

Analysis of Operational Risk Losses in Water Conveyance Channels of Water Diversion Projects: The Case of the Yangtze-to-Huaihe Water Diversion Project (Henan Reach)

Huan Jing^{1,2,3}, Mingzhi Yang^{1,2,3}, Guangdong Wu^{1,2,3}, Yanjun Wang^{1,2,3 *},
Yongqiang Wang^{1,2,3}

¹ Key Laboratory of Yangtze River of the Ministry of Water Resources, Changjiang River Scientific Research Institute, Wuhan, 430010, China;

² Hubei Key Laboratory of Water Resources & Eco-Environmental Sciences, Wuhan, 430010, China;

³ Innovative Team on Key Technologies of Water Resources Conservation and Efficient Utilization, Changjiang Water Resources Commission of the Ministry of Water Resources, Wuhan, 430010, China;

^a jinghuan@mail.crsri.cn, ^b mzyang199006@163.com, ^c wugd@mail.crsri.cn, ^d wangyj@mail.crsri.cn, ^e wangyq@mail.crsri.cn

Abstract. Influenced by climate change, topographic variations, and seasonal precipitation, the regional contradiction between water supply and demand has become increasingly prominent, posing a critical bottleneck restricting high-quality development in water-scarce areas. To address this issue, China has planned and constructed a series of water diversion projects. As long-distance large-scale systems exposed to multi-source risks including flood hazards, structural failure, and management inadequacy, making systematic risk assessment crucial. However, existing studies generally emphasize risk probability while neglecting risk losses, exhibiting a structural imbalance of “focusing on probability while downplaying consequences”, which makes it difficult to meet the comprehensive risk assessment requirements of inter-basin water diversion projects. Therefore, this study focuses on the Yangtze-to-Huaihe Water Diversion Project (Henan Reach), integrating channel structural damage and water supply area losses (industrial production losses and domestic water supply impacts). Characteristic risk loss indicators are selected, with evaluation criteria and weights determined via expert consultation. A risk loss index (LE) is proposed to assess the failure consequences of the project's water conveyance channels from an economic loss perspective. The results indicate that the LE is rather higher for the Qingshuihe–Zhaolou Reach (2.91) and Zhaolou–Shiliang Reach (3.17), owing to their high construction costs and large water supply scale. The Shiliang–Shiliang Reservoir Reach (2.35) shows a moderate LE, as its large supply coverage is offset by low construction costs. The Shiliang–Houchenlou Reach (1.81) has the lowest LE due to its low construction cost and small supply scale. This study offers technical support for future risk management of the Yangtze-to-Huaihe Water Diversion Project.

Keywords: Water diversion project; Water conveyance channel; Yangtze-to-Huaihe Water Diversion Project (Henan Reach); Risk loss assessment; Risk loss index (LE)

1. Introduction

Influenced by climate change, topographic variations, and seasonal precipitation patterns, the spatial and temporal distribution of water resources is significantly uneven, leading to a structural mismatch between regional water supply and demand, which has become a critical bottleneck restricting the sustainable socio-economic development of water-scarce areas [1-3]. Against this backdrop, the construction of water diversion projects is an important measure to address the uneven spatial and temporal distribution of water resources and support the high-quality development of water-receiving areas [4-7]. As a typical example of significant imbalance in the spatial and temporal distribution of water resources, China has successively planned and constructed a series of inter-basin water diversion projects to alleviate water resource pressure in

northern regions, including the South-to-North Water Diversion Project, the Yangtze-to-Huaihe Water Diversion Project, and the Hanjiang-to-Weihe Water Diversion Project [8-9].

