TU Delft

Delft University of Technology

Document Version
Final published version

Licence
Dutch Copyright Act (Article 25fa)

Citation (APA)
Chen, Y., Hu, S., Yang, Y., Cui, K., Zhu, C., Zhang, M., Zhang, Y., Li, C. X., Mohapatra, S., Jiang, P., & Tong, X. (2026). Modelling and assessing eutrophication and antibiotic risks in a lake system under large-scale water diversion. *Journal of Hydrology*, *671*, Article 135255. https://doi.org/10.1016/j.jhydrol.2026.135255

Important note
To cite this publication, please use the final published version (if applicable).
Please check the document version above.

Copyright
In case the licence states “Dutch Copyright Act (Article 25fa)”, this publication was made available Green Open Access via the TU Delft Institutional Repository pursuant to Dutch Copyright Act (Article 25fa, the Taverne amendment). This provision does not affect copyright ownership.
Unless copyright is transferred by contract or statute, it remains with the copyright holder.

Sharing and reuse
Other than for strictly personal use, it is not permitted to download, forward or distribute the text or part of it, without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license such as Creative Commons.

Takedown policy
Please contact us and provide details if you believe this document breaches copyrights.
We will remove access to the work immediately and investigate your claim.

This work is downloaded from Delft University of Technology.

Journal of Hydrology 671 (2026) 135255

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Research papers

Modelling and assessing eutrophication and antibiotic risks in a lake system under large-scale water diversion

Yihan Chen [a,b], Shuanggang Hu [a], Yongjie Yang [a], Kangping Cui [a,b,*], Chao Zhu [c], Min Zhang [c], Youde Zhang [d], Chen-Xuan Li [a,b], Sanjeeb Mohapatra [e], Peng Jiang [f], Xuneng Tong [g,**]

[a] School of Resources and Environmental Engineering, Hefei University of Technology, Hefei 230009, China
[b] Anhui Engineering Research Center of Industrial Wastewater Treatment and Resource Recovery, Hefei University of Technology, Hefei 230009, China
[c] Anhui Ecological and Environmental Monitoring Center, Hefei 230071, China
[d] Anhui Xinyu Environmental Sci-Tech Co., Ltd, Hefei 230041, China
[e] Department of Water Management, Faculty of Civil Engineering and Geosciences, Delft University of Technology, P.O Box 5048, 2600 GA Delft, the Netherlands
[f] Department of Industrial Engineering and Management, Business School, Sichuan University, Chengdu 610064, China
[g] School of Energy and Environment and State Key Laboratory of Marine Environmental Health, City University of Hong Kong, Hong Kong SAR, China

ARTICLE INFO

This manuscript was handled by Huaming Guo, Editor-in-Chief, with the assistance of Xiaolang Zhang, Associate Editor

Keywords:
Water diversion project
Hydrodynamic-environmental model
Risk assessment
Antibiotics
Eutrophication
Water quality management

ABSTRACT

Water diversion projects are widely implemented to address water scarcity, improve water quality, and restore ecological conditions in degraded aquatic systems. This study applies a process-based hydrodynamic-environmental model to investigate the dynamics of eutrophication and the representative antibiotic tetracycline in Chaohu Lake under the influence of the Yangtze–Chaohu Water Diversion Project. To explore the influence of different diversion pathways, two numerical scenarios were developed representing two alternative water diversion options: western and eastern routes. The model was validated against field data, achieving Nash–Sutcliffe efficiency values ranging from 0.34 to 0.80 and absolute relative differences between 9.31% and 18.64%, indicating satisfactory performance. Assessment results revealed that tetracycline posed high ecological risks during summer, while nutrient concentrations and eutrophication levels remained within mild to moderate ranges throughout the study period. Comparison of the two scenarios indicated that the western route more effectively reduced ecological risks, yielding annual reductions of 9.12% in total phosphorus, 13.68% in chlorophyll-a, and 11.5% in tetracycline concentrations. This study provides critical insights for optimizing the operation of water diversion projects and supports the sustainable management of aquatic ecosystems, particularly in mitigating the combined threats of eutrophication and antibiotic pollution.

1. Introduction

Rapid urbanization has exacerbated industrial wastewater and domestic sewage discharges into Chaohu Lake, particularly around the inlet estuary, significantly impairing its ecological functions (Li et al., 2019a). The large agricultural area within the Chaohu catchment also aggravates the pollution from the land to the lake (Min et al., 2023). Eutrophication issue has plagued the water quality management of Chaohu Lake in the last several decades (Kong et al., 2017).

The Water Diversion Project (WDP) is a general infrastructure initiative designed to achieve specific goals, such as redistributing water to address shortages in water-deficient regions (Li et al., 2016). Such projects can be implemented to improve water quality by introducing large amounts of clean water to the reservoirs (Zhang et al., 2022). This process dilutes the concentration of pollutants, accelerates the flow rate, and reduces the residence time of water in lakes, thereby restoring the water quality (Fu et al., 2022). Generally, WDPs aimed at improving water quality focus on general water quality issues, with eutrophication being the most prevalent (Yan et al., 2024). A representative WDP for water quality improvement in lakes is the 'Yangtze-Taihu Water Diversion Project' via the Wangyu River in China, which has been operational since 2002. Over the past two decades, the eutrophication problem in Taihu Lake has continuously improved, and the water diverted volume has steadily increased (Li et al., 2013).

* Corresponding author at: School of Resources and Environmental Engineering, Hefei University of Technology, Hefei 230009, China.
** Corresponding author at: School of Energy and Environment and State Key Laboratory of Marine Environmental Health, City University of Hong Kong, Hong Kong SAR, China.
E-mail addresses: cuikangping@hfut.edu.cn (K. Cui), xuneng.tong@cityu.edu.hk (X. Tong).

https://doi.org/10.1016/j.jhydrol.2026.135255
Received 11 January 2026; Received in revised form 27 February 2026; Accepted 2 March 2026
Available online 6 March 2026
0022-1694/© 2026 Elsevier B.V. All rights are reserved, including those for text and data mining, AI training, and similar technologies.

To mitigate the eutrophication issue in Chaohu Lake, the large-scale 'Yangtze River to Chaohu Lake Water Diversion Project' (YCWDP) was launched in 2016 and began trial operation in 2022. While its primary purposes are to supply water for residents and develop shipping, the project will also support agricultural irrigation and improve the ecological environment of Chaohu Lake (Peng et al., 2021; Wang et al., 2023). Currently, the YCWDP proposes two routes: the Eastern option (Route 1), which channels water through the Zhao and Baishitian Rivers and exits via the Yuxi River; and the Western option (Route 2), which requires pumping to direct water through the Pai River into the Huai River.

In addition to eutrophication, Chaohu Lake is also plagued by the issue of emerging contaminants (ECs), which pose relatively high ecological risks (Tang et al., 2015). The persistent nature of some chemicals used for diverse purposes in daily life, such as pharmaceutical and personal care products, endocrine-disrupting compounds, and artificial sweeteners, forms the primary categories of ECs (Mohapatra et al., 2023; Ngoc Han et al., 2018; Tong et al., 2021). Among pharmaceuticals, antibiotics are extensively used for treating bacterial infections and promoting livestock growth (Tong et al., 2024). Numerous studies have reported higher levels of antibiotics in Chaohu Lake compared to other lakes in China (Liu et al., 2018; Zhou et al., 2022). Among these, tetracycline stands out as a commonly detected and environmentally persistent antibiotic in Chaohu Lake (Zhou et al., 2022). Moreover, the ecological concern is compounded by the widespread occurrence of tetracycline resistance genes, which have been reported at high detection frequencies in Chaohu Lake and other freshwater systems across China (Liu et al., 2018). Tetracyclines are among the most widely used veterinary drugs and feed additives in China's aquaculture and livestock industries, with an annual usage of over 10,000 tons (Hu et al., 2008). Given its environmental persistence, ecological risks, and association with antibiotic resistance, tetracycline represents a critical target for management in Chaohu Lake.

The previous studies of the occurrence of antibiotics and their potential impacts on ecosystems commonly centers around sampling activities and laboratory analysis (Tong et al., 2022). However, field sampling activities for monitoring purposes are costly, time-consuming, and hard to sustain (Stock et al., 2019). Furthermore, limited sampling points for a few sites in a large water body make it difficult to comprehensively interpret the dynamic distribution of pollutants across the entire study area in terms of time and space (Chapra, 2008). Therefore, numerical simulation of the fate and transport of pollutants has become an indispensable tool for investigating the fate and transport of ECs in the aquatic environment (Tong et al., 2025). However, current hydrological models (e.g., SWAT, Delft3D, MIKE series) continue to face challenges in studying ECs. A primary limitation is that many frameworks model the fate of ECs in isolation, failing to capture their complex kinetics and interactions with co-occurring environmental stressors, such as algal blooms. While integrated approaches have been developed by extending traditional eutrophication modules with EC mechanisms like adsorption and degradation (Tong et al., 2022), they often lack the dynamic coupling needed to simulate synergistic effects, leading to biases in assessing combined risks, for instance, between eutrophication and antibiotics.

