2019; Xing et al., 2021).

Since the 1980s, significant research has been conducted on flow conditions and riverbed evolution induced by unsteady flow discharged from power stations (García-Navarro & Savirón, 1992; Sincock et al., 2003). The relationship between the daily regulation of hydropower stations and downstream navigation has been extensively investigated (Zhao et al., 1994; Jian et al., 2012a; Zhao et al., 2012). Daily regulation can result in water level fluctuations, which can adversely affect navigation safety (Zheng, 2016; Wan et al., 2020). Shang et al. (2017) established a one-dimensional mathematical model to simulate the influence of daily regulation of the Xiaonanhai hydropower station on navigation downstream. The maximum additional flow rate and gradient that occurred during the discharge flow through the dam increased to 4,010 m^3/s. This reduced the downstream flow conditions of the dam during the dry season, which inevitably impedes navigation along the Yangtze River. Zhang et al. (2019) focused on a typical 5000 t cargo ship navigation risk assessment based on four typical hydrological scenarios: 7,000, 10,000, 20,000, and 30,000 m^3/s, and derived a serious shipping risk map between the Three Gorges Dam (TGD) and the Gezhouba Dam (GZB). Furthermore, they proposed four determination indices for navigational safety and a five-level classification for navigation risk assessment. However, their method lacked actual ship tests, and further investigation with an index for the propagation characteristics of unsteady flow is required. Daily regulation of hydropower stations is often considered the main object in the tradeoff between the daily regulation of hydropower stations and downstream shipping. Therefore, a balance between the two dams is required (Liu et al., 2011; Babel et al., 2012).

NOMENCLATURE			
d	static water depth	$\bar{u}$	water depth average velocities
g	acceleration of gravity	u_s	source-sink flows in the direction of x
h	total water head	v	velocity component in the direction of y
P_a	atmospheric pressure	$\bar{v}$	water depth average velocities
S	point source flow size	v_s	source-sink flows in the direction of y
s_{ij}	radiation stress components	η	river bottom elevation
t	time	ρ	density of water
u	velocity component in the direction of x	ρ_0	relative density of water

Previous studies have focused primarily on unsteady flow discharged by a single power station. However, only a few studies have considered the navigation conditions in the reservoir area, which is affected by the combined operation of cascade hydropower stations. This study proposes a 2-D mathematical model that is validated by prototype observation to determine the characteristics of unsteady flow and its effect on the navigation conditions in a deep reservoir between two dams. Furthermore, to satisfy the daily regulation of hydropower stations and consider the safety of downstream shipping, the peak regulation suggestions of the combined operation of cascade power stations are proposed reasonably.

2. CASE STUDY

The Yangtze River is located on the eastern coast of China (Liu et al., 2019; Cai et al., 2013). It originates from the Qinghai-Tibetan Plateau with a length of 6397 km and drainage area of 15.84 km^2; it flows from west to east China (Wang et al., 2016; Deng et al., 2019). The river section between the TGD and GZB is located in Yichang City, Hubei Province, China.

The 38-km river-reach spanning between TGD and GZB has one of the worst navigation conditions in the upper reaches of the Yangtze River during the flood season. The operation of TGD has a significant influence on the downstream of the Yangtze River (Tian et al., 2019). During peak shaving, the flow variation can reach up to 12000 m^3/s in two hours, and the maximum rate in 1 h can reach 6000 m^3/s. This variation increases with the peak shaving capacity. The GZB is an anti-regulation power station for TGD. The primary task is to stabilize the daily hydropeaking flow released from the TGD without changing the average daily discharge of the Three Gorges Reservoir (Wang et al., 2013). The river reach between the two dams is located in the backwater zone of the GZB reservoir throughout the year, where the flow characteristics are affected by both the TGD and GZB reservoirs (Wang et al., 2020). Therefore, this study chose the navigational channel between these two dams as the research object. Furthermore, we systematically analyzed the characteristics of unsteady flow in the navigational channel under the influence of daily regulation of the hydropower station.

3. METHOD

3.1 Mathematical Model

To simulate the hydrodynamic conditions in the study area, a depth-averaged 2-D model was developed by DHI MIKE ZERO, which was based on the 2-D incompressible fluid Reynolds mean stress equation and obeyed the Boussinesq hypothesis and hydrostatic pressure assumption. The unstructured triangular mesh field was obtained by solving Reynolds-averaged Navier–Stokes equations, which was adopted by explicit time integration. The equations for continuity (Eqs. 1 and 2) and momentum (Eqs. 3～6) can be expressed as:

$$h = \eta + d \tag{1}$$

Continuity equation

$$\frac{\partial h}{\partial t} + \frac{\partial h\bar{u}}{\partial x} + \frac{\partial h\bar{v}}{\partial y} = hs \tag{2}$$

