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# Maintaining healthy rivers and lakes through water diversion from Yangtze River to Taihu Lake in Taihu Basin

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**Abstract:** On the basis of the Taihu water resources assessment, an analysis of the importance and rationality of the water diversion from the Yangtze River to Taihu Lake in solving the water problem and establishing a harmonious eco-environment in the Taihu Basin is performed. The water quantity and water quality conjunctive dispatching decision-making support system, which ensures flood control, water supply and eco-aimed dispatching, is built by combining the water diversion with flood control dispatching and strengthening water resources monitoring and forecasting. With the practice and effect assessment, measures such as setting the integrated basin management format, further developing water diversion and improving the hydraulic engineering projects system and water monitoring system are proposed in order to maintain healthy rivers and guarantee the development of the economy and society in the Taihu Basin.

**Key words:** *Taihu Basin*; *water resources distribution*; *water diversion from the Yangtze River to Taihu Lake*; *healthy rivers and lakes*

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## 1 Introduction

The Taihu Basin, lying in China’s bustling and productive Yangtze Delta and divided by different administrative entities, has a dense river network system and a large and concentrated population, and is becoming one of the most economically developed areas in China. In 2005, the Taihu Basin reported a total population of 45.33 million, which is 3.5% of the total population of China, and a GDP of CNY 2 122.1 billion, which is 11.7% of the national GDP.

The Taihu Basin’s history is closely linked with water. Due to the climate, geographic conditions and social development, flood disaster occurs frequently, the water environment is seriously degraded, pollution-induced water shortages are pronounced and the rivers’ health is damaged. Water sustains all living systems. Effective water resources management and rehabilitation of the water ecosystem should be integrated with the development of the economy and society. The establishment of a harmonious relationship between human beings and the natural ecosystem is urgently needed, requiring all kinds of effective, secure, practical and economical methods and approaches to improving the status of the local water resources and environment (Wang 2003; Su 2003; Liu 2004; Liu and Wu 2003; Wu 2004a). Now,

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through methods such as utilizing the main hydraulic projects that the Taihu Basin managers began to build in 1991, regulating the operation of the water control pivot, and managing water transfers into the basin and water resources distribution across its plains and river network, clean water from plentiful water sources has flowed into areas where water is stagnant, polluted and insufficient, improving the water quality in the Taihu Basin. This enhances the water supply and helps to maintain healthy rivers and lakes in the Taihu Basin (Wu 2004b; Dong 2004; Chen and Zhu 2004; Hu and Tian 2004; Pang et al. 2004; He and Peng 2003).

## 2 Assessment of water resources status in Taihu Basin

The Taihu Basin lies in the Yangtze River Delta, with the Yangtze River to the north, Hangzhou Bay to the south, the Tianmu and Yili mountains to the west, and the East China Sea to the east. The topography of the basin mostly consists of flat plains, with some depressions, and surface water. A smaller portion of the basin is mountainous (Figure 1).

Hills and river networks each occupy the same proportion (roughly one sixth) of the basin's total surface area, while plains make up two thirds of the remaining area. The total length of rivers in the basin is 120 000 km and the density of the river networks is 3.3 km/km$^2$. The total area of the surface water of the basin is 5 551 km$^2$, making up 15% of the basin's land cover, which is the highest percentage of land covered by surface water of any basin in China. There are 189 lakes with a surface area greater than 0.54 km$^2$. Taihu Lake, in the middle of the basin, has a surface area of 2 338 km$^2$ at normal water levels.

