

Discussion on Water Supply Safety Countermeasures for the East Route of South-to-North Water Diversion Project

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Abstract: At present, the East Route of South-to-North Water Diversion Project is in good operation, ensuring the safety of water supply in the water intake areas. However, there are many kinds of hydraulic structures in the project. Due to the cross influence of water supply, flood control, drainage, shipping and other functions of the project, some problems exist in the operation and dispatching of the project. These problems can be divided into two types: water quantity dispatching problem and water quality guarantee problem. Aiming at the potential problems of water dispatching, we proposed safety countermeasures of pumping stations, rivers and lakes; In view of the problems existing in water quality, corresponding system and management measures were proposed. Based on the above, this paper summarizes the beneficial experience of the East Route project in improving the project transportation management system, strengthening water quality monitoring management, standardizing the dispatching management process, preparing reasonable dispatching scheme and emergency plan. This paper can provide references for the safety guarantee of dispatching operation for the subsequent water diversion projects.

1 INTRODUCTION

South-to-North Water Diversion Project is a major project to channel water from the Yangtze River in the southern part of the mainland China to the north through three routes. The project, considered by the authorities since the 1950s, was formally launched in 2002. Three 1,300-km canals will be constructed in the western, central and eastern parts of China so that water from the upper, middle and lower reaches of the Yangtze River will be brought to the north, where water supply is not adequate. With an estimated investment of 486 billion CNY, the three routes are supposed to be able to transfer 44.8 billion m³ of water by 2050. To date, the East Route of the South-to-North Water Diversion Project has been working for almost five years in a good condition. To better assess the effectiveness and efficiency of the East Route, in the first, the operation condition of the Phase I of the East Route were described. Then the main difficulties in dispatching operation were summarized and the security problems in the dispatching operation were analyzed. In the end,

Safety measures were proposed and the experience and Enlightenment were concluded.

2 OPERATION OF PHASE I OF EAST ROUTE

The Phase I of the East Route of the South-to-North Water Diversion Project was officially opened on November 15, 2013. It has completed seven annual water diversion tasks, with a cumulative water diversion volume of 4.616 billion m³ into Shandong Province. Among them, the water diverted into Shandong Province from 2019 to 2020 is 703 million m³, and the net water supply is 434 million m³, including 404 million m³ of urban domestic and industrial water supply and 30 million m³ of ecological water supply. The Phase I project of the East Route is stably operating and working in good conditions with stable water quality, thus alleviating the shortage of water resources in the water intake areas, and resulting in good social, ecological and economic benefits.

Emergency water supply has been carried out for many times during the operation of the Phase I project of the East Route. In 2015, Liushan station and Jietai station in Jiangsu Province were put into drought relief operation in Huaibei area with the pumping volume of 69 million m³, which played an important role in ensuring regional production, living, shipping and ecological environment. After the completion of the 2016-2017 water diversion plan, in view of the serious drought in Jiaodong and Shandong Province, according to the relevant requirements, the Jiaodong water division main route was used to continuously divert water from the Yellow River to the Jiaodong region. The existing water volume of East Pinghu Lake was used as the supplementary water source to supply 220 million m³ of water to four cities in the Jiaodong region. In addition, from 2019 to 2020, 30 million m³ of water was supplied to protect the springs and replenish the ecological water of Changqing Lake in Jinan, which alleviated the downward trend of groundwater level in Jinan during the water diversion period and improved the water quality and ecological environment of the Changqing Lake area.

3 MAIN DIFFICULTIES IN DISPATCHING OPERATION

There are many kinds of hydraulic structures in the East Route project, especially in the water network of Northern Jiangsu area. Many rivers and lakes are connected and intertwined with each other and the water supply, flood control, waterlogging drainage, shipping and other functions undertaken by the project are cross influencing each other, which brings some difficulties to the operation and dispatching of the project, mainly in the following aspects:

(1) The East Route project has a number of large-scale water lifting pumping stations, recycled water interception, storage and diversion works, T-shaped water transfer main route, Nansi Lake regulation and dredging, Yellow River Crossing Tunnel and other node projects. The water transmission route is long with many water intakes. There are mixed configurations with local water and other external water transfer (mainly yellow river water diversion in Shandong), so the water dispatching relationship is complex.

(2) The water supply dispatching of the East Route project needs to be considered in combination with the flood control, drought resistance, waterlogging drainage, shipping and other

dispatching of the basin and region. The implementation of multi-objective joint dispatching involves the interests of many water departments in the water intake area, which is difficult to coordinate (Li, 2010).