Momentum equation:

$$\frac{\partial h\bar{u}}{\partial t} + \frac{\partial h\bar{u}^2}{\partial x} + \frac{\partial h\overline{vu}}{\partial y} = f\bar{v}h - gh\frac{\partial \eta}{\partial x} - \frac{h\partial p_a}{\rho_0 \partial x} - \frac{gh^2}{2\rho_0}\frac{\partial \rho}{\partial x} + \frac{\tau_{sx}}{\rho_0} - \frac{\tau_{bx}}{\rho_0} - \frac{1}{\rho_0}\left(\frac{\partial s_{xx}}{\partial x} + \frac{\partial s_{xy}}{\partial y}\right) + \frac{\partial}{\partial x}\left(hT_{xx}\right) + \frac{\partial}{\partial x}\left(hT_{xy}\right) + hu_s S \tag{3}$$

$$\frac{\partial h\bar{u}}{\partial t} + \frac{\partial h\overline{uv}}{\partial x} + \frac{\partial h\bar{v}^2}{\partial y} = f\bar{u}h - gh\frac{\partial \eta}{\partial y} - \frac{h\partial p_a}{\rho_0 \partial y} - \frac{gh^2}{2\rho_0}\frac{\partial \rho}{\partial y} + \frac{\tau_{sy}}{\rho_0} - \frac{\tau_{by}}{\rho_0} - \frac{1}{\rho_0}\left(\frac{\partial s_{yx}}{\partial x} + \frac{\partial s_{yy}}{\partial y}\right) + \frac{\partial}{\partial x}\left(hT_{xy}\right) + \frac{\partial}{\partial y}\left(hT_{yy}\right) + hv_s S \tag{4}$$

$$h\bar{u} = \int_{-d}^{\eta} u dz \tag{5}$$

$$h\bar{v} = \int_{-d}^{\eta} v dz \tag{6}$$

where x, y, and z are the Cartesian coordinates; $h = \eta + d$; ρ is the density of water; s_{xx}, s_{xy}, s_{yx}, s_{yy} are the components of radiation stress; Pa is the atmospheric pressure; ρ_0 is the relative density of water; S is the point source flow size; and u_s and v_s are the source-sink flows.

In a 2-D flow model, the boundary conditions typically include the river inlet and outlet boundary, bank boundary, and the moving boundary treatment. In this model, the boundary conditions were as follows.

1) Inlet boundary: The transverse distribution of the inflow flow along the section is defined according to the known inlet full-section flow.

2) Outlet boundary: This generally indicates the water level of the outlet section.

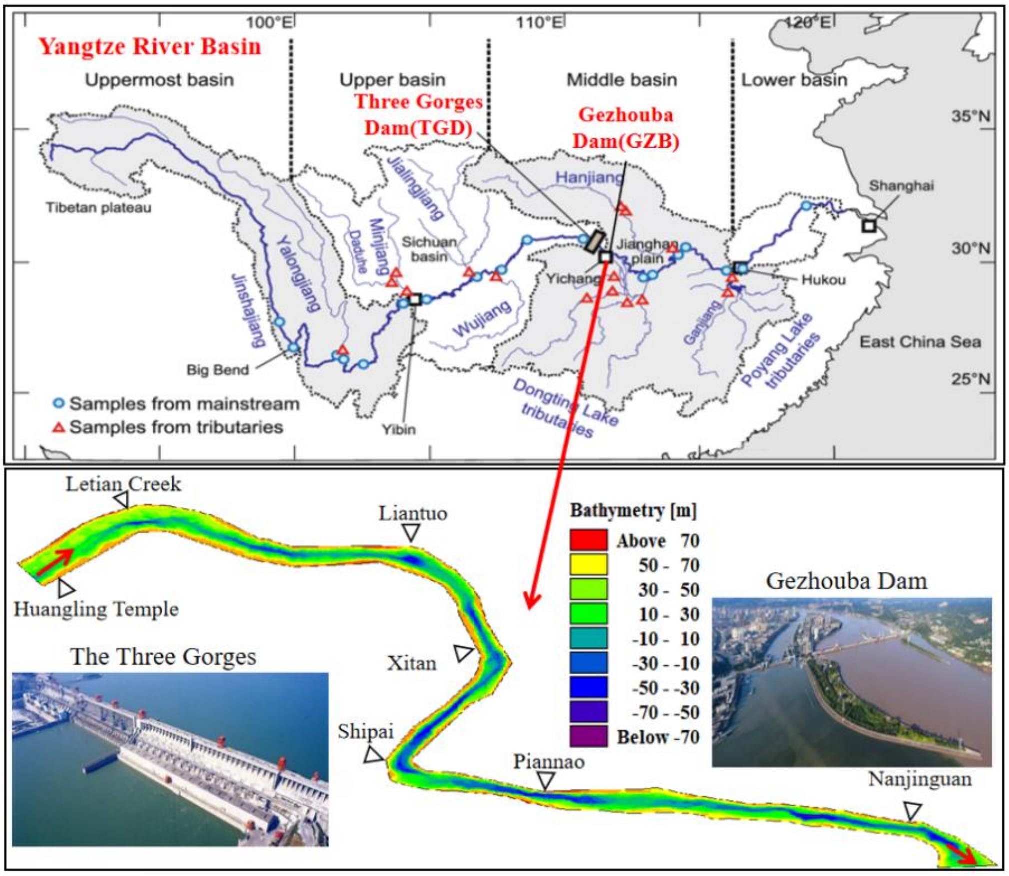


Fig. 1 Geographical location and river reach between the TGD and GZB reservoirs

3) Bank boundary: This is a no-slip boundary, and the flow velocity is set to zero.

4) Moving boundary: In this model, the 'freezing' method is used to deal with the moving boundary depending on the elevation of the river bottom at the water level node. Furthermore, the exposure of the grid unit to the water surface is analyzed. If it is not exposed, the roughness is considered; else, the roughness is considered as a positive number close to infinity. Simultaneously, a thin water layer is added at the node exposed to the water surface to ensure the solution of the water flow control equation remains unaffected. The thickness of the water layer is generally set as 0.5 cm.