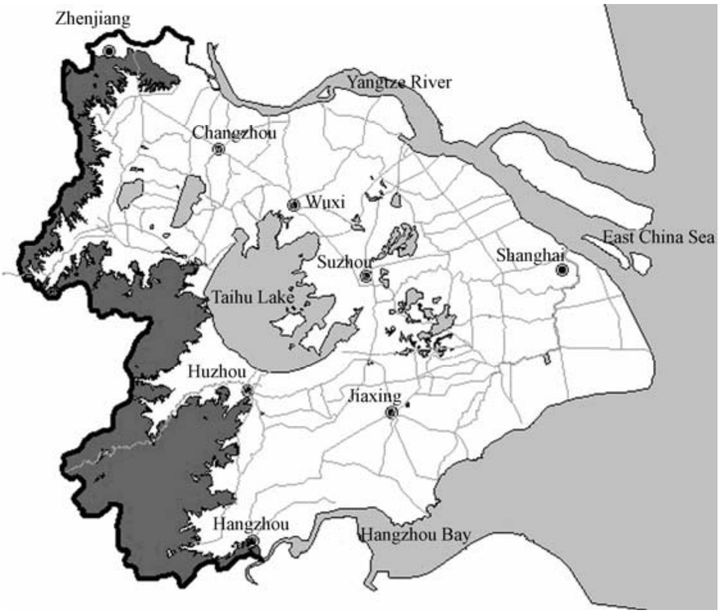


**Figure 1** Sketch map of water system in Taihu Basin

The basin's annual average rainfall reaches 1 177 mm and the quantity of the surface water resources is 17.74×10$^9$ m$^3$ in normal years. The original per capita water resources in the basin are 456 $m^3$, one fifth of the national average. The Yangtze River, lying to the north of the basin, with a total annual flow of $933.5\times10^9$ $km^3$, has plenty of water and high water quality, and is a stable source of water for the replenishment of the Taihu Basin.

Taihu Lake is an important source of water in the basin. Before the 1970s, the average water quality in Taihu Lake was graded class II-III (according to the GB3838-88 standard). From the 1980s on, because of the increasing discharge of wastewater into the lake, the water quality deteriorated by one grade every ten years. As time passed, the rate of deterioration grew faster and faster. In the 1980s, the lake was graded class II, and after 1998 it reached class III-V (Figure 2). Now the lake is in a mid-trophic to eutrophic condition, resulting in the blue algae bloom that often occurs in the lake and affects the water supply in surrounding cities.

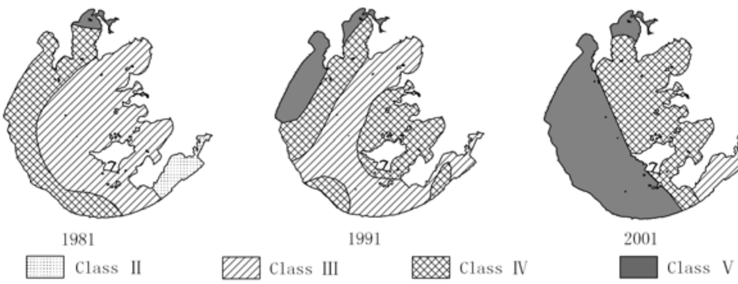


**Figure 2** Variation of water quality of Taihu Lake from 1981 to 2001

Wastewater discharge from point sources amounts to 6 billion t, with $8.48\times10^6$ t per year of $COD_{Cr}$ and $6.27\times10^4$ t per year of $NH_3$-N flowing into the lake. A large amount of the discharged pollutants has exceeded the water bearing capability, causing serious water pollution. In 2000, the total length of evaluated rivers in the Taihu Basin was 4037.8 km. The length of the rivers with a comprehensive assessment of water quality of class II was only 2.91% of the total, while class III was 12.74%, class IV 21.12%, and class V 9.75%. Rivers with water quality lower than class V accounted for 53.48%.

Taihu Lake has large-scale sediment with an area of 1547 $km^2$, which is 66% of the total area of Taihu Lake. The flowing mud, which amounts to $2.33\times10^8$ $m^3$, is the main inner pollution source. With wind-waves and water flow, the pollutants are easily adsorbed by sediment or become suspended in the lake, causing the secondary pollution. The deteriorating water environment has not been controlled, the ecological condition of the key lakes and rivers is worrying, and the water quality in the water headland is still a problem.