(3) The water intake areas along the East Route project are economically developed with large sewage discharge. Although the pollution control planning and supplementary planning of the East Route project have been implemented successively when the main project started construction, and certain effects have been achieved through the implementation of structural adjustment, sewage treatment, sewage interception and diversion, ecological restoration and other projects. However, there still exists serious phenomena water pollution rebounding, low illegal cost and high cost of law abiding. In addition, sudden pollution accidents in the Huaihe River Basin occur from time to time (Jiang et al., 2007), therefore how to continuously ensure water quality is very important.

4 SECURITY PROBLEMS IN THE DISPATCHING OPERATION

The problems affecting the normal dispatching operation of Phase I project of the East Route mainly come from two aspects: water dispatching risk and water quality guarantee.

4.1 Water Dispatching Problems

In the first phase of the East Route project, the water head is increased step by step through the pumping stations, and the water level difference between the pumping stations at all levels is transmitted by gravity through the river. Several regulation and storage lakes and reservoirs are set along the water diversion route. According to different engineering structures and functions, the East Route project can be divided into four parts: water source, water lifting, water transmission and water storage. The safety of each part can affect the normal operation of water dispatching.

(1) Hydrological problems of water source

The first phase of the East Route project raises water from Jiangdu water control project in Yangzhou, Jiangsu Province. The risk of water source is mainly caused by the randomness of hydrological phenomena (Tang, 2020), such as water shortage due to the reduction of rainfall and

the increase of project scale, flood risk caused by rainstorm, etc.

(2) Operation problems of lift pumping station

The water lifting system consists of 13-level 22 hubs as 34 pumping stations set up along the way with a total lift of 65 m. With a total installed capacity of 160 pumps, the total installed flow is 4,447.6 m³/s and the installed power is 366,000 kW. It is a modern pumping station group with the largest number of large pumping stations in Asia and even in the world. 13 cascaded pumping stations are distributed along the river section to the south of the Yellow River. For the north of the Yellow River water can be transferred by gravity (Liu et al., 2020).

The pumping stations of the East Route project are mainly characterized by low lift, large flow and long operation time. Some pumping stations also have waterlogging drainage tasks. Therefore, the pumping stations are required to be flexible, efficient and reliable. Affected by the operating conditions, equipment quality and technical conditions, the water lifting efficiency of the pumping station is reduced, and the water lifting capacity cannot meet the planning requirements (Liu & Geng, 2010). The East Route project partially uses the completed River Water to North Diversion Project in Jiangsu Province. The latter has operated for nearly 40 years, so the pumping station is partially aging and the motor power is partially attenuated, affecting the water lifting efficiency; 3 stations in Huai'an should be overhauled every year and before the flood season, otherwise the water lifting efficiency will be affected due to the change of working point of the pumping station. Secondly, because some pumping stations have flood control functions to ensure normal operation in flood season, flood overtopping has become one of the risks threatening the safety of the pumping station project.

(3) Operation safety of water conveyance channel

The water conveyance channel is located in the south of Dongping River, and the double line water conveyance is mainly composed of the Canal Route and Yunxi Route as auxiliary. After the two routes meet at Nansi Lake, they enter Dongping Lake through Liangji canal. After leaving Dongping Lake, it is divided into two routes, one through the Yellow River and the small canal to Datun reservoir in Dezhou and the other route connected to the channel from the Yellow River to Qingdao through Jiaodong water diversion main route to supply water to Jiaodong area.

Some water delivery channels undertake the tasks of water supply, flood control and shipping and always maintain high water level operation.

Therefore, high water level operation and floods are the main problems faced by the water delivery channel of the East Route project, which is manifested in the failure of the safety and stability of the river embankment. Its planned water delivery function have not been achieved, thus affecting the function of the water delivery channel. In addition, 90 km of the canal line of the East Route project passes through the Tanlu fault zone near Zaohe-Suqian-Luoma Lake in Northern Jiangsu (Geng et al., 2012), which may be affected by earthquakes and other geological disasters.

(4) Operation safety of impoundment lake system

The water storage system mainly refers to four natural lakes along the water diversion route, including Hongze Lake, Luoma Lake, Nansi Lake and Dongping Lake. Before the water supply of the East Route of the South-to-North Water Diversion Project, the operation of the water storage system can be mainly divided into flood season and non-flood season; after the water was supplied, it is mainly the flood season and the water diversion period. The impoundment lakes have encountered high water level for a long time and some embankments, especially those in Xuzhou, Zaozhuang, Jining and other coal mining subsidence areas near Nansi Lake, may cause subsidence due to the increased load.