3.2 Computational Domain

The TGD Project has remarkable economic, social, and environmental sustainability benefits (Morgan et al., 2012). However, river flow and navigational conditions are both significantly affected by the long-term operation of the TGD. The river reach under study is the golden waterway of the Yangtze River, which has a significant navigational position along this river (Jian et al., 2012).

Figure 1 shows that the geographical location of reach river in the Yangtze River Basin. The area of study is a 38-km long reach from Sandouping to Nanjinguan, which is indicated by triangular structured meshes. The mesh sensibility analysis revealed that the maximum grid area was 389 m^2, and the total number of elements was 48872 within the entire computational domain.

Boundary conditions of the model include the inlet, outlet, and bank boundaries, as well as the moving boundary treatment. The inlet boundary is the flow inlet, the outlet boundary is the water level outlet, and the bank boundary is the no-slip boundary, where the particle velocities in all directions must be zero.

3.3 Model Verification

To further conduct the model test, the reliability of the numerical model must be validated with prototype observation data. The upstream boundaries are 30,100 m^3/s, 20,200 m^3/s, and 10,500 m^3/s from the TGD outflow, and the corresponding water levels are 65.58 m, 64 m, and 66.3 m, respectively, in front of GZB. The model calculation results were verified based on the measured water levels between the two dams in April 2017, July 2018, and September 2018. The simulation results matched well with the measured values, and the maximum absolute error was 0.09 m, as shown in Fig. 2. Therefore, the requirements for the calculation accuracy and precision were met.

Due to the lack of experimental observation data, the Technical Standard Test Study on Navigable Water Flow between the two dams (Gezhouba Dam-Three Gorges) (2005) was used to verify the unsteady flow calculation of the model. The discharge process (December scheme) and water level observation test data of the TGD under the 175 m scheme in the report were verified, as shown in Figs. 3 (a) and (b). The deviation between the calculation results and test data was found to be within 0.10 m.

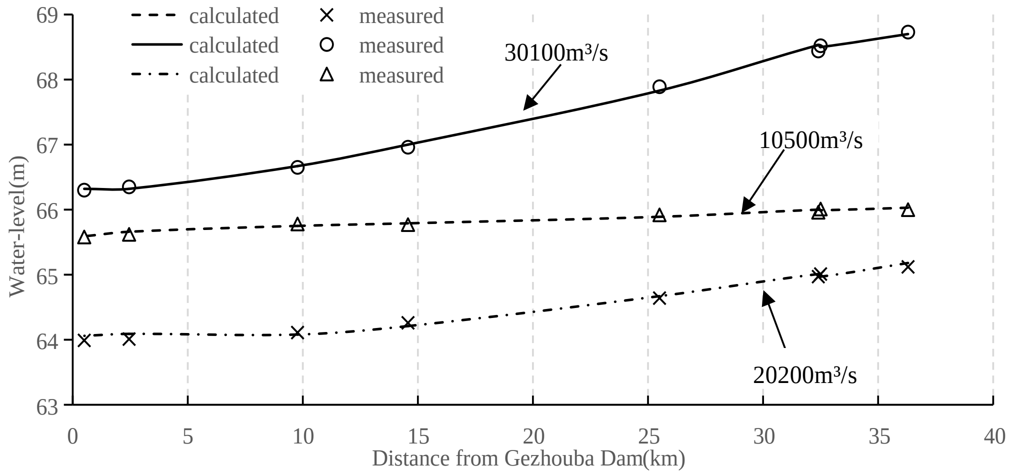
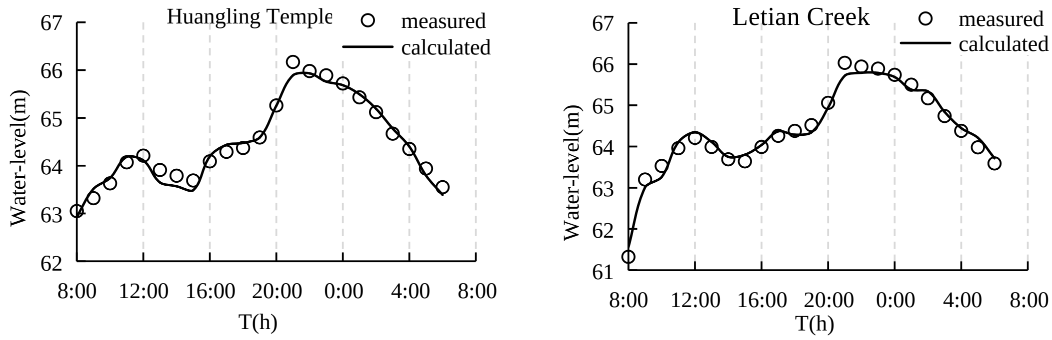


Fig. 2 Verification results of water lines at different discharge levels between the TGD and GZB



(a) Huangling Temple cross-section unsteady flow verification result

(b) Leian Creek cross-section unsteady flow verification result

Fig. 3 Verification results of unsteady flow between the TGD and GZB reservoirs

Furthermore, the research requirements for the unsteady flow in the river reach studied by the model were satisfied. By considering the error superposition effect of the test and calculation, the calculated water level change trend was found to be consistent with the observation results.