As the aorta of inter-basin water diversion projects, the water conveyance system is characterized by numerous water supply recipients and a massive water supply scale, and often faces multi-source risks such as flood inundation, structural damage, and management failure. It is widely acknowledged that risk comprises event probability and potential consequences. The former describes the likelihood of adverse events occurring, while the latter refers to the severity of consequences resulting from functional failures. Only by comprehensively considering both dimensions of risk, can the operational risk status of inter-basin water diversion projects be fully and systematically assessed. Extensive research on the risk probability of water conveyance channels have been conducted in the past few years[10-14]. However, due to the difficulty of quantifying risk losses, relatively few related studies have been conducted domestically or internationally. Existing research has mostly focused on analyzing the economic, social, and environmental impacts of projects on water-supplying and water-receiving areas from a macro perspective. For example, Peng et al. [15] took the South-to-North Water Diversion Project as a case study and quantitatively evaluated the social and economic impacts of the water diversion project on the receiving areas through a comparative analysis of different water supply modes. Lin et al. [16] employed the water footprint method to conduct a monetized assessment of the water footprints in both the donating and receiving areas before and after project implementation, concluding that the net environmental benefits generated jointly by the Eastern and Middle Routes of the South-to-North Water Diversion Project (excluding the Western Route) were significant. Yu et al. [17], based on the GIS platform and the Pressure-State-Response framework, constructed an ecological security evaluation indicator system for Nanyang City, the water source area of the Middle Route Project, and conducted an in-depth analysis of the spatiotemporal variation characteristics of ecological security in Nanyang City, finding that the overall level of ecological security in Nanyang City had improved. Long et al. [18] systematically analyzed the evolution characteristics of the coordinated development status of the Middle Route of the South-to-North Water Diversion Project from three aspects: social development, economic growth, and ecological environment. However, the aforementioned studies mostly focus on the positive outcomes of projects (such as water supply, economic benefits, and ecological improvements), with the core objective of measuring “benefits,” making it difficult to meet the needs of quantifying the negative losses caused by operational failures.

In summary, although significant progress has been made in the risk assessment of inter-basin water diversion projects, existing research has mostly focused on the calculation of risk probability while neglecting the quantification of risk “consequences” following an event. This structural imbalance of “emphasizing probability while downplaying consequences” makes it difficult to meet the comprehensive risk assessment needs of water conveyance channels in inter-basin water diversion projects, and consequently, the assessment results can hardly support refined management decision-making.

2. Study Area

The Yangtze-to-Huaihe Water Diversion Project is a core component of China's national water network major projects, encompassing three sections: Diversion from the Yangtze to Chaohu Lake, Connection between the Yangtze and Huaihe Rivers, and Water Transfer North from the Yangtze. It undertakes multiple tasks including urban and rural water supply for Anhui and Henan Provinces, navigation between the Yangtze and Huaihe Rivers, irrigation supplementation, and ecological and environmental improvement of Chaohu Lake and the Huaihe River. Administratively, the project consists of the Anhui Reach and the Henan Reach, and this study takes the Henan Reach as the research object. This section starts from the provincial boundary between Henan and Anhui and includes two water conveyance channels (namely the Qingshui River and the Luxin River, with

conveyance lengths of 47.46 km and 16.26 km, respectively), ten water conveyance pipelines, and four regulating reservoirs (the Shiliang Regulating Reservoir, Houchenlou Regulating Reservoir, Qiliqiao Regulating Reservoir, and Xincheng Regulating Reservoir). The schematic diagram of the study area is shown in Figure 2.1.

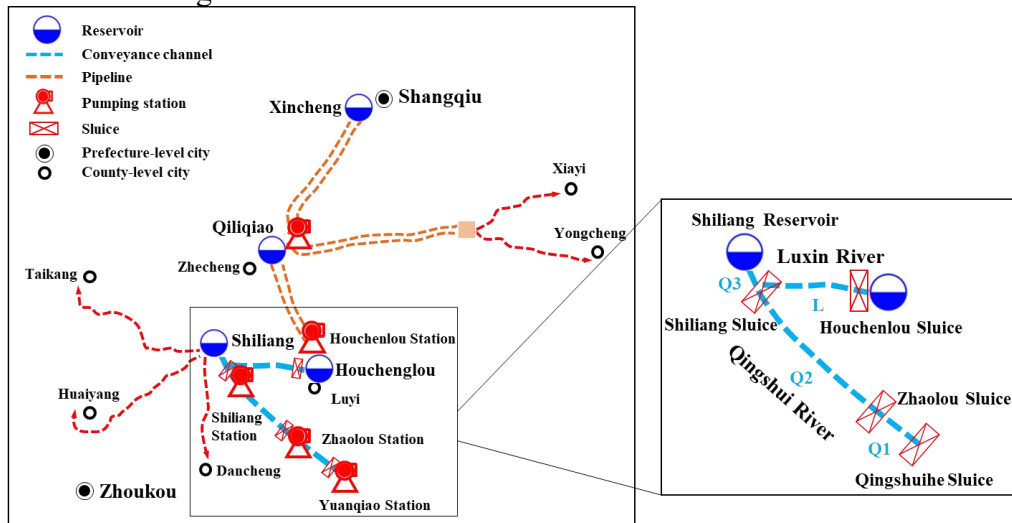


Fig.1 Schematic diagram of the Yangtze-to-Huaihe Water Diversion Project (Henan Reach) [19]