Recent modelling studies have investigated the effects of the YCWDP on general water quality index improvements (e.g., nutrients, dissolved oxygen, and Chlorophyll-a) and demonstrated its positive feedback (Peng et al., 2021; Wang et al., 2023). However, the influence of the YCWDP on the transport, fate, and environmental risks of antibiotics in this eutrophic lake remains largely unexplored. Therefore, a modelling study is essential to investigate how, and to what extent, the YCWDP under different routing scenarios affects the spatiotemporal distribution of antibiotics in Chaohu Lake.

This study aims to assess the dynamics of eutrophication, the representative antibiotic tetracycline, and the associated ecological risks in Chaohu Lake under the influence of the YCWDP, using a process-based hydrodynamic–environmental model. The model simulates hydrodynamic and biogeochemical processes related to both eutrophication and antibiotic behavior and is calibrated against key environmental parameters obtained from field sampling campaigns. This study assesses two principal environmental risks in Chaohu Lake: (1) eutrophication status, quantified using the Trophic Level Index (TLI) and the Carlson Trophic State Index (TSI); and (2) ecological risks from antibiotic contamination, which encompass direct toxicological effects and the potential for antimicrobial resistance (AMR) development. Finally, two numerical scenarios were designed to compare the responses of eutrophication and antibiotic-related ecological risks under two potential water diversion routes of the YCWDP. These scenarios allow for an assessment of how different inflow pathways influence the spatiotemporal distribution of nutrients and antibiotics in Chaohu Lake, offering valuable insights for optimizing water diversion strategies and mitigating environmental risks.

2. Materials and methods

2.1. Sampling and environmental dataset

The study area, Chaohu Lake, is one of the five largest freshwater lakes in China (Fig. 1). It primarily receives water from 10 tributaries within its catchment area (He et al., 2023). Detailed land use within the Chaohu basin is shown in Fig. S1. The lake is divided into the western and eastern lakes, separated by Mushan Island. Correspondingly, the rivers entering the lake are categorized as western rivers and eastern rivers. The sampling campaign was conducted in tributaries (R1-R10) and lakes (L1-L20) from January to December 2021. Table S1 provides specific details about these sampling points. The monthly samples were analyzed for general water quality parameters, including Temperature (Temp), Dissolved Oxygen (DO), Chlorophyll-a (Chla), Total Nitrogen (TN), and Total Phosphorus (TP). Temperature data were measured on-site using a portable multifunctional sonde. 5-liter water samples were collected and stored in amber plastic bottles, placed in an ice box, and then immediately transported to the laboratory for chemical analysis. The water samples were filtered through a 0.45 μm glass fiber membrane upon arrival. The filtered samples were subsequently analyzed for Chla, TN and TP according to standard methods (Bureau, 2002). Target antibiotic, tetracycline, was analyzed using solid-phase extraction followed by high-performance liquid chromatography-tandem mass spectrometry (SPE-HPLC/MS/MS). Detailed information on the watershed geography, sampling campaigns, and detection of antibiotics and water quality indicators can be found in the Supplementary Materials (Text S1) and previous studies (Hu et al., 2024).

2.2. Modelling framework

Overview of the modeling framework: A coupled 3D hydrodynamic-eutrophication-antibiotics-risk assessment (HEAR) model was developed based on the Delft3D software suite (https://oss.deltares.nl/web/delft3d). The integrated framework couples sequential hydrodynamic, eutrophication, antibiotics and ecological risk modules (conceptualized in Fig. 2 and detailed steps is shown in Fig. S2). The model was applied to Chaohu Lake, China, employing a boundary-fitted orthogonal curvilinear grid with a spatial resolution of approximately 150 m (360 × 220 cells). Grid generation and bathymetric interpolation were performed using the Delft3D-RGFGRID and QUICKIN modules, ensuring geometric accuracy and orthogonality (Fig. S3). The simulation period spanned January to December 2021, concurrent with comprehensive field monitoring. The time step of one hour was adopted to balance computational stability and detail.

Hydrodynamic Forcing and Configuration: Hydrodynamic processes were simulated using the Delft3D-FLOW module, which solves the unsteady shallow-water equations. The model domain incorporated ten open boundaries, representing major tributary inflows and the lake

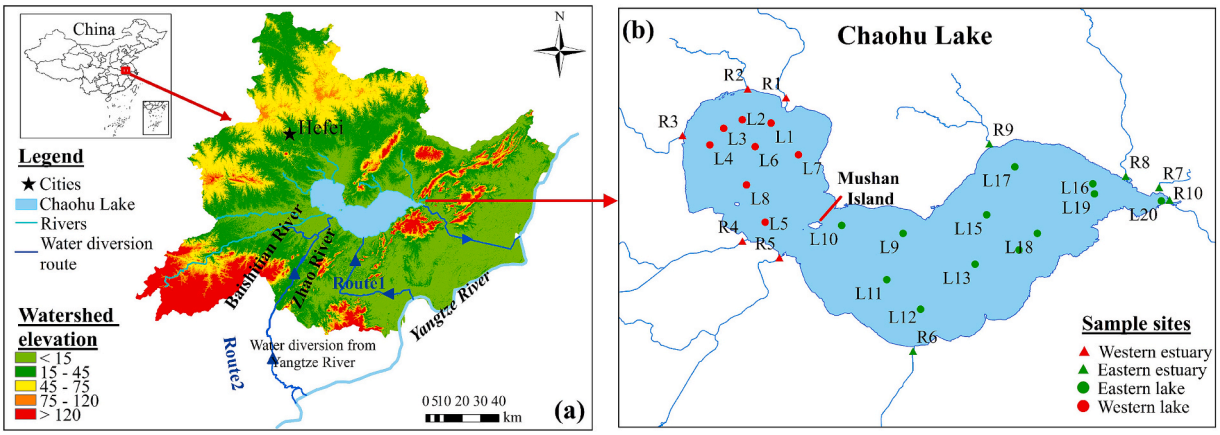

Fig. 1. The study area, routes of the Yangtze River to Lake Chaohu Water Diversion Project (YCWDP), and sampling sites are depicted. Blue arrows indicate the flow direction of the eastern (Route 1: Zhaohe River, R6) and western (Route 2: Baishitian River, R6) routes of the YCWDP. Western samples are marked in red, while eastern samples are marked in green. Sampling sites in lakes and rivers are represented by circles and triangles, respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

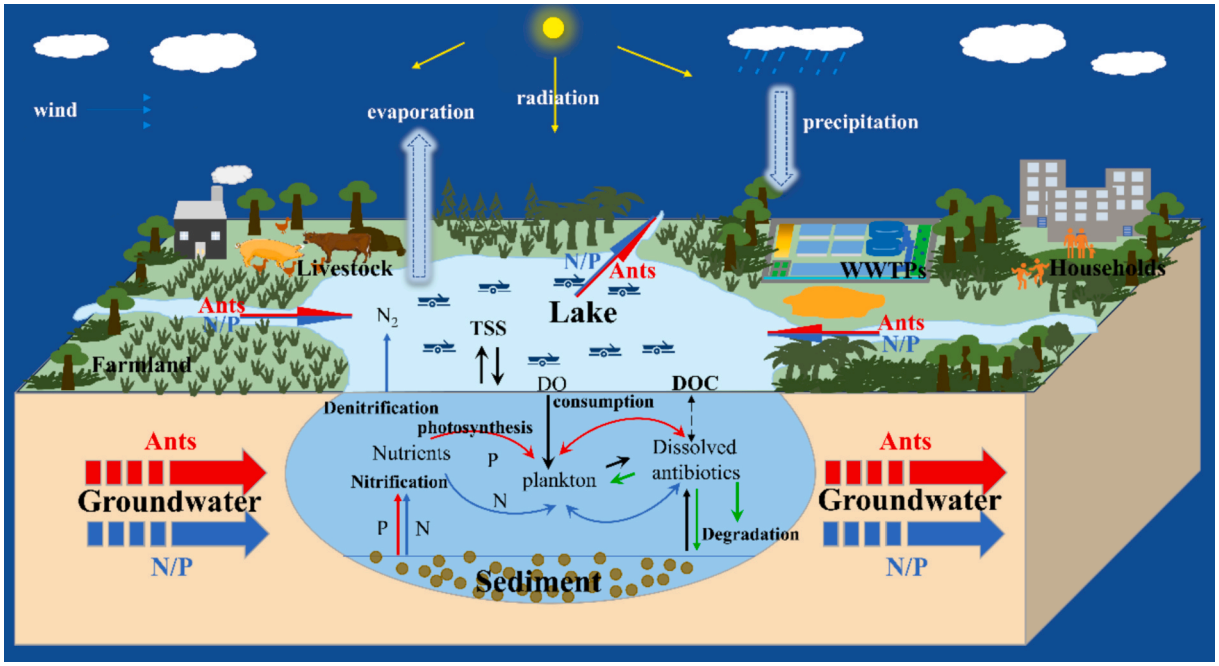

Fig. 2. The conceptual diagram of the modelling framework.

outlet. Upstream boundaries were forced with daily discharge time series, while the downstream boundary was prescribed with observed water level series, both derived from 2021 monitoring data. Meteorological forcing including wind speed/direction, solar radiation, air temperature, and relative humidity was obtained from the National Meteorological Science Data Center (https://data.cma.cn/en). The resultant flow and transport fields provided the physical foundation for subsequent biogeochemical simulations. Details on the hydrodynamic module, including data sourcing, governing equations, and model parameters, can be found in the Supplementary Materials.