4. RESULTS AND DISCUSSION

4.1 Analysis of Unsteady Flow Characteristics Under the Actual Scheduling Scheme

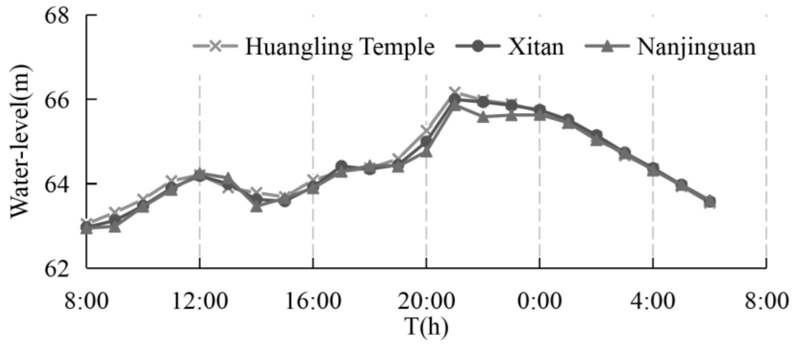
In Fig. 4. The outflow process of the TGD for the 175 m scheme in December was from reference materials of "Experimental Study on Navigation Flow Technical Standards between Two Dams (the Gezhouba～the Three Gorges)". The maximum hourly variation was 5670 m^3/s (11:00–12:00), and the discharge decreased from 7573 m^3/s to 1903 m^3/s. The maximum and minimum outflows of GZB were 7189 m^3/s and 4193 m^3/s, respectively. Under the regulation of the upstream and downstream hydropower projects, the water level in the river reach between the two dams fluctuated, thus presenting a certain attenuation effect with an increase in mileage from the TGD site. The hourly variation of the water level at the typical section was similar to the overall trend of the outflow process of the TGD; however, a certain time delay was noted in the hourly variation of the water level compared with the outflow process, which fluctuated up and down within a period of time (Fig. 4). The maximum hourly variation of water level at each section occurred at 21:00. The maximum hourly variation of water level at Huangling Temple, Letian Creek, Xitan, Shipai, and Nanjinguan typical sections were 0.91 m, 0.97 m, 1.00 m, 1.06 m, and 1.10 m respectively.

4.2 Hydraulic Characteristics Analysis of Generalized Unsteady Flow Process

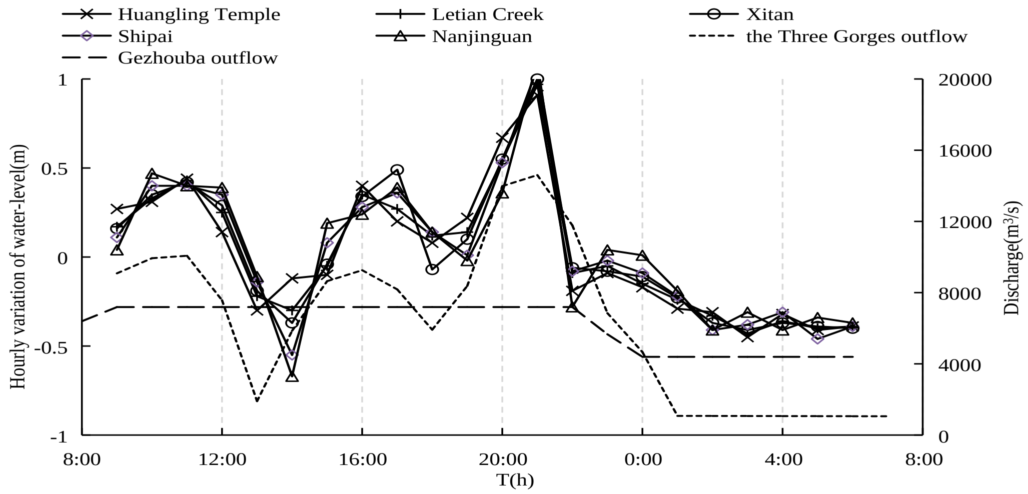
4.2.1. Calculation Scheme

According to the statistical results of the actual daily regulation process of TGD and GZB, it is difficult to analyze the law of unsteady flow considering the hydraulic characteristics of the reach in the reservoir region are simultaneously regulated by both reservoirs.

Through experimental observation and laboratory tests, we preliminarily determined that unsteady flow is affected primarily by factors such as base flow, water level in front of GZB, and the variation in discharge. To



(a) Hourly variation process of water level in different sections



(b) Statistical results of time-varying amplitude of water level in typical sections of each river section

Fig. 4 Statistical results of the daily regulation process of the TGD and GZB reservoirs and hourly variation of the water level at typical cross-sections of each river reach

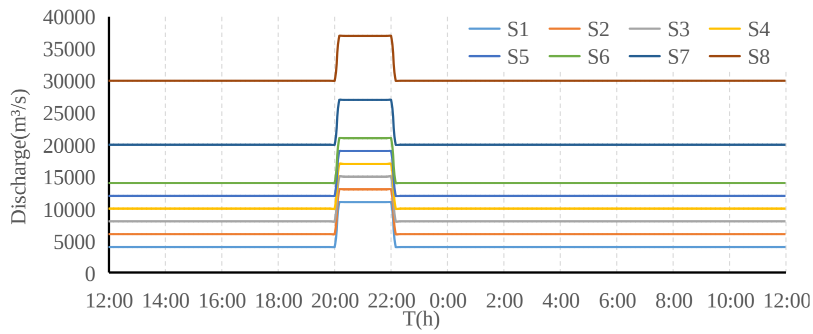


Fig. 5 Inflow process of TGD (scenarios s1–s8)

systematically analyze the effect of daily regulation of hydropower projects on the characteristics of unsteady flow, single factor analysis according to the operation characteristics of TGD and GZB was set and analyzed, wherein 30 sets of calculation conditions were set. The specific working conditions are listed in Table 1. The inflow processes (which include the base flow), the variation in discharge and the duration of peak regulation were set as the inlet boundary conditions, whereas the water level in front of GZB was set as the outlet condition.