Based on the control gates, the study reaches can be divided into four segments: Qingshuihe Gate–Zhaolou Gate, Zhaolou Gate–Shiliang Gate, Shiliang Gate–Shiliang Reservoir Reach (located on the Qingshui River), and Shiliang Gate–Houchenlou Gate Reach (Luxin River). The core parameters of the water conveyance channels are shown in the table below.

Table.1 Basic information of studied reaches of the Yangtze-to-Huaihe River Water Diversion Engineering (Henan Reach)

Channel	Studied segment	Length (km)	Discharge (m ³ /s)	Conveyance method
Qingshui	Qingshuihe Gate—Zhaolou Gate	15.10	43	Open-channel
	Zhaolou Gate—Shiliang Gate	31.61	42	Open-channel
	Shiliang Gate—Shiliang Reservoir	0.75	9.60	Open-channel
Luxin	Shiliang Gate—Houchenlou Gate	16.26	30.90	Open-channel

In terms of water supply regulation, water is sequentially supplied to nine administrative regions, namely Dancheng, Taikang, Huaiyang, Liangyuan District, Suiyang District, Yongcheng, Xiayi, Zhecheng, and Luyi, through four regulating reservoirs: Shiliang, Houchenlou, Qiliqiao, and Xincheng. The project utilizes the Qingshui River, where water is lifted upstream by pumping stations. After flowing into the Shiliang Reservoir, the water passes through the Shiliang Gate to Houchenlou Gate segment into the Houchenlou Reservoir, and then enters the Qiliqiao and Xincheng reservoirs in sequence via pipelines. Consequently, the operational safety of each channel reach has different scopes of impact. Failure of any water conveyance reach on the Qingshui River will affect all corresponding water receiving areas. In contrast, failure of the Shiliang Gate to Houchenlou Gate segment (i.e., the Luxin River) will affect all water receiving areas except those served by the Shiliang Reservoir, namely Dancheng, Huaiyang, and Taikang.

3. Risk Loss Assessment of Water Conveyance Channels

3.1 Analysis of Single Risk Loss Indicators

This paper provides a preliminary discussion on the failure consequences of water conveyance channels in the Yangtze-to-Huaihe Water Diversion Project (Henan Reach) from the perspective of economic losses. As a key component of the inter-basin water diversion system, failure of the water

conveyance channels will directly or indirectly trigger multi-dimensional economic losses. Based on the engineering characteristics and regional socioeconomic features, the economic losses can be summarized into the following three aspects:

(1) Engineering investment loss: refers to the physical damage or functional degradation suffered by the water conveyance channel itself during the failure process, including the direct engineering investment required for structural repair, equipment replacement, and system reconstruction.

Engineering damage is one of the significant sources of economic loss for water conveyance channels in water diversion projects. The higher the construction cost of a channel reach, the greater its structural scale, complexity, and the investment required for repair. Once damage occurs, the direct economic loss is correspondingly higher. Therefore, this paper selects the engineering cost ratio (D1) as a quantitative indicator to characterize the degree of economic loss caused by structural damage to channel engineering.

(2) Industrial production loss: refers to the restriction or even cessation of production activities of industrial enterprises along the route due to water supply interruption or insufficient water volume, thereby leading to indirect economic impacts such as a decline in industrial added value.

Industrial production generally has high dependence on and continuity requirements for water resources. Once the water conveyance channel is damaged, resulting in water supply suspension, industrial enterprises along the route and in the water-receiving areas will be directly forced to reduce or halt production. Therefore, this paper selects the industrial production loss index (D2) to characterize the reduction in industrial added value caused by water supply suspension resulting from damage to the water conveyance channel.

(3) Domestic water supply impact: mainly reflected in the shortage of domestic water for urban and rural residents, which may force the adoption of measures such as emergency water supply, timed water supply, or inter-regional water transfer, resulting in additional water supply costs and social emergency management expenses.