Eutrophication Processes: Water quality processes were simulated with the Delft3D-WAQ module, which solves advection–diffusion-reaction equations for multiple interacting constituents. The eutrophication sub-model tracks key state variables: multiple species of nitrogen and phosphorus, phytoplankton biomass, dissolved oxygen, and organic carbon pools. Core biogeochemical processes represented include phytoplankton growth (limited by nutrients and light), basal metabolism, mortality, sedimentation, and nutrient transformations (mineralization, nitrification, denitrification). The system dynamically resolves the coupling between the nitrogen, phosphorus, and carbon cycles, with growth optimized under stoichiometric and kinetic constraints at each time step. The governing reaction network and associated kinetic parameters are cataloged in Table S2.

Antibiotic Fate Processes: Tetracycline was selected as the model antibiotic for this study based on a prior comprehensive risk assessment of the Chaohu Lake basin (Hu et al., 2024), which identified it as a high-priority contaminant exhibiting consistently high ecological risk levels, comparable to or exceeding those of other major antibiotic classes such as sulfonamides and fluoroquinolones (see Fig. S4). Its environmental fate is governed by partitioning and degradation. Sorption to organic phases including particulate organic carbon (POC), dissolved organic carbon (DOC), and phytoplankton was modeled as an instantaneous linear equilibrium process, defined by an organic-carbon-based partition coefficient. Overall antibiotic removal was represented as a pseudo-first-

order degradation process, aggregating photolytic, hydrolytic, and microbial pathways, with a temperature-dependent rate constant. It should be noted that tetracycline, as an amphoteric compound, exhibits pH-dependent adsorption characteristics and may demonstrate nonlinear behavior under high concentration conditions. Given the relatively stable pH range (7.8–8.3) observed in Lake Chaohu during the monitoring period and the trace-level detection concentrations of tetracycline (ng/L), the errors introduced by the linear adsorption assumption are expected to remain within acceptable bounds for the scale of this study. The governing equations for sorption and degradation are provided in Table S3. The substance was implemented in Delft3D-WAQ by adapting a structurally analogous organic micropollutant template from the process library, with reactions focused on transport, phase partitioning, and decay.

Environmental Risk Assessment: Integrated environmental risk was assessed using a multi-tiered framework, quantifying eutrophication status, direct ecotoxicological effects, and the potential for antimicrobial resistance (AMR) selection. (1) The eutrophication risk was assessed via two common eutrophication indexes: the trophic level index (TLI) (Burns et al., 1999) and the Carlson trophic status index (TSI) (Carlson, 1977). Standard interpretations of trophic level are as follows: TLI $<$ 30, TSI $<$ 40, oligotrophic; 30 $<$ TLI $\leq$ 50, 40 $<$ TSI $\leq$ 50, mesotrophic; 50 $<$ TLI or TSI $\leq$ 60, mild eutrophic; 60 $<$ TLI or TSI $\leq$ 70, moderate eutrophic; and TLI or TSI $>$ 70, hypereutrophic. (2) Ecotoxicological Risk: The potential for direct ecological harm was assessed using a probabilistic species sensitivity distribution (SSD) approach. The hazardous concentration for 5% of species (HC_5) was extrapolated from a log-logistic SSD curve fitted to chronic toxicity data for aquatic taxa (algae, invertebrates, plants, fish). A predicted no-effect concentration (PNEC_ECO) was derived by applying an assessment factor (AF) of 4 to the HC_5. Then, ecotoxicological risk quotient (RQ_ECO) was calculated based on the predicted antibiotic concentrations and PNEC_ECO; (3) AMR Selection Risk: To assess the risk of antibiotic concentrations selecting for resistance, we applied a predicted no-effect concentration for resistance selection (PNEC_AMR) of 1 μg L^{-1}, consistent with the threshold established by Bengtsson-Palme and Larsson (2016). Then, AMR risk quotient (RQ_AMR) was calculated based on the predicted antibiotic concentrations and PNEC_AMR. Standard risk level classifications are as follows: RQ $<$ 0.01, no risk; 0.01 $<$ RQ $<$ 0.1, low risk; 0.1 $<$ RQ $<$ 1, medium risk; RQ $>$ 1, high risk. The detailed calculation methods for environmental risk are provided in the Supplementary Materials (Supplementary Text S3).

2.3. Numerical scenarios

The modelling results represent general water quality parameters and typical antibiotic concentration levels under current conditions (Scenario A, baseline). Two water diversion scenarios were designed based on the main limiting factors and nutrient contributions observed in the lake to investigate the effects of ecological water diversion projects on eutrophication and antibiotics ecological risks. The detailed routines are presented in Fig. 1, outlining the Eastern Water Diversion Route (Scenario B, Route 1) and the Western Water Diversion Route (Scenario C, Route 2). The Eastern Route spans 74.45 km. It draws water from the Yangtze River at the Fenghuangjing Pumping Station; this flow subsequently passes through the Xihe and Zhaohe rivers before entering Chaohu Lake via the Zhaohe Sluice. The Western Route, extending 113.18 km in total, begins at the Zongyang Sluice. From there, it passes through Caizi Lake, the Kongcheng River, and the Baishitian River before reaching Chaohu Lake. Two diversion scenarios were analyzed. Route 1 extracts water from the Yangtze River at the Fenghuangjing Pumping Station, while Route 2 extracts water at the Zongyang Sluice. The corresponding water quality parameters for each intake location are detailed in Supplementary Materials Table S5. Both scenarios maintain an identical designed water diversion capacity, with an annual diversion volume of 1 billion m^3 (Huang et al., 2016). Detailed descriptions of the water diversion plans are provided in the Supplementary Materials (Supplementary Text S4). The percentage improvement in water quality (IPWQ) (Zhang et al., 2016) was calculated to evaluate the effectiveness of various water diversion projects, as shown in Eq. (1).

$$IPWQ_{i,j} = \frac{WQ_{b,j} - W_{i,j}}{WQ_{b,j}} \times 100\% \quad (1)$$

where j is the water quality variable; $WQ_{b,j}$ represents the spatial averaged water quality concentration under the baseline (scenario A); and $W_{i,j}$ is the spatial average water quality concentration under the scenario i.

3. Results and discussion

3.1. Model performance

The overall model performance with evaluation metrics is summarized in Table 1. The predicted hydrodynamic results demonstrate a commendable agreement with observed hourly water levels (Fig. S5), with an NSE of 0.80 for water level and 0.94 for water temperature, along with low RMSE and ARD values, indicating accurate predictions. Consequently, the hydrodynamic model effectively captures the authentic hydrodynamic field conditions of Chaohu Lake, making it suitable for subsequent simulations related to the eutrophication-antibiotics model. The eutrophication model was calibrated using monthly general water quality parameters (DO, Chla, TN, and TP) obtained from three representative sampling points in both the western lake (L1, L6, L8) and eastern lake (L11, L13, L16) (Fig. S6) and the measured data from other stations were used to validate the water quality model. Generally, Chla shows good model performance, with an NSE of 0.61 and an ARD of 15.56%, indicating strong predictive capability. TN, TP, and DO exhibit reasonable model performance, with NSE values of 0.46, 0.34, and 0.38, respectively, and ARD values below 25%, suggesting satisfactory predictions. All modeled substances in the eutrophication module fall within the satisfactory range, with Chla being the most accurately predicted. The antibiotics module for the selected antibiotic, tetracycline, shows excellent model performance, with an NSE of 0.68, a low RMSE of 0.23, and an ARD of 12.49%, indicating highly accurate and reliable predictions. In addition to the

Table 1
Overall model performance of hydrodynamic-eutrophication-antibiotics-risk assessment model.