4.2.2. Analysis of the Daily Regulation Impact

(1) Base Flow

To address the influence of the base flow released by the upper station, the base flow rate of TGD was varied from 4000 m^3/s to 30000 m^3/s, as presented in Table 1. The variation in discharge and duration of the peak regulation were fixed at 7000 m^3/s and 2 h, respectively. The water level in front of GZB was set as 63 m. Figure 5 shows the inflows for this group of calculation scenarios.

According to the spatial distribution of water levels in the reservoir, the surface elevation stabilized under a base flow of 30, 000 m^3/s until 1:00 the next day. Some distinct fluctuations were observed in the water level for a base flow of 4000 m^3/s, which lasted 24 h. Therefore, in conclusion, the base flow has a significant influence on the duration of water level fluctuation. Under the calculation conditions, the maximum daily variation of the water level meets the standard of 3 m, whereas the maximum hourly variation rises above the standard of 1 m. As shown in Fig. 6, the reach length wherein the maximum daily variation in the water level exceeds the permitted level extends as the base flow increases. As shown in Fig. 7, the channel mileage with the hourly variation of the maximum water

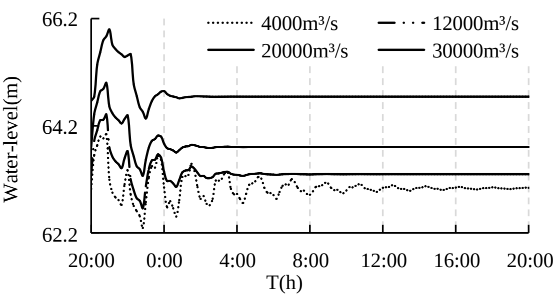


Fig. 6 Hourly change of water level (Channel mileage 40 km)

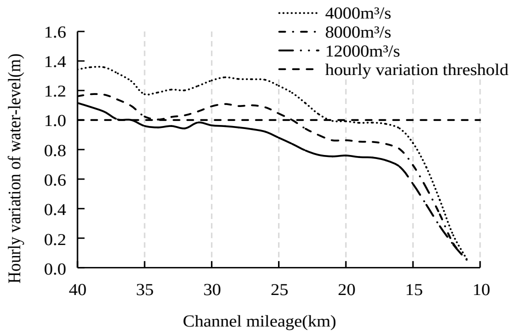


Fig. 7 Change of the water level along the channel waterway

Table 1 Calculation conditions of generalized unsteady flow process

Scenarios	Base flow (m³/s)	Water level in front of the GZB (m)	Variation in discharge (m³/s)	Duration of peak regulation (h)
S1–S8	4000, 6000, 8000, 10000, 12000, 14000, 16000, 20000, 30000	63	7000	2
S9–S13	8400	63	1000, 2000, 4000, 8000, 16000	2
S14–S18	8400	62, 63, 64, 65, 66, 67	7000	2
S19–S25	8400	63	7000	0.5, 1, 1.5, 2, 4, 8, 16
S26–S30	8400	63	7000	2

Table 2 Statistical results of the water level variation of Huangling Temple section under different initial discharge values

Initial discharge (m³/s)	Maximum daily variation (m/d)	Maximum hourly variation (m/h)
4000	1.753	1.343
6000	1.747	1.252
8000	1.748	1.161
10000	1.750	1.091
12000	1.750	1.116
14000	1.750	1.139
20000	1.734	1.198
30000	1.662	1.334
Standard	3 m	1 m

level less than 1.0 m starts from 35 km under the base flow of 12000 m^3/s and decreases to 20 km under 4000 m^3/s.

Based on the simulation results, the maximum daily and hourly water level variations under different base flows were statistically obtained. Because the water level fluctuation decays with the distance to TDG, results in the Huangling Temple section were used for the analysis, as presented in Table 2. The maximum daily variation of the water level under each condition was 1.662–1.753 m, whereas the maximum hourly variation of the water level was 1.091–1.334 m. The occurrence was as a trend; that is, the maximum daily variation of water level decreased as the base flow increased. However, an inflection point of the maximum hourly variation existed when the base flow was 10000 m^3/s.

(2) Variation of Discharge

Calculation scenario settings to analyze the effect of the variation of discharge were S9~S13 listed in Table 1. The variation of discharge of the inflow was set as 1000m³/s, 2000m³/s, 4000m³/s, 8000m³/s and 16000m³/s based on the operation-scheduling mode of the TGD. The base flow, the duration of the peak regulation, as well as the water level in front of the GZB was fixed. Inflows for this group of calculation scenario is shown in Fig. 8.