Considering that the Yangtze-to-Huaihe Water Diversion Project (Henan Reach) takes urban and rural water supply as its primary task, once the water conveyance channel fails, it will directly affect the daily water use of residents along the route and in the water-receiving areas. The severity of the consequences is closely related to the scale of the affected population. Therefore, this paper selects the domestic water supply impact indicator (D3) for elaboration.

3.1.1 Engineering cost ratio (D1)

This indicator introduces the ratio of the construction cost of each studied channel reach to the total construction cost of the entire water diversion project, which reflecting the potential engineering economic loss intensity that may occur when different reaches fail. The calculation formula for the engineering cost ratio D1 is as follows:

$$D1 = Lc/LT \times 100\%$$

where Lc and Lt represent the construction cost of the study channel reach and the total construction cost of the civil works, respectively (unit: ten thousand yuan / RMB 10,000).

The engineering cost ratio D1 is divided into five levels: <1%, 1%–5%, 5%–10%, 10%–20%, and >20%, corresponding to five risk loss grades: very low, low, medium, high, and very high, respectively. The indicator grading criteria are shown in Table 2.

Table. 2 Grading standards for engineering cost loss indicator D1

Grade	I	II	III	IV	V
D1(%)	<1%	[1%, 5%)	[5%, 10%)	[10%, 20%)	>20%
Loss index	(0, 1]	(1, 2]	(2, 3]	(3, 4]	(4, 5]

According to the Design Report of the Yangtze-to-Huaihe Water Diversion Project (Henan Reach), the construction costs of each study channel reach are shown in Table 3. It should be noted that for the Luxin River in Table 3, no disaggregated investment data were available. Based on the engineering quantities of earth excavation, sludge excavation, river dredging works, turf slope protection, and earth replacement, the channel investment cost was converted proportionally to be

approximately 20.81 million yuan. Based on the total civil works construction cost of 5,976.5 million yuan obtained from the Design Report of the Yangtze-to-Huaihe Water Diversion Project (Henan Reach), the ratio of the construction cost of each study channel reach to the total civil works construction cost was calculated, as shown in Table 4. According to the indicator grading criteria given in Table 2, the scoring results of the engineering cost ratio for each study channel reach are presented in Table 5.

Table. 3 Channel Construction Cost of the Yangtze-to-Huaihe Water Diversion Project (Henan Reach) (Unit: 10,000 yuan)

Channel	Earth excavation	Earth backfill	River revetment	Impacted engineering works
Qingshui	4771	97	29228	521
Luxin	2081			

Table. 4 Proportion of channel construction cost to total civil works construction cost for each study reach of the Yangtze-to-Huaihe Water Diversion Project (Henan Reach)

Variable	Qingshuihe Gate—Zhaolou Gate	Zhaolou Gate—Shiliang Gate	Shiliang Gate—Shiliang Reservoir	Shiliang Gate—Houchenlou Gate
Channel construction Cost (10,000 yuan)	11014	23056	547	2081
Ratio (%)	1.84	3.86	0.09	0.35

Table 5 Indicator values of engineering cost ratio D1 for each study channel reach of the Yangtze-to-Huaihe Water Diversion Project (Henan Reach)

Studied segment	Qingshuihe Gate—Zhaolou Gate	Zhaolou Gate—Shiliang Gate	Shiliang Gate—Shiliang Reservoir	Shiliang Gate—Houchenlou Gate
Loss index	1.21	1.72	0.09	0.35

Note: The evaluation indicator values in the table are calculated by interpolation.

3.1.2 Industrial production loss index (D2)

To facilitate quantification, this indicator is represented by calculating the loss of industrial added value on a daily basis. Considering that each water-receiving area is supplied by multiple water sources, including groundwater, surface water, reclaimed water, and allocated water from water resource allocation systems, when one water source fails, other sources can temporarily provide emergency water supply to minimize economic losses. Accordingly, the “daily industrial production loss” is calculated as 10% of the daily industrial output value.

Drawing on the Regulations on the Handling of Quality Accidents in Water Conservancy Projects (Order No. 57 of the Ministry of Water Resources, effective 2025), the industrial production loss is divided into five grades: minor accident, with loss less than 1 million yuan; general accident, with loss ranging from 1 million to 10 million yuan; relatively major accident, with loss ranging from 10 million to 20 million yuan; major accident, with loss ranging from 20 million to 50 million yuan; and extraordinarily major accident, with loss exceeding 50 million yuan. The grading criteria for the industrial production loss index (D2) are determined and shown in Table 6.