Module	Variables	Metrics	Value
Hydrodynamic	Water level	NSE	0.80
		RMSE	0.13
		ARD (%)	9.31
	Water temperature	NSE	0.93
		RMSE	2.31
		ARD (%)	12.65
Eutrophication	DO	NSE	0.38
		RMSE	1.72
		ARD (%)	12,91
	Chla	NSE	0.61
		RMSE	7.05
		ARD (%)	15.56
	TN	NSE	0.46
		RMSE	0.32
		ARD (%)	18.64
	TP	NSE	0.34
		RMSE	0.01
		ARD (%)	13.73
Antibiotics	Tetracycline	NSE	0.68
		RMSE	0.23
		ARD (%)	12.49

overall performance summarized in Table 1, detailed model performance metrics are provided in Table S6. For parameters with NSE values in the range of 0.2–0.5, particularly TP (0.34), these statistical metrics must be interpreted within the context of the complex physical and biogeochemical processes governing shallow lake systems. As a large shallow lake with an average depth of only 2.7 m, Chaohu is subject to frequent wind-wave disturbances that induce sediment resuspension, causing transient, event driven fluctuations in TP concentrations that are inherently difficult to capture with monthly monitoring frequency. Additionally, internal phosphorus loading exhibits pronounced seasonal dynamics, shifting between net uptake during algal blooms and net release during post bloom decomposition, which introduces further variability that simplified model parameterizations cannot fully reproduce. The pulse characteristics of external inputs from agricultural nonpoint sources during rainfall events add another layer of complexity. Despite these challenges, the model successfully reproduces the fundamental spatial patterns (west high east low gradient) and seasonal trends of TP, and the supporting metrics (RMSE = 0.01, ARD% = 13.73) confirm that simulation errors remain within acceptable bounds. Therefore, NSE values in this range are considered satisfactory given the inherent complexity of simulating phosphorus dynamics in such highly dynamic shallow lake systems, and they provide sufficient reliability for assessing relative differences between scenarios, the primary objective of this study. The discussion on model reliability and uncertainty analysis is detailed in Supplementary Text S5.

3.2. *Predicted seasonal distribution of eutrophic-antibiotics*

The concentrations of the representative antibiotic tetracycline exhibited clear seasonal variations, likely influenced by abiotic factors such as hydrodynamic conditions, which are often driven by the combined effects of multiple external forces. Peak concentrations were observed during the summer rather than in winter (Fig. 3c), primarily due to increased antibiotic loading associated with greater rainwater influx from tributaries into the lake during the rainy season (Burns et al., 2018; Luo et al., 2011). In the Chaohu catchment, intense summer rainfall events exacerbate pollution, as substantial precipitation induces surface runoff that transports antibiotics from agricultural and urban areas into receiving rivers and lakes, leading to higher summer concentrations compared to other seasons (Liu et al., 2021). To directly address whether this summer peak is driven by increased inflow loads or by changes in degradation/dilution capacity, we quantitatively compared these contributing factors. Mass balance analysis indicates that external loading during summer months (June–August) is approximately 2.3 times higher than the winter average, primarily from agricultural runoff and wastewater inputs. Meanwhile, hydraulic dilution capacity, represented by total inflow volume, increases by a factor of 1.8 in summer due to higher precipitation and controlled water diversion releases. Antibiotic degradation rates, primarily driven by photolysis and biodegradation, are enhanced by approximately 40% under summer conditions (average water temperature 26.5 °C) compared to winter (7.2 °C). Despite enhanced dilution and degradation, the net increase in

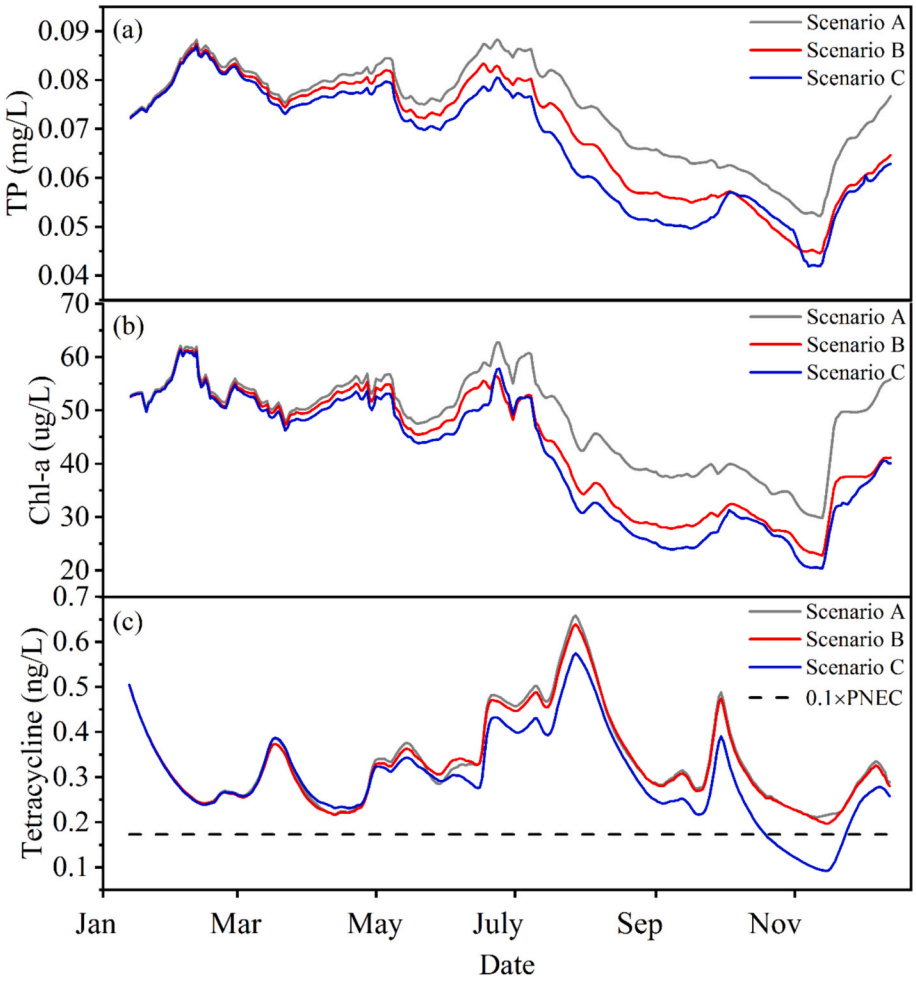

Fig. 3. Time series of average concentrations of (a) total phosphorus, (b) chlorophyll-a, and (c) tetracycline under different operation scenarios of the YCWDP. The gray curve represents Scenario A (Base scenario), the red curve represents Scenario B (Eastern Route), and the blue curve represents Scenario C (Western Route). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

summer concentrations confirms that the magnitude of external input elevation exceeds the combined effects of dilution and degradation enhancements. Therefore, the summer risk peak is predominantly attributed to increased external loading, though this loading is partially offset by concurrent improvements in dilution and degradation capacity.

In addition, hydrodynamic simulation results indicate lower water levels and weaker flow intensity during winter, which promote the adsorption of tetracycline onto sediments and suspended solids, enhancing its deposition from the water column into the sediment layer (Sarmah et al., 2006). Conversely, under high flow conditions in summer, previously accumulated antibiotics may be remobilized from sediments back into the water column, increasing their bioavailability (Knapp et al., 2012). This sediment resuspension mechanism acts as an amplifying factor: while external loading provides the primary material basis, internal release from disturbed sediments can contribute an estimated 15–25% of summer water column concentrations based on our sediment flux calculations, further exacerbating the summer peak. Wind is another key factor influencing hydrodynamics in shallow lakes (Jalil et al., 2018). The wind patterns for the study region are shown in the wind rose diagram in Fig. S7. The momentum and energy generated by wind-induced currents are transmitted both horizontally and vertically, affecting pollutant advection, diffusion, vertical mixing, and sediment resuspension (Li et al., 2017). Consequently, strong summer winds can further enhance the resuspension of antibiotics, contributing to elevated concentrations during this period. Thus, the summer high risk can be attributed to a hierarchical mechanism: elevated external loading serves as the fundamental driver, while sediment resuspension acts as a secondary amplifier, and enhanced degradation/dilution functions as a partial offset that is ultimately overwhelmed. Furthermore, high summer temperatures promote the activity of pathogenic microorganisms, potentially increasing the use of antibiotics in the livestock and poultry industries for growth promotion and disease prevention (Luo et al., 2010). To sum up, summer high risk is primarily attributable to the synergistic effects of peak external inputs and intensified internal release, rather than any single factor. This understanding provides guidance for developing season-specific regulatory strategies during the rainy season, emphasis should be placed on controlling non-point source inputs, while during windy periods, attention should be directed to the potential impacts of sediment disturbance. The concentration increase observed from March to May was likely attributed to spring farming and irrigation activities, which increase agricultural drainage compared to winter levels. Concurrently, relatively low precipitation during early spring (accounting for only 23% of the annual average) and decreased lake water levels (0.52 ± 0.20 m lower than the wet season) significantly enhance pollutant concentration effects. The peak observed between September and November coincides with discharges from aquaculture pond dredging activities, characterized by increased antibiotic application, while reduced autumn precipitation (24.4% lower than summer levels) weakens the dilution capacity. This leads to an extended water renewal cycle and substantially diminished self-purification capacity.