According to the simulation results, the discharge variations did not cause a difference in the fluctuation duration between the two dams, unlike the effect of the base flow (Fig. 9). Moreover, owing to the attenuation of water level fluctuation along the channel, the daily and hourly maximum water level variations of each section

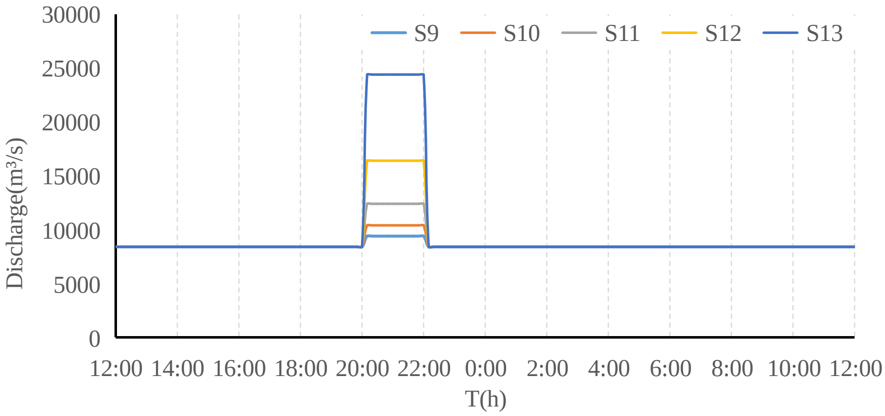


Fig. 8 Inflow process of TGD (scenarios S9–S13)

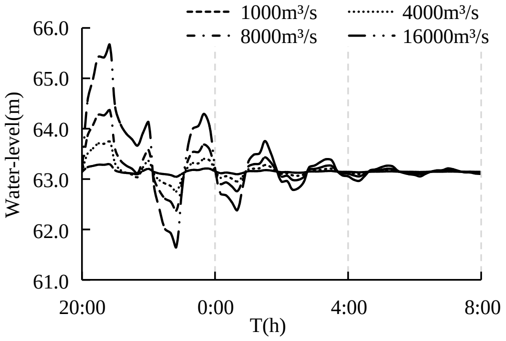


Fig. 9 Spatial variation of the water level under each scenario (Huangling Temple section)

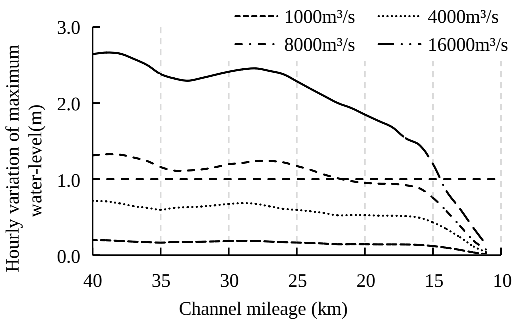
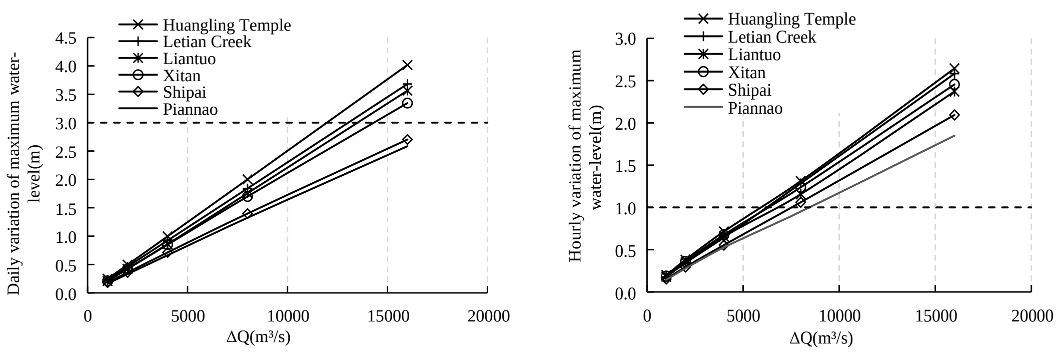


Fig. 10 Spatial variation of the water level along the channel waterway



(a) Daily variation of maximum water level ≤ 3 m

(b) Hourly variation of maximum water level ≤ 1m

Fig. 11 Relationship between water level variation and discharge variation in each typical section

exceeded the threshold of discharge, i.e., daily variation ≤ 3 m and hourly variation ≤ 1 m. Essentially, both variations decreased as the distance along TGD increased (Fig. 10). The water level variation and the discharge variation at each typical section exhibited a good linear correlation (Fig. 11). By considering the lower limit of the flow increase threshold for the section. The range of flow increase threshold for the maximum water level variation between the two dams under the calculation scenario was approximately 5914 m with an amplitude of ≤ 1 m^3/s. The threshold range for flow increase with a maximum daily variation of water level ≤ 3 m was approximately 11967 m^3/s.

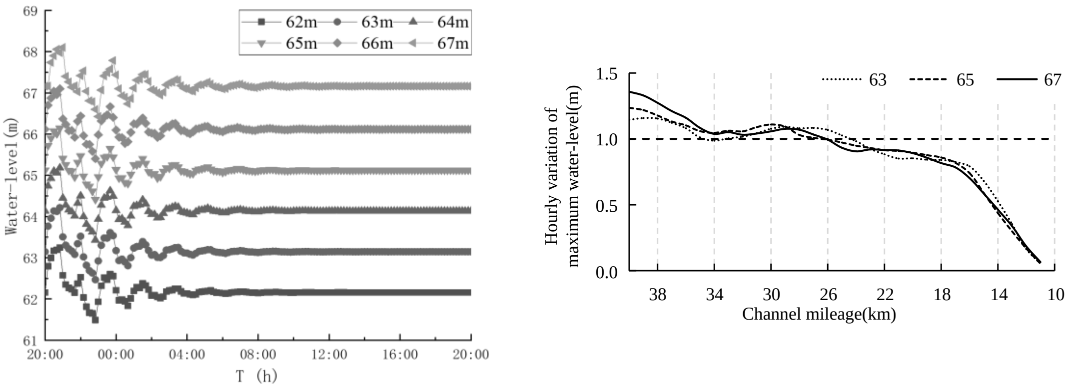
Considering the minimum of the maximum value of the increased threshold in flow at each section, the threshold range of the maximum hourly and daily variation of the water level ≤ 1 m and ≤ 3 m was 5914 m^3/s and 11,967 m^3/s, respectively, as presented in Table 3.