Table. 6 Grading standards for industrial production loss index D2

Grade	I	II	III	IV	V
Industrial Production Loss (10,000 yuan)	<100	[100, 1000)	[1000, 2000)	[2000, 5000)	>5000
Loss index	(0, 1]	(1, 2]	(2, 3]	(3, 4]	(4, 5]

According to the water resources allocation calculation results of the Yangtze-to-Huaihe Water Diversion Project (Henan Reach), by the planned year 2030, the average annual water supply outside the river channels in the receiving areas of Henan Province will be 500 million m³, of which domestic water supply accounts for 216 million m³, industrial production water supply accounts for

272 million m³, and ecological water supply accounts for 13 million m³. The specific water supply allocation for each receiving area is shown in the table below.

Table 7 Water supply allocation of the Yangtze-to-Huaihe Water Diversion Project (Henan Reach) in 2030 (10,000 m³)

Water-receiving area	Off-channel water supply			Total
	Domestic	Industrial	Ecological	
Dancheng	2424	701	112	3237
Huaiyang	2631	1033	122	3786
Taikang	2663	939	123	3725
Liangyuan District	2428	1005	257	3690
Suiyang District	2247	1864	216	4372
Zhecheng	1875	809	185	2868
Xiayi	2073	1130	78	3281
Yongcheng	3024	12158	106	15287
Luyi	2198	7526	102	9826

According to the operation scheme of the Yangtze-to-Huaihe Water Diversion Project (Henan Reach), during project operation, relying on the four regulating reservoirs, urban and rural domestic water, industrial production water, and ecological water are supplied to the surrounding nine counties (districts). The corresponding relationship between the four regulating reservoirs and the nine water-receiving counties (districts) is shown in the table below.

Table 8 Corresponding relationship between the four reservoirs and the nine water-receiving areas

Reservoir	Water supply target
Qiliqiao	Zhecheng
	Xiayi
	Yongcheng
Shiliang	Dancheng
	Taikang
	Huaiyang
Houchenlou	Luyi
Xincheng	Liangyuan District
	Suiyang District

The industrial production water supply scale that may be affected by the operational failure of each study channel reach of the Yangtze-to-Huaihe Water Diversion Project (Henan Reach) is shown in the table below.

Table. 9 Industrial water supply scale potentially affected by failure of study channel reaches

Variable	Qingshuihe Gate—Zhaolou Gate	Zhaolou Gate—Shiliang Gate	Shiliang Gate—Shiliang Reservoir	Shiliang Gate—Houchenlou Gate
Industrial water supply scale (10,000 m ³)	27165	27165	27165	24492

According to the regional water-saving indicators of the project's water-receiving areas for the year 2030, the water use per ten thousand yuan of value added for general industry is 18 m³/ten thousand yuan. The "daily industrial production loss" that may be caused by the operational failure

of each study channel reach, as well as the scoring results of the industrial production loss index for the study channel reaches, are shown in the table below.

Table. 10 Industrial production loss index (D2) values for the study channel reaches

Studied segment	Qingshuihe Gate—Zhaolou Gate	Zhaolou Gate—Shiliang Gate	Shiliang Gate—Shiliang Reservoir	Shiliang Gate—Houchenlou Gate
Industrial production loss (10,000 yuan)	4134	4134	4134	3727
Loss index	3.71	3.71	3.71	3.57

Note: The evaluation indicator values in the table are calculated by interpolation.

3.1.3 domestic water supply impact (D3)

Considering that the project is primarily focused on urban and rural water supply, failure of the water conveyance channel will affect residents around the channel as well as those in the water-receiving areas. The severity of the consequences is closely related to the scale of the affected population. This indicator is defined as the proportion of the affected population, i.e., the ratio of the population that may face water shortage in the event of failure of each study channel reach to the total regional population, which is used to approximately characterize the magnitude of risk losses caused by the failure of different reaches. The calculation formula is as follows:

$$FP = Pi/TP \times 100\%$$

where Pi is the population affected by the failure of the water conveyance channel (10,000 persons); TP is the total beneficiary population of the water conveyance channel (10,000 persons).

The grading criteria for the domestic water supply impact (D3) are shown in Table 11. The affected population status and indicator scoring results for each studied channel reach are shown in Table 12.