4.2 Safety Problems of Water Quality

The first phase of the East Route project uses the existing regulation and storage lakes and canals to deliver water, undertaking the functions of shipping, flood control, waterlogging drainage, aquaculture etc. Under normal working conditions, the water quality of the water diversion main route has basically met the water diversion requirements. However, once problems in the working conditions of the pollution control and water quality assurance system, such as the sudden increase of pollution load input or the operation failure of the pollution control project happen, it will result in sudden water pollution accidents and the water quality of the East Route may be threatened. According to the survey, the natural risk source of the water quality of the first phase of the East Route project is flooding in Nansi Lake basin. If the first major flood in the four lakes in Central and South China occurs in advance during the operation and coincides with the water diversion period with the rubber dam at each estuary collapsing and discharging, the polluted water in the river will be discharged together with the large flow

of flood, which will lead to water pollution accidents. There are many man-made risk sources, mainly including pollution control unit operation failure, pollutants entering the water body caused by shipping accidents, pollution accidents caused by

bridge and highway transportation accidents along the main route etc. The main route of the East Route project faces many kinds of sudden pollution accidents, and different canal sections face different risk sources, as shown in Table 1.

Table 1: Statistics of water quality risk sources during water diversion.

Canal section of main route	Level of risk	Possible water quality accidents during water diversion				
		Natural factors	Artificial factors			
		Flooding in Nansi Lake basin	Pollution control unit fault	Shipping accident	Road and bridge transportation accident	Contrived event
Yangtze River ~ Jiangdu	Low			•	•	•
Jiangdu ~ Hongze Lake	Low			•	•	•
Hongze Lake	Low			•		•
Hongze Lake Luoma Lake	Low			•	•	•
Luoma Lake	Low			•		•
Luoma Lake ~ Nansi Lake	High	•	•	•	•	•
Nansi Lake	High	•	•	•	•	•
Nansi Lake ~ Dongping Lake	Low		•	•	•	•
Dongping Lake	Low		•	•		•
Jiping main canal	Low				•	•
Jiaodong water conveyance section	Low				•	•
North section of the Yellow River	Low				•	•

5 SAFETY MEASURES

5.1 Water Dispatching Management Measures

The water supply risk in the water source area of the East Route project is low, so the preventive water supply safety measures mainly focus on water lifting, water diversion and water storage.

(1) Safety measures for water lifting pumping station

The safety of the large water lifting pumping station is an important guarantee to ensure the safe operation of the East Route project. The specific risk prevention and control countermeasures mainly focus on paying attention to the inspection, protection and maintenance of the pumping station system, improving the management system of the pumping station hub, improving the automation degree of the pumping station, regularly monitoring the foundation and improving the quality of the management personnel of the pumping station hub. The above measures can effectively avoid and reduce the failure of the pumping station and ensure the safe operation of the pumping station, thus achieving the goal of water supply.

(2) Safety measures for water conveyance channel

The water delivery channel of the East Route is mainly to reduce the failure of the embankment project. The specific countermeasures mainly include strengthening and improving the embankments; in case of seepage, improving the resistance of embankment body and foundation to seepage damage; in case of slope instability, the upper slope should be cut and the lower foot fixing and weight pressing should be adopted; for the landslide caused by seepage, the measures of front blocking and back blocking should be taken. At the same time, implementing the approval procedures for coal mining through the embankments, taking countermeasures in the pre sedimentation area in advance, obtaining water information in time and implementing the real-time safety monitoring system of embankment engineering (Zhang et al., 2021).

(3) Safety measures for impoundment lakes

The main measures to ensure the safety of the impoundment system are to timely and comprehensively grasp the operation of the flood control project; do a solid job in sluice engineering maintenance to ensure flexible opening, closing and free operation; speed up the emergency treatment and

reinforcement of coal mining subsidence section; improve flood forecasting methods and continuously improve forecasting speed and accuracy; further improve the emergency plan, implement flood control measures, and clarify the flood control responsibilities.