The high frequency of algal bloom outbreaks was predicted in lakes during the summer, where the eutrophication model predicted the highest Chla level in summer, reaching nearly 70 μg/L (Fig. 3), respectively. Temperature and nutrient availability are recognized as two important factors driving algal blooms in this study, as positive correlations were found between temperature, TP, and Chla. As lakes warm from winter to summer, they undergo changes in physical processes (Li et al., 2019b), biological processes (e.g., growth and respiration of aquatic organisms (Van de Waal et al., 2010), and biochemical transformations of nutrients (e.g., mineralization, denitrification) (Wu et al., 2017). These changes collectively influence the overall functioning of aquatic ecosystems, potentially creating an environment conducive to the growth of certain phytoplankton species, such as cyanobacteria. Additionally, water temperature is crucial in initiating internal nutrient cycling, transforming lake sediments from a phosphorus sink in the overlying water during winter and spring to a phosphorus source in summer and autumn (Wang et al., 2019). During the summer, increased rainfall intensifies surface runoff from the surrounding catchment, particularly from agricultural areas where phosphorus-containing fertilizers are extensively applied (Wang et al., 2015). This hydrological process facilitates the transport of phosphorus and other nutrients into the lake, leading to elevated nutrient concentrations in the water column. The influx of phosphorus from agricultural runoff plays a critical role in accelerating eutrophication, thereby creating favorable conditions for the proliferation of algal blooms.

3.3. Spatial variability of eutrophication and antibiotic ecological risks

The evaluation of eutrophication levels reveals clear spatial heterogeneity, with the western part of the lake exhibiting significantly higher ecosystem stress compared to the eastern part (Fig. 4a–d). TLI values in the western lake range from 60.14 to 62.88, indicating a moderate eutrophic state. In contrast, the eastern lake shows TLI values between 54.54 and 62.05, corresponding to a mild eutrophic condition. Similarly, TSI values in the western lake range from 68.08 to 70.57 (reaching hypereutrophic conditions in some areas), while values in the eastern lake range from 63.11 to 69.83, suggesting a moderate eutrophic state. The consistent finding of higher TLI and TSI values in the west is likely due to increased nutrient loading from its tributaries. This aligns with previous studies reporting that the annual nutrient input to the western part of Chaohu Lake is approximately twelve times greater than that of the eastern part (Yang et al., 2020). This established gradient of eutrophication provides critical context for the spatial distribution of contaminant-specific risks.

Superimposed on this eutrophic background is the contaminant-specific risk from tetracycline. The SSD curve for tetracycline (Fig. S9), constructed from chronic toxicity data across three trophic levels ($R^2 = 0.97$), yielded a hazardous concentration for 5% of species (HC_5) of 6.90 ng/L and a predicted no-effect concentration (PNEC) of 1.73 ng/L. Modeled tetracycline concentrations in the western lake range from 0.33 to 2.25 ng/L, resulting in ecological risk quotients (RQ_ECO) between 0.190 and 1.301, indicating medium to high-risk levels for direct toxicity. The highest risk occurs near the inflows from River 1 and River 2 (Fig. 1). In contrast, tetracycline concentrations in the eastern lake are lower (0.01–0.10 ng/L), with RQ_ECO values from 0.005 to 0.057, indicating predominantly low toxicological risk.

Beyond direct toxicological risk, the potential for antibiotic resistance dissemination represents a distinct environmental concern. The modeled tetracycline concentrations in Lake Chaohu yield RQ_AMR values ranging from 9.23×10^{-6} to 0.002 across the lake (Fig. 4g), indicating negligible direct chemical selection pressure for resistance under current conditions. However, the hydrodynamic transport patterns characterized in this study reveal that the operational water diversion project may facilitate the physical redistribution of antibiotics from source areas where local concentrations could be higher to other regions of the lake. This hydrodynamic pathway, combined with potential future increases in antibiotic inputs, fluctuations in usage intensity, or sediment resuspension events, could create conditions where even low antibiotic concentrations contribute to resistance development over longer time scales. While the immediate selective pressure remains minimal, these transport mechanisms warrant consideration as potential preestablished channels for resistance risk under changing environmental scenarios.

The spatial patterns of eutrophication, antibiotic toxicity, and AMR selection pressure are thus strongly correlated, with the western lake experiencing a compounded and multifaceted ecological burden (Fig. 4e and f). This pattern is directly linked to its proximity to major anthropogenic sources. The western catchment contains densely populated urban and commercial areas, including Hefei, the capital of Anhui Province, which contribute significant pollutant loads from diverse human activities via tributaries (Han et al., 2022). High population

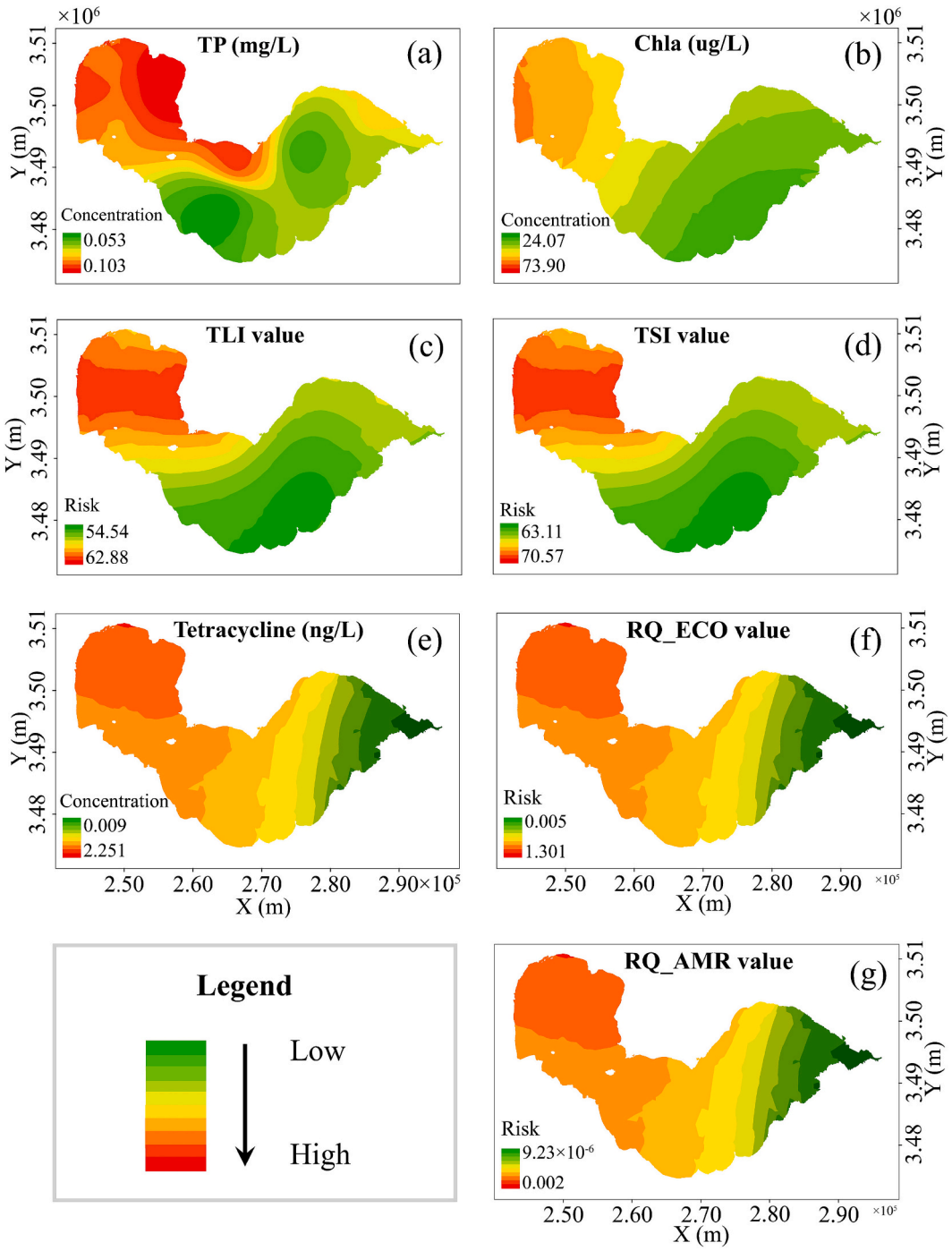

Fig. 4. Spatial distribution of (a) TP, (b) Chla, (c) TLI, (d) TSI, (e) tetracycline, (f) RQ_ECO values, and (g) RQ_AMR values on 16 August. Note: Model results from 16 August were selected to assess spatial environmental risk because both Chla and tetracycline concentrations peaked during this month (Fig. S8). This approach provides an upper-bound estimate of potential ecological risks, serving as a conservative assessment strategy.

density is a known key driver of antibiotic emissions (Zhang et al., 2020), and tetracycline contamination in this region has also been linked to veterinary drug use in the suburban breeding industry within the Shiwuli River basin (Tang et al., 2015). Consequently, the western lake is subject to a convergence of stressors: high nutrient loading driving eutrophication, substantial anthropogenic emissions driving antibiotic contamination and associated toxicological risks, and elevated concentrations posing a potential hotspot for AMR selection. This collectively defines the western region as the area of greatest integrated ecological and public health risk.

3.4. YCWDP impacts on eutrophication and ecological risk mitigation

The construction of the YCWDP has contributed to reducing TP and Chla concentrations in Chaohu Lake, thereby alleviating eutrophication. Initially, its impact on water quality was not prominent due to a delayed response in parameter changes, as observed from scenario comparisons (Fig. 3). However, over time, the operation of the YCWDP led to positive improvements in water quality, especially during the dry winter season, when relative changes in concentrations became more pronounced (Fig. 3). Specifically, TP and Chla concentrations showed a noticeable decrease after the YCWDP became operational ($P < 0.001$, Fig. 3a and

3b, and Table S7), with Scenario C exhibiting a more substantial decline compared to Scenario B. In contrast, the difference in tetracycline concentrations between Scenario A and Scenario B was negligible ($P > 0.05$). However, Scenario C displayed a notable reduction in tetracycline concentrations relative to Scenario A ($P < 0.001$, Fig. 3c and Table S7).