Table. 11 Grading criteria of domestic water supply impact indicator (D3)

Grade	I	II	III	IV	V
D3 (%)	(0, 20]	(20,40]	(40, 60]	(60, 80]	(80, 100]
Loss index	(0,1]	(1, 2]	(2, 3]	(3, 4]	(4, 5]

Table. 12 Scoring results of domestic water supply impact indicator for each studied channel reach

Studied segment	Qingshuihe Gate—Zhaolou Gate	Zhaolou Gate—Shiliang Gate	Shiliang Gate—Shiliang Reservoir	Shiliang Gate—Houchenlou Gate
Affected population (10,000 persons)	956.1	956.1	956.1	599.4
Proportion of affected population (%)	100.0	100.0	100.0	62.7
Loss index	5	5	5	3.13

Note: The evaluation indicator values in the table are calculated by interpolation.

4. Comprehensive Risk Loss Index (LE) Assessment

Integrating structural damage to the channel engineering and losses in the adjacent water supply areas (industrial production losses and domestic water supply impacts), a comprehensive risk loss index (LE) is constructed to characterize the comprehensive economic loss risk degree of water conveyance channel failure. The calculation formula is as follows:

$$LE = \sum \beta_i W_i$$

where, W_i and β_i are the weight and risk grade of the i-th category of economic loss, respectively. Based on the results of data collection and expert consultation, the risk loss index (LE)

of the water conveyance channels for the Qingshuihe Gate–Zhaolou Gate, Zhaolou Gate–Shiliang Gate, Shiliang Gate–Shiliang Reservoir, and Shiliang Gate–Houchenlou Gate of the Yangtze-to-Huaihe Water Diversion Project (Henan Reach) are shown in Table 13.

Table13 Risk loss index LE of each studied channel reach of Yangtze-to-Huaihe Water Diversion Project (Henan Reach)

Studied segment	Qingshuihe Gate–Zhaolou Gate	Zhaolou Gate–Shiliang Gate	Shiliang Gate–Shiliang Reservoir	Shiliang Gate–Houchenlou Gate
LE	2.91	3.17	2.35	1.81

5. Summary

Considering that risk is the combined result of risk probability and risk consequences, this study integrates structural damage to channel engineering and losses in adjacent water supply areas to construct a risk loss index (LE), and explores the failure consequences of water conveyance channels in the Yangtze-to-Huaihe Water Diversion Project (Henan Reach) from the perspective of economic losses. The results show that the Qingshuihe Gate–Zhaolou Gate and Zhaolou Gate–Shiliang Gate reaches have the highest risk loss index (LE) due to their high channel construction costs and large water supply scale and coverage. Among them, the Zhaolou Gate–Shiliang Gate reach has the highest LE (3.17), indicating that it has the greatest comprehensive potential loss in terms of structural damage and water supply impact. The Qingshuihe Gate–Zhaolou Gate reach ranks second (2.91), also exhibiting a relatively higher risk loss level that requires priority monitoring and prevention. Although the Shiliang Gate–Shiliang Reservoir reach has a large water supply coverage, its low construction cost results in a moderate LE (2.35). The Shiliang Gate–Houchenlou Gate reach has the lowest LE (1.81) due to its low channel construction cost and relatively small water supply scale and coverage. Overall, the reaches with higher risk loss indices are concentrated in the front and middle sections of the main water conveyance line. It is recommended that emergency response plans be improved for high-risk reaches and water supply operation schemes be optimized to effectively reduce potential failure losses.

Acknowledgements

Funding: This research was funded by the Central Public-interest Scientific Institution Basal Research Fund (CKSF2026349/SZ), the National Natural Science Foundation of China (52509085, 42271044, 52509004), Innovative Group Project of the Natural Science Foundation of Hubei Province: “Evolution of Water Resource Patterns and Adaptive Regulation in the Yangtze River Basin under Changing Environments” (Grant No.2024AFA011), National Key Research and Development Program of China (Grant No.2023YFC3205600), the National Natural Science Foundation of Hubei Province (2024AFB012).

References

- [1] Donoso, M., Baldassarre, G.D., Boegh, E., et al. International Hydrological Programme (IHP) eighth phase: Water security: Responses to local, regional and global challenges. Strategic plan, IHP-VIII (2014-2021). In Zbornik Nije Izdan; Unesco: Paris, France, 2012.
- [2] Kummu, M., Guillaume, J.H.A., De Moel, H., et al. The world’s road to water scarcity: Shortage and stress in the 20th century and pathways towards sustainability. *Sci. Rep.* 2016, 6, 38495.
- [3] Long, Y., Xu, L.Y., Lei, X.H., et al. The risk assessment model for water diversion projects based on a fuzzy Bayesian network. *J. Hydrol.* 2025. 662,134053.