(3) Water Level in Front of the GZB Reservoir

The river channel is located between the two dams and is simultaneously affected by the daily and reverse regulations of the upstream and downstream hydropower stations, respectively. By setting different water levels in front of the GZB, as presented in Table 1 (listed as S19–S25), we obtained the temporal and spatial variations of the water level between the two dams (Fig. 12). In terms of the duration of the water level fluctuation, the hourly

Table 3 Calculation results of discharge variation threshold (Unit: m³/s)

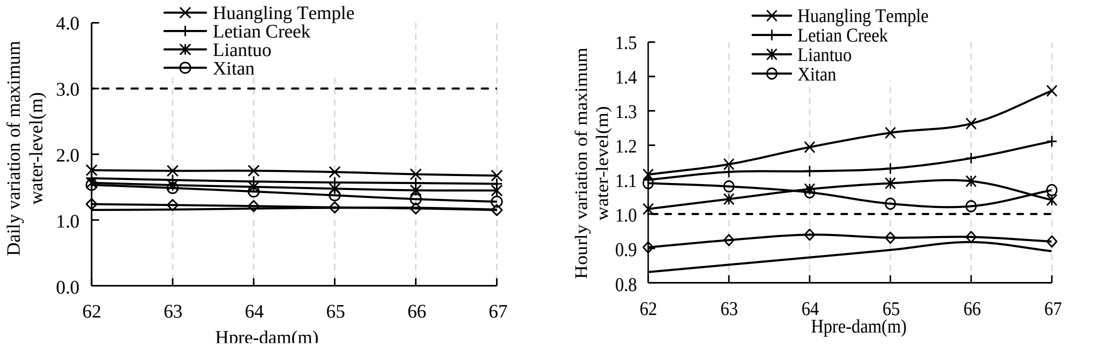
Scenarios	Huangling Temple	Letian Creek	Liantuo	Xitan	Shipai	Piannao
Daily variation of maximum water level ≤ 3 m	11967	12345	12426	12857	17819	18632
Hourly variation of maximum water level ≤ 1 m	5914	6222	6750	6308	7521	8466



(a) Huangling Temple section

(b) Hourly variation of maximum water level along the channel

Fig. 12 Temporal and spatial variation processes of different water levels in front of the GZB reservoir



(a) Daily variation of maximum water level ≤ 3 m

(b) Hourly variation of maximum water level ≤ 1 m

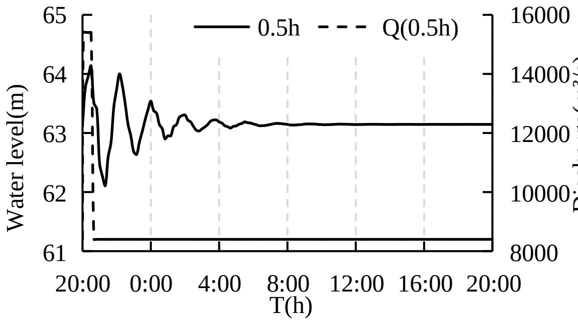
Fig. 13 Maximum water level variation in each typical beach section at different water levels in front of the GZB reservoir

variation process of the water level in the Huangling Temple section exhibited a similar change process. From the perspective of spatial change, the amplitude of the water level fluctuation decreased as the distance from

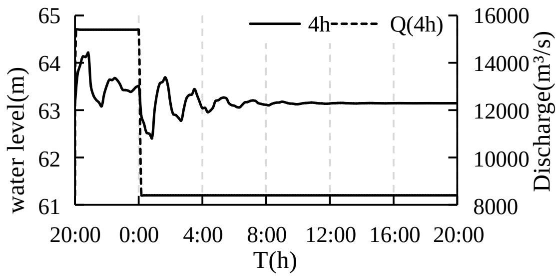
GZB decreased, whereas the change in water level in front of GZB did not impact the mileage range of water level fluctuation exceeding the threshold. The water level in front of the GZB had little influence on the duration and spatial range of the water level fluctuation. In the calculation scenario, the daily variations of water levels between the two dams were lower than 3 m, as shown in Fig. 13 (a). As the water level in front of the dam increased, the maximum daily variation of the water level in each typical section decreased linearly, whereas the maximum hourly variation of the water level in the river reach above Xitan was greater than 1 m; further, an increasing trend was observed as the water level in front of the GZB increased, as shown in Fig. 13(b).

(4) Duration of Peaking

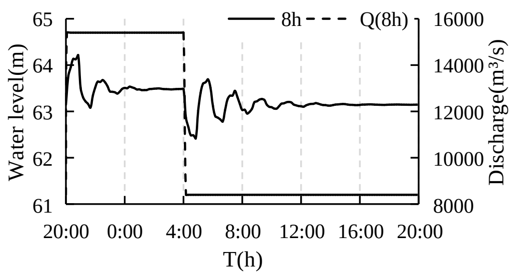
The water level variations with the duration of peak regulation under different operating scenarios, denoted by