Risk analysis based on the SSD-RQ method indicates that water diversion in Scenario C effectively reduces the ecological risks associated with antibiotics, particularly around December 5, with the risk level being lowered by one category (from medium to low risk) after one year of operation. To enhance clarity regarding the impact of the YCWDP on the spatial distribution of risk levels, we analyzed the simulation results for December 5, which represents the final period of the simulation (Fig. 5). The results show that the TLI value for Scenario A ranges from 49.33 to 58.83, while Scenario B and Scenario C exhibit TLI values within the ranges of 45.95–54.66 and 44.78–54.09, respectively. Additionally, the TSI values for Scenario A vary between 58.43 and 66.89, whereas Scenario B and Scenario C show TSI values within the ranges of 55.49–63.19 and 54.48–62.71, respectively. The RQ_ECO values for tetracycline in Scenario A range from 0.008 to 0.420, while Scenario B and Scenario C exhibit RQ_ECO values within the ranges of 0.007–0.374 and 0.001–0.339, respectively. Overall, the water quality of Chaohu Lake has been moderately improved under the operation of YCWDP. Regionally, Scenario shows a more favorable impact on reducing comprehensive risks in the western lake compared to Scenario B.

The effectiveness of various water diversion projects was evaluated using the index of percentage improvement in water quality (IPWQ). Under Scenario B, the IPWQ values for the average concentrations of total phosphorus (TP) and chlorophyll-a (Chla) across the entire lake were 6.12% and 10.14%, respectively (Fig. 6). Correspondingly, improvements in the eutrophication status of Chaohu Lake under Scenario B reached 1.85% based on the Trophic Level Index (TLI) and 1.45% based on the Trophic State Index (TSI) (Fig. S10). In Scenario C, the IPWQ values for average TP and Chla concentrations across the lake were higher, at 9.12% and 13.68%, respectively (Fig. 6), indicating a more substantial enhancement in eutrophication status, with increases of 2.67% in TLI and 2.09% in TSI (Fig. S10). Moreover, for tetracycline, the IPWQ value in Scenario B was 1.35%, whereas Scenario C achieved a significantly higher value of 11.50% (Fig. 6). Based on the risk quotient (RQ) values, Scenario C demonstrated a more effective reduction in ecological risk from antibiotic contamination compared to Scenario B (11.50% vs. 1.35%) (Fig. S10). These results suggest that the Baishitian River water diversion route (Scenario C) is the optimal strategy for mitigating comprehensive water quality risks in Chaohu Lake.

Scenario C (Western Route), which introduces higher-quality water through the western route, led to a more pronounced reduction in TP and Chla concentrations than Scenario B. Furthermore, improvements in water quality were more significant in the eastern lake compared to the western lake. This pattern can be attributed to the predominant west-to-east flow direction of water in the offshore area of Chaohu Lake, driven by the concentration of most tributaries in the western region (Fig. 1). As a result, water diversion under Scenario C enhances hydrodynamic

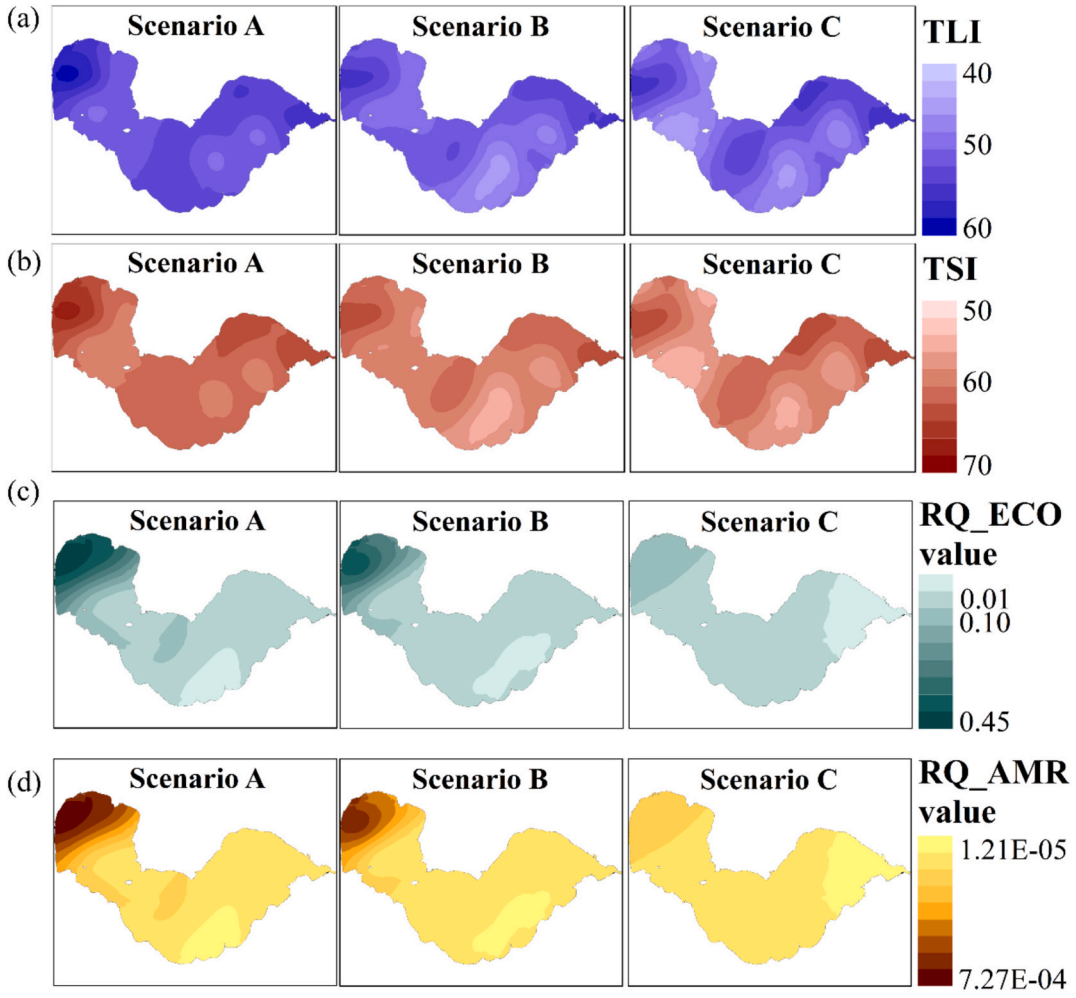

Fig. 5. Spatial distribution of (a) TLI, (b) TSI, (c) RQ_ECO values, and (d) RQ_AMR values for tetracycline under different operation scenarios of the YCWDP on December 5. Scenario A represents the base scenario, Scenario B represents the Eastern Route, and Scenario C represents the Western Route.