- [4] Andreide, J.P.G., Zhu, Q. Comparison of Brazil's cross-basin water transfer practice and inter-national cases. *Water Resour. Hydropower Bull.* 2011, 32, 1–6.
- [5] Long, D., Yang, W., Scanlon, B.R., et al. South-to-North Water Diversion stabilizing Beijing's groundwater levels. *Nat. Commun.* 2020, 11, 3665.
- [6] Liu Weifeng, Guo Xuning, Li Yunling, et al. Compensation Scheduling of the First Phase of the South-to-North Water Diversion Project's Eastern Route. *Strategic Study of CAE*, 2025, 27 (05): 236-248. (in Chinese)
- [7] Liu Dan, Liu Shengjie, Liao Junxian, et al. Economy reanalysis of typical large-scale inter-basin water transfer projects in China. *South-to-North Water Transfers and Water Science & Technology*, 2025, 23(5): 1047-1058. (in Chinese)
- [8] Gan Rong, Liu Jinhan, Gu Changkuan, et al. Water Resources Allocation in the Henan Section of Yangtze-to-Huaihe River Diversion Project. *Journal of North China University of Water Resources and Electric Power (Natural Science Edition)*, 2025, 46 (03): 51-60. (in Chinese)
- [9] Wang Tao, Sun Zechao, Guo Xinlei, et al. Cold wave grades and air temperature thresholds during wintertime water diversion in the Middle Route of South-to-North Water Diversion Project in China. *Journal of Hydraulic Engineering*, 2025, 56 (10): 1267-1279. (in Chinese)
- [10] Fang, G., Zhu, X., Huang, X. Risk analysis of floodwater resources utilization along water diversion project: A case study of the Eastern Route of the South-to-North Water Diversion Project in China. *Water Supply*, 2019, 19, 2464–2475.
- [11] Fu, X.D., Wang, G., Ren, M.L., et al. Flood Control Risk Identification and Quantitative Assessment of a Large-Scale Water Transfer Project. *Water*, 2021, 13, 1770.
- [12] Zhang, W., Liu, G., Chiwiukem, C.J., et al. Flood risk cascade analysis and vulnerability assessment of watershed based on Bayesian network. *J. Hydrol.* 2023, 626 (Part A), 130144.
- [13] Geng, L.H.; Jiang, B.L.; Fu, K.W.; Mao, Y.J. Risk Analysis and Assessment of the Water Conveyance System Operation in the East Route of South-to-North Water Transfer Project. *Yellow River* 2012, 34, 92–95. (in Chinese)
- [14] Liu Weilin, Liu Lina, Liang Yanhong, et al. Risk assessment of floods of dike-break in medium and small rivers based on MIKE FLOOD. *Water Resources and Hydropower Engineering*, 2020, 51(1): 88-99.
- [15] Peng, Z., Yin, J., Zhang, L., et al. Assessment of the sociol-economic impact of a water diversion project for a water-receiving area[J]. *Polish Journal of Environmental Studies*, 2019, 29(2): 1771-1784.
- [16] Lin, C., Suh, S., Pfister, S. Does South-to-North Water Transfer reduce the environmental impact of water consumption in China? *J. Ind. Ecol.* 2012, 16, 647–654.
- [17] Yu Tianshu, Zheng Shuanning, Zhu Jieyuan, et al. Evaluation on the ecological security status in Nanyang city, the water source region of the Middle Route of South-to-North Water Diversion Project in China[J]. *Acta Ecologica Sinica*, 2021, 41(18): 7292-7300.
- [18] Long, Y., Li, Y., Lei, X., et al. A study on comprehensive evaluation methods for coordinated development of water diversion projects based on advanced SWOT analysis and coupling coordination model. *Sustainability*, 2021, 13(24).
- [19] Jing Huan, Wang Yanjun, Wang Yongqiang, et al. The Risk Assessment for Water Conveyance Channels in the Yangtze-to-Huaihe Water Diversion Project (Henan Reach). *Water*, 2025, 17, 2992.