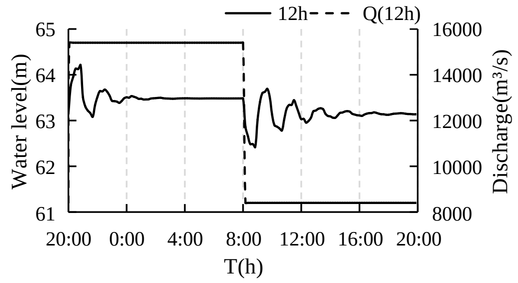
(a) 0.5 h



(b) 4 h

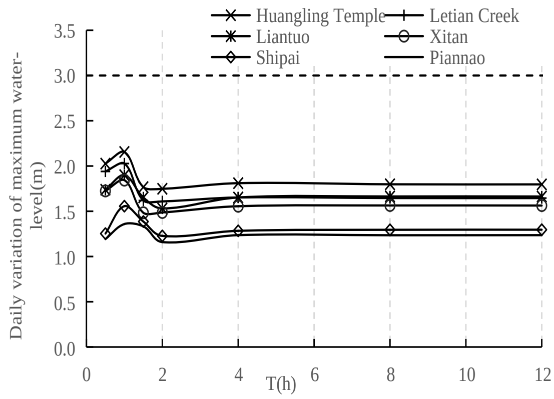


(c) 8 h

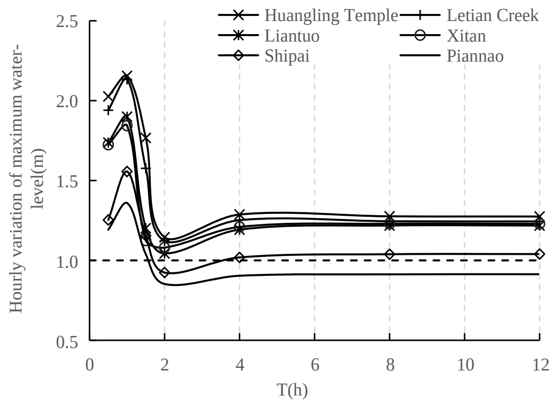


(d) 12 h

Fig. 14 Processes of water level change between two dams under different peaking duration



(a) Daily variation



(b) Hourly variation

Fig. 15 Relationship between the water level variation and duration of peak shaving

S26–S30, were compared. Evidently from Table 1, the daily and hourly variation of the maximum water level first increased, and then decreased and stabilized as the peaking duration increased (Fig. 14). In this group of calculation scenarios, the maximum peak duration of 1 h under the maximum variation of the water level at each section was determined. When the peak duration was ≥ 2 h, the water level variation decreased. As the duration of the water level increased, the variation was maintained owing to the existence of a critical peak duration time that leads to the maximum variation of the water level, which is influenced by the reservoir storage capacity. When the peak duration is extended appropriately, it can reduce the variation of the water level to a certain extent, as shown in Fig. 15.

Effect of Daily Regulation on Unsteady Flow Characteristics in the Reservoir Region

According to the actual daily regulation process of the hydropower project, the water level of each section between the two dams fluctuated to a certain extent as the TGD and GZB outflow changed. From a temporal point of view, when the outflow from TGD was greater than the outflow from GZB, the water level at each section increased, and vice versa. Further, the change in the water level between the two dams was simultaneously regulated by the upstream and downstream hydropower projects. The fluctuation of the water level presented a certain attenuation effect as mileage from the TGD site increased. The changes in the water level and velocity in each typical beach section were similar to the overall trend of the outflow process of the Three Gorges Reservoir; however, a certain temporal delay was noted, which fluctuated up and down in a certain period of time.

The amplitude of the water level change was affected primarily by the amplitude of peak regulation and duration of peak regulation. A significant linear correlation was observed between the amplitudes of the water level change and the peak regulation. According to the standard of the water level change between the two dams (daily amplitude ≤ 3 m, hourly amplitude ≤ 1 m), the increasing thresholds of daily regulation discharge of the TGD under the calculation scenario in this study were 11967–18632 m^3/s and 5914–8466 m^3/s, respectively. Although the base flow exhibited a relatively small effect on water level variability, it had a significant effect on the time-domain distribution of water level fluctuations. Additionally, owing to the influence of reservoir storage, a critical time existed for the influence of the peak regulation duration on water level variation, thus resulting in the maximum water level variation. When the peak regulation duration is appropriately extended, the water level variation can be reduced to a certain extent.

5. Conclusions

This study evaluated the influence of daily regulation of hydropower stations on the propagation characteristics of unsteady flow in the reservoir region. The 38-km long reach between the TGD and GZB reservoirs was considered as the research object. Based on experimental research, the main influencing factors of daily regulation on the characteristics of unsteady flow were identified. The generalized unsteady flow process was simulated and analyzed by using the two-dimensional shallow water equation. Furthermore, the daily variation and hourly variation of the channel water level in the reservoir region were analyzed in detail. The results showed that the unsteady flow characteristics in the reservoir region were affected primarily by the variation and duration of peak regulation during the daily regulation of the power station. Although the base flow and water level in front of the reverse regulation hydropower station had little influence on the variation in water level fluctuation, it had a significant influence on the duration and range of fluctuation. To ensure the navigation safety of the channel in the reservoir region, the daily regulation process of the power station must set the peak regulation variation reasonably and control the peak regulation time reasonably according to the storage capacity of the reservoir region.

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Conflict of Interest

No potential conflict of interest was reported by the authors.

Authors Contribution

All authors contributed to the conception and design of the study; L. Y. Xie, C. H. Xie performed the experiment; P. Y. Zhou, Q. Ma contributed significantly to analysis and manuscript preparation; H. C. Xue performed the data analyses and wrote the manuscript; P. Y. Peng, X, J, Zhang helped perform the analysis with constructive discussions.

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