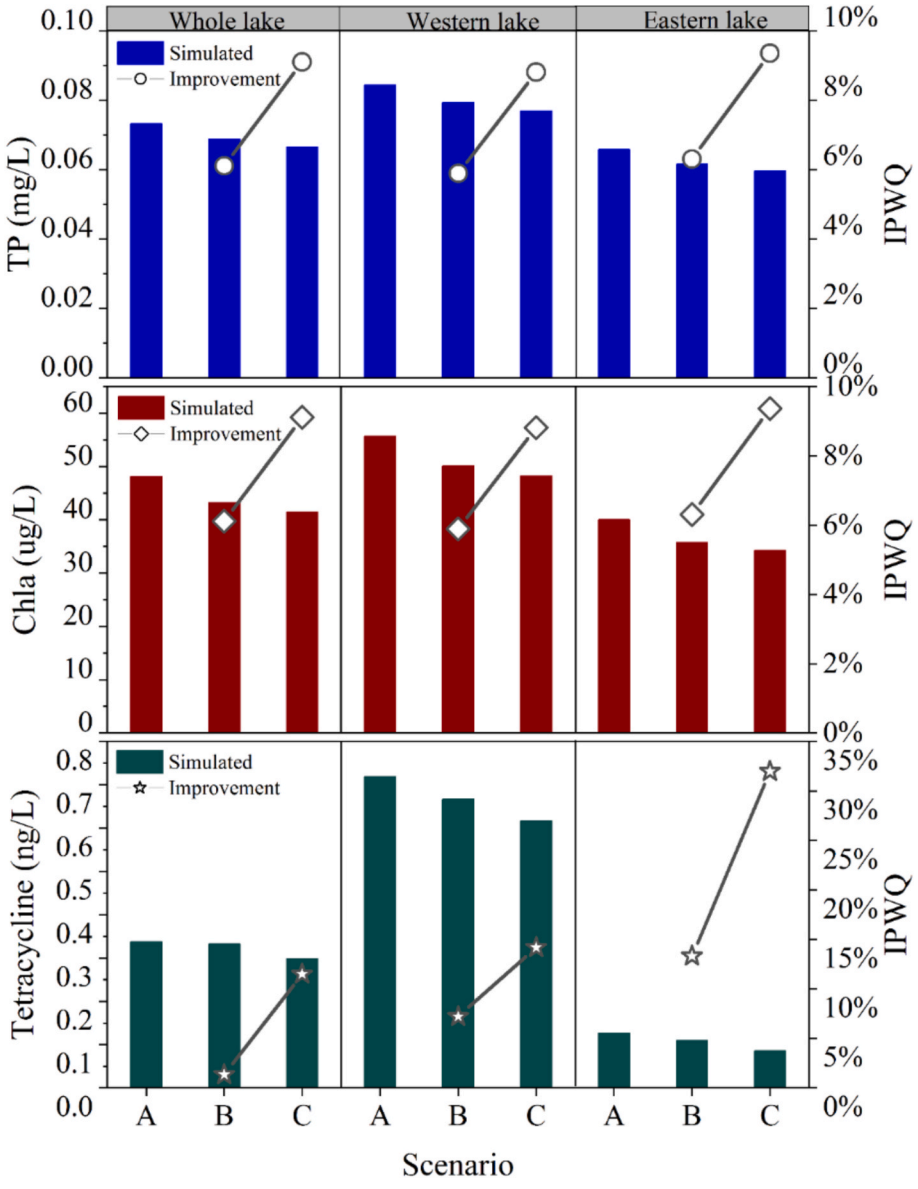

Fig. 6. Responses of the water diversion project for Chaohu Lake to water quality.

conditions in the western lake, promotes nutrient diffusion, and facilitates the downstream transport of pollutants toward the eastern lake (Fig. S11). As illustrated in Fig. S11, Route 1 creates a high velocity connectivity zone directly between the inlet and outlet, forming a hydraulic short-circuiting effect that confines water exchange to a narrow corridor. This flow pattern leaves substantial portions of the lake, particularly the eastern and western bays, with limited flushing and longer water retention, thereby reducing the efficiency of pollutant transport and dilution. In contrast, Route 2 generates a more uniform flow field structure that extends across approximately 60% of the lake surface. This broader flow distribution enhances overall water exchange, promotes mixing between inflow and ambient lake water, and facilitates the transport and dilution of both nutrients and antibiotics throughout a larger portion of the lake. The more extensive flow coverage also reduces stagnation zones and minimizes spatial heterogeneity in water quality improvement. These hydrodynamic differences provide a mechanistic explanation for the superior risk reduction performance of Route 2 observed in our simulations, as the optimized flow field enables more effective delivery of cleaner inflow water to regions that would otherwise experience limited exchange under Route 1. This hydrodynamic flushing effect contributes to the overall improvement in water quality, particularly in the western part of the lake (Peng et al., 2021). Additionally, Scenario C significantly decreased tetracycline concentrations compared to Scenario B. This may be due to initially higher tetracycline concentrations in the western lake, where the dilution effect of introduced clean water is more pronounced, effectively reducing antibiotic concentrations (Hu et al., 2024).

4. Conclusions

The model exhibited robust predictive performance across hydrodynamic, eutrophication, and representative antibiotic tetracycline simulations, as evidenced by satisfactory NSE, RMSE, and ARD values for key parameters. Simulated results indicated that the spatiotemporal distribution of tetracycline closely follows nutrient patterns, with elevated ecological risks observed during summer. Nutrient levels suggested conditions ranging from mild to moderate eutrophication. Among the evaluated scenarios, Scenario C of the YCWDP (western route) proved most effective, reducing TP and Chla concentrations by 9.12% and 13.68%, respectively. However, the improvements in TSI and

TLI were comparatively modest (2.67%), underscoring the limitations of relying solely on nutrient-based indicators to assess eutrophication status. Scenario C also achieved the greatest reduction in tetracycline concentrations (11.50%), making it the most favorable option for mitigating both nutrient and emerging contaminant risks in Chaohu Lake. These findings support the value of integrated water quality modelling in guiding hydraulic project operations and promoting sustainable aquatic ecosystem management. Given the complexity of assessing large-scale water diversion impacts, particularly constrained by limitations in characterizing sediment–water interface exchange processes, future research should prioritize more systematic analyses of water–sediment coupled system responses. In particular, the potential for secondary release of sediment-bound pollutants under altered hydrodynamic conditions warrants further investigation through long-term monitoring and dynamic sediment modules. This study establishes a transferable modeling framework (HEAR) that not only elucidates the fate and risk of tetracycline in Lake Chaohu but also provides a methodological blueprint and critical process-based insights for assessing a wider range of emerging contaminants in large lake ecosystems.

CRediT authorship contribution statement

Yihan Chen: Writing – review & editing, Writing – original draft, Funding acquisition, Conceptualization. **Shuanggang Hu:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis. **Yongjie Yang:** Writing – review & editing, Methodology, Investigation. **Kangping Cui:** Writing – review & editing, Project administration, Funding acquisition. **Chao Zhu:** Writing – review & editing, Project administration, Funding acquisition. **Min Zhang:** Writing – review & editing, Investigation. **Youde Zhang:** Writing – review & editing, Resources. **Chen-Xuan Li:** Writing – review & editing, Validation, Investigation. **Sanjeeb Mohapatra:** Writing – review & editing, Validation. **Peng Jiang:** Writing – review & editing, Validation. **Xuneng Tong:** Writing – review & editing, Writing – original draft, Validation, Supervision, Formal analysis, Conceptualization.

Declaration of competing interest

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

Acknowledgments

The authors are grateful for the financial support from the National Natural Science Youth Science Foundation of China (Grant Nos. 42007330, 72104164), the Fundamental Research Funds for the Central Universities (JZ2024HGTG0290), and the Open Project of the State Key Laboratory of Urban Water Resources and Environment (Grant No. ES202124). Dr. Xuneng Tong is also supported by Start-up Grant for New Faculty from City University of Hong Kong (9610723) and State Key Laboratory of Marine Environmental Health (SKLMEH), Innovation and Technology Commission (ITC) of the Hong Kong SAR Government (9448002).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jhydrol.2026.135255.

Data availability

Data will be made available on request.