5.2 Water Quality Safety Measures

(1) Institutional measures

Both Jiangsu Province and Shandong Province have strengthened the construction of laws and regulations to deal with water quality risks. For example, Jiangsu Province has promulgated the “administrative measures for the prevention and control of water pollution in areas along the South-to-North Water Diversion Project of Jiangsu Province” and the “regulations on the prevention and control of ship pollution in inland rivers of Jiangsu Province”, so as to clarify the measures for banning and limiting discharge in areas along the East Route water transfer project; Shandong Province implemented the “regulations on the prevention and control of regional water pollution along the South-to-North Water Diversion Project in Shandong Province”, revised the “regulations on the prevention and control of water pollution in the Nansi Lake Basin in Shandong Province” and made clear provisions on the control of water pollution in the main area of the South-to-North Water Diversion Project in Shandong Province.

(2) Management measures

In view of the water quality problems existing in the first phase of the East Route project, relevant environmental safety assurance measures should be taken from all stakeholders, such as advocating pollutant discharge enterprises to carry out cleaner production and strictly controlling the abnormal discharge of sewage, strengthening the operation management of sewage interception and diversion works to reduce the probability of abnormal operation of the works, ensuring the normal operation of the sewage treatment plant and reducing the sewage concentration, controlling shipping pollution and reducing ship oil spill accidents, solving inter provincial water quality disputes, etc.

6 SUMMARY AND CONCLUSIONS

Since the five water diversion years of water supply and operation of the East Route project, the

beneficial experience in improving the project transportation and management system, strengthening water quality monitoring and management, standardizing the dispatching management process, preparing reasonable dispatching scheme and emergency plan can provide reference and enlightenment for the safety guarantee of dispatching and operation of subsequent water diversion projects.

(1) Perfecting the engineering transportation and management system is the primary basis to ensure the safety of water supply

In the water supply security of water diversion project, it is necessary to formulate corresponding dispatching schemes and put forward specific preventive measures in close combination with the project transportation management system and actual operation environment. Drawing on the experience of the East Route project, referring to the regulations on the management of water supply and consumption of the South-to-North Water Diversion Project, and combining with the actual situation of water supply of the project, formulating the division of labor and responsibility system, clarifying the responsibilities and rights of stakeholders and building a management mechanism of unified organization, hierarchical responsibility, joint participation, respective responsibilities, risk sharing and benefit sharing; improving the coordination mechanism between river basins and regions; building an implementation mechanism that the region obeys the river basin and the river basin drives the region, thus promoting the standardized management of water diversion projects.

(2) Strengthening water quality monitoring and management is a prerequisite for ensuring water supply safety

In the operation management, establishing a fast and accurate water quality monitoring system together with the water quantity and quality monitoring, supervision and inspection means, optimizing the water quality monitoring schemes and monitoring methods of water diversion projects, and implementing the sharing of water quality monitoring information between management institutions and local governments. At the same time, strengthening the supervision and inspection of the sewage outlet and pollution source of the project to ensure that the water quality of water diversion is continuously improved and stably up to the standard.

(3) Standardizing the dispatching management process is an important measure to ensure the safety of water supply

The operation of water diversion projects, including the East Route project, needs plans and systems in decision-making process, instruction issuance and implementation, supervision and feedback control and the improvement of the accuracy of decision-making and the effectiveness of instruction implementation. Firstly, when formulating scheduling schemes, comprehensive analysis and scientific demonstration should be carried out to provide a good basis for decision-making; secondly, we should standardize the generation, decision-making, release, implementation, supervision, feedback and adjustment procedures of the dispatching instructions, and use reasonable systems to reduce the problems that may be caused by human errors; thirdly, it is necessary to strictly implement the operation technical regulations or application methods of water conservancy projects and do a good job in operation scheduling, project monitoring, water volume monitoring, equipment maintenance and other work, so as to avoid the risk of endangering project safety caused by non-standard operation.

(4) The preparation of feasible dispatching scheme and emergency plan is the basic guarantee to ensure the safety of water supply

The water diversion project should be based on the design function, which may involve flood control, water transfer, water quality protection and other aspects. The analysis and research on the rain, flood, drought and water demand laws of the river basins involved in the project should be strengthened. On the basis of scientific analysis, the dispatching schemes should be further refined to enhance the practicability and guidance of the schemes, so as to do a good job in water dispatching, shipping management, power guarantee, aquaculture management and other guarantee work, thus to meet the needs of daily operation and dispatching of the project and ensure the safety of water supply along the route. At the same time, preparing corresponding emergency plans for possible cross-border water and solid disputes, abnormal discharge of pollutants and other emergencies, and conducting troubleshooting in a timely or regular manner to ensure that emergencies can be handled quickly. Through the above measures, further coordinating the dispatching objectives and the interests of all parties as well as restricting the dispatching behavior and improving the emergency response capacity.

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