References

Bengtsson-Palme, J., Larsson, D.G.J., 2016. Concentrations of antibiotics predicted to select for resistant bacteria: proposed limits for environmental regulation. Environ. Int. 86, 140–149.
Bureau, S.E.P., 2002. Methods for Monitoring and Analysis of Water and Wastewater. China Environmental Science Press Beijing.
Burns, E.E., Carter, L.J., Kolpin, D.W., Thomas-Oates, J., Boxall, A.B., 2018. Temporal and spatial variation in pharmaceutical concentrations in an urban river system. Water Res. 137, 72–85.
Burns, N.M., Rutherford, J.C., Clayton, J.S., 1999. A monitoring and classification system for New Zealand lakes and reservoirs. Lake Reservoir Manage. 15 (4), 255–271.
Carlson, R.E., 1977. A trophic state index for lakes 1. Limnol. Oceanogr. 22 (2), 361–369.
Chapra, S.C., 2008. Surface Water-Quality Modeling. Waveland Press.
Fu, L., Shen, Y., Zhang, H., Wang, X., 2022. Effects of water diversion projects on water environment in Chaohu Lake. Limnologica 97, 126026.
Han, M., Zhang, L., Zhang, N., Mao, Y., Peng, Z., Huang, B., Zhang, Y., Wang, Z., 2022. Antibiotic resistome in a large urban-lake drinking water source in middle China: dissemination mechanisms and risk assessment. J. Hazard. Mater. 424, 127745.
He, M., Liu, G., Wu, L., Zhou, L., Liu, Y., 2023. Spatial–temporal distribution, occurrence, water quality, and risk assessment of trace elements in ten rivers surrounding Chaohu Lake in China. Environ. Geochem. Health 45 (5), 2167–2182.
Hu, J., Shi, J., Chang, H., Li, D., Yang, M., Kamagata, Y., 2008. Phenotyping and genotyping of antibiotic-resistant *Escherichia coli* isolated from a natural river basin. Environ. Sci. Technol. 42 (9), 3415–3420.
Hu, S., Zhang, H., Yang, Y., Cui, K., Ao, J., Tong, X., Shi, M., Wang, Y., Chen, X., Li, C., 2024. Comprehensive insight into the occurrence characteristics, influencing factors and risk assessments of antibiotics in the Chaohu Basin. Front. Environ. Sci. Eng. 18 (5), 57.
Huang, J., Yan, R., Gao, J., Zhang, Z., Qi, L., 2016. Modeling the impacts of water transfer on water transport pattern in Lake Chao, China. Ecol. Eng. 95 (Complete), 271–279.
Jalil, A., Li, Y., Du, W., Wang, W., Wang, J., Gao, X., Khan, H.O.S., Pan, B., Acharya, K., 2018. The role of wind field induced flow velocities in destratification and hypoxia reduction at Meiling Bay of large shallow Lake Taihu, China. Environ. Pollut. 232, 591–602.
Knapp, C.W., Lima, L., Olivares-Rieumont, S., Bowen, E., Werner, D., Graham, D.W., 2012. Seasonal variations in antibiotic resistance gene transport in the Almendares River, Havana, Cuba. Front. Microbiol. 3, 396.
Kong, X., He, Q., Yang, B., He, W., Xu, F., Janssen, A.B., Kuiper, J.J., van Gerven, L.P., Qin, N., Jiang, Y., 2017. Hydrological regulation drives regime shifts: evidence from paleolimnology and ecosystem modeling of a large shallow Chinese lake. Glob. Chang. Biol. 23 (2), 737–754.
Li, S., Xiao, W., Zhao, Y., Xu, J., Da, H., Lv, X., 2019a. Quantitative analysis of the ecological security pattern for regional sustainable development: case study of Chaohu Basin in Eastern China. J. Urban Plann. Dev. 145 (3), 04019009.
Li, X., Peng, S., Deng, X., Su, M., Zeng, H., 2019b. Attribution of lake warming in four shallow lakes in the middle and lower Yangtze River Basin. Environ. Sci. Technol. 53 (21), 12548–12555.
Li, Y., Jalil, A., Du, W., Gao, X., Wang, J., Luo, L., Li, H., Dai, S., Hashim, S., Yu, Z., 2017. Wind induced reverse flow and vertical profile characteristics in a semi-enclosed bay of large shallow Lake Taihu, China. Ecol. Eng. 102, 224–233.
Li, Y., Tang, C., Wang, C., Anim, D.O., Yu, Z., Acharya, K., 2013. Improved Yangtze River diversions: are they helping to solve algal bloom problems in Lake Taihu, China? Ecol. Eng. 51, 104–116.
Li, Y., Xiong, W., Zhang, W., Wang, C., Wang, P., 2016. Life cycle assessment of water supply alternatives in water-receiving areas of the South-to-North Water Diversion Project in China. Water Res. 89, 9–19.
Liu, X., Lu, S., Guo, W., Xi, B., Wang, W., 2018. Antibiotics in the aquatic environments: a review of lakes, China. Sci. Total Environ. 627, 1195–1208.
Liu, X., Wang, Z., Zhang, L., Fan, W., Yang, C., Li, E., Du, Y., Wang, X., 2021. Inconsistent seasonal variation of antibiotics between surface water and groundwater in the Jianghan Plain: risks and linkage to land uses. J. Environ. Sci. 109, 102–113.
Luo, Y., Mao, D., Rysz, M., Zhou, Q., Zhang, H., Xu, L., Alvarez, J.J., 2010. Trends in antibiotic resistance genes occurrence in the Haihe River, China. Environ. Sci. Technol. 44 (19), 7220–7225.
Luo, Y., Xu, L., Rysz, M., Wang, Y., Zhang, H., Alvarez, P.J., 2011. Occurrence and transport of tetracycline, sulfonamide, quinolone, and macrolide antibiotics in the Haihe River Basin China. Environ. Sci. Technol. 45 (5), 1827–1833.
Min, M., Li, H., Ma, T., Miao, C., 2023. Will agricultural land scale management aggravate non-point source pollution?–Chaohu Lake Basin, China as a case study. Appl. Geogr. 158, 103056.
Mohapatra, S., Bhatia, S., Senaratna, K.Y.K., Jong, M.-C., Lim, C.M.B., Gangesh, G.R., Lee, J.X., Giek, G.S., Cheung, C., Yutao, L., 2023. Wastewater surveillance of SARS-CoV-2 and chemical markers in campus dormitories in an evolving COVID-19 pandemic. J. Hazard. Mater. 446, 130690.
Ngoc Han, T., Reinhard, M., Gin, K.-Y.-H., 2018. Occurrence and fate of emerging contaminants in municipal wastewater treatment plants from different geographical regions-a review. Water Res. 133, 182–207.
Peng, Z., Hu, W., Zhang, Y., Liu, G., Zhang, H., Gao, R., 2021. Modelling the effects of joint operations of water transfer project and lake sluice on circulation and water quality of a large shallow lake. J. Hydrol. 593, 125881.
Sarmah, A.K., Meyer, M.T., Boxall, A.B., 2006. A global perspective on the use, sales, exposure pathways, occurrence, fate and effects of veterinary antibiotics (VAs) in the environment. Chemosphere 65 (5), 725–759.

Stock, F., Kochleus, C., Bänsch-Baltruschat, B., Brennholt, N., Reifferscheid, G., 2019. Sampling techniques and preparation methods for microplastic analyses in the aquatic environment–a review. TrAC Trends Anal. Chem. 113, 84–92.
Tang, J., Shi, T., Wu, X., Cao, H., Li, X., Hua, R., Tang, F., Yue, Y., 2015. The occurrence and distribution of antibiotics in Lake Chaohu, China: seasonal variation, potential source and risk assessment. Chemosphere 122, 154–161.
Tong, X., Goh, S.G., Mohapatra, S., Tran, N.H., You, L., Zhang, J., He, Y., Gin, K.-Y.-H., 2024. Predicting antibiotic resistance and assessing the risk burden from antibiotics: a holistic modeling framework in a tropical reservoir. Environ. Sci. Technol. 58 (15), 6781–6792.
Tong, X., Mohapatra, S., Zhang, J., Tran, N.H., You, L., He, Y., Gin, K.-Y.-H., 2022. Source, fate, transport and modelling of selected emerging contaminants in the aquatic environment: current status and future perspectives. Water Res., 118418
Tong, X., Xiang, Z., You, L., Zhang, J., Gin, K.-Y.-H., 2025. Modelling approach to understanding the nexus of emerging contaminants, climate change, and water security. Curr. Opin. Environ. Sci. Health, 100650.
Tong, X., You, L., Zhang, J., Chen, H., Nguyen, V.T., He, Y., Gin, K.-Y.-H., 2021. A comprehensive modelling approach to understanding the fate, transport and potential risks of emerging contaminants in a tropical reservoir. Water Res. 200, 117298.
Van de Waal, D.B., Verschoor, A.M., Verspagen, J.M., van Donk, E., Huisman, J., 2010. Climate-driven changes in the ecological stoichiometry of aquatic ecosystems. Front. Ecol. Environ. 8 (3), 145–152.
Wang, J., Lü, G., Guo, X., Wang, Y., Ding, S., Wang, D., 2015. Conservation tillage and optimized fertilization reduce winter runoff losses of nitrogen and phosphorus from farmland in the Chaohu Lake region, China. Nutr. Cycl. Agroecosyst. 101, 93–106.
Wang, M., Xu, X., Wu, Z., Zhang, X., Sun, P., Wen, Y., Wang, Z., Lu, X., Zhang, W., Wang, X., 2019. Seasonal pattern of nutrient limitation in a eutrophic lake and quantitative analysis of the impacts from internal nutrient cycling. Environ. Sci. Technol. 53 (23), 13675–13686.
Wang, Y., Liu, G., Zhu, S., Hu, W., Zhang, H., Zhou, X., Peng, Z., 2023. Assessment of impacts of water transfer on lake flow and water quality in Lake Chaohu using a three-dimensional hydrodynamic-ecological model. J. Hydrol.: Reg. Stud. 46, 101333.
Wu, Z., Liu, Y., Liang, Z., Wu, S., Guo, H., 2017. Internal cycling, not external loading, decides the nutrient limitation in eutrophic lake: a dynamic model with temporal Bayesian hierarchical inference. Water Res. 116, 231–240.
Yan, X., Xia, Y., Ti, C., Shan, J., Wu, Y., Yan, X., 2024. Thirty years of experience in water pollution control in Taihu Lake: a review. Sci. Total Environ. 169821.
Yang, X., Cui, H., Liu, X., Wu, Q., Zhang, H., 2020. Water pollution characteristics and analysis of Chaohu Lake basin by using different assessment methods. Environ. Sci. Pollut. Res. 27, 18168–18181.
Zhang, L., Yang, J., Zhang, Y., Shi, J., Yu, H., Zhang, X., 2022. eDNA biomonitoring revealed the ecological effects of water diversion projects between Yangtze River and Tai Lake. Water Res. 210, 117994.
Zhang, S.-X., Zhang, Q.-Q., Liu, Y.-S., Yan, X.-T., Zhang, B., Xing, C., Zhao, J.-L., Ying, G.-G., 2020. Emission and fate of antibiotics in the Dongjiang River Basin, China: implication for antibiotic resistance risk. Sci. Total Environ. 712, 136518.
Zhang, X., Zou, R., Wang, Y., Liu, Y., Zhao, L., Zhu, X., Guo, H., 2016. Is water age a reliable indicator for evaluating water quality effectiveness of water diversion projects in eutrophic lakes? J. Hydrol. 542, 281–291.
Zhou, Q., Liu, G., Arif, M., Shi, X., Wang, S., 2022. Occurrence and risk assessment of antibiotics in the surface water of Chaohu Lake and its tributaries in China. Sci. Total Environ. 807, 151040.