# 3 Integrating functions of hydraulic engineering projects to promote healthy rivers and lakes

## 3.1 Brief introduction to water diversion from Yangtze River to Taihu Lake and research achievements

The Chinese Central Government has highlighted water environmental regulation in the

Taihu Basin. Since the serious flood in 1991, nearly CNY 10 billion has been invested in the construction of the basin key flood control and water resources dispatching system, which connects Taihu Lake with the Yangtze River, Hangzhou Bay and the Huangpu River. At the same time, according to the long-term practice of basin flood control and water resources dispatching, the State Flood Control and Drought Relief Office permitted the Taihu Basin flood dispatching plan which integrated flood resources usage with the security of the water supply, actively improving the water environment. Moreover, the eco-system of rivers and lakes in the basin was restored by carrying out hydraulic engineering projects. The Tenth Five-Year Plan for Taihu Water Pollution Control permitted by the State Council further affirmed water diversion from the Yangtze River to Taihu Lake as an effective measure to control water pollution in the Taihu Basin.

In accordance with Premier Wen Jiabao’s suggestion that the water quality be improved by allowing plentiful clean water to flow into polluted water areas where the water supply is insufficient, the completed basin key flood control and water resources dispatching system is used, with experimental diversion of water from the Yangtze River to Taihu Lake in the complex river network plain area. Real-time water quantity and quality monitoring was developed (Figure 3), and advanced techniques were applied, including combining the prototype test with the mathematical model, virtual reality and information integration, building up the water dispatching effect assessment system and water quantity and quality joint dispatching decision support system (Figure 4), developing the Taihu Lake ecology model, proposing a discharge framework for the west bank of the Wangyu River, and researching the management mechanism and operational system for the water diversion.

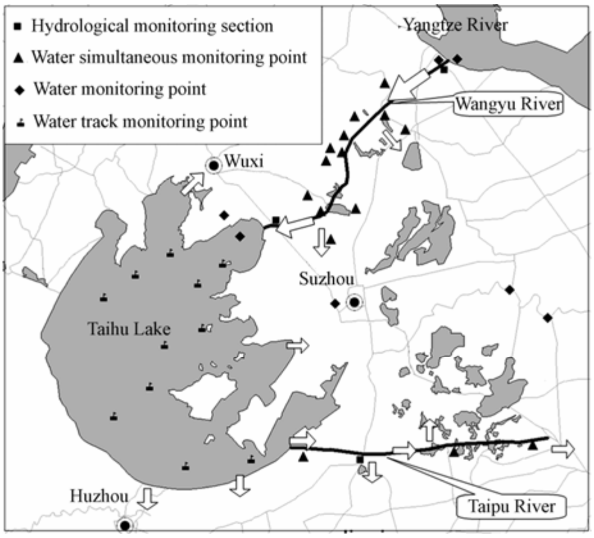


**Figure 3** Water quantity and quality monitoring points for the water diversion

These relevant research achievements have been applied in basin water diversion practice. They provided technical support to the solution to the drought from 2003 to 2005 and the oil pollution problem in the Huangpu River in 2003, and played an especially large role in the urgent diversion confronting the water supply crisis in the city of Wuxi in 2007 (Figure 5). In practice, water diversion from the Yangtze River to Taihu Lake effectively integrated flood control with water supply, with emphasis placed on both water quantity and water quality. Moreover, the allocation, protection and application of water resources were strengthened through water diversion. Therefore, the water diversion project is necessary for the temporarily hard task of basin pollutant source regulation, and is also useful to the constant basin water eco-environmental restoration.

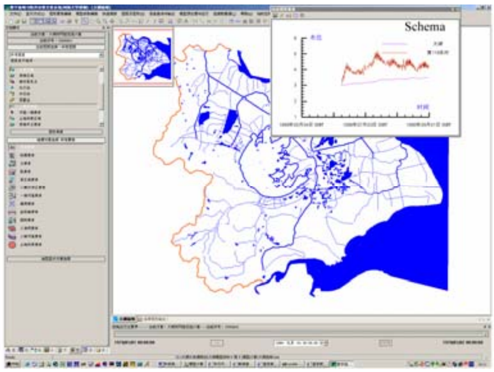


**Figure 4** Water quantity and quality joint dispatching decision-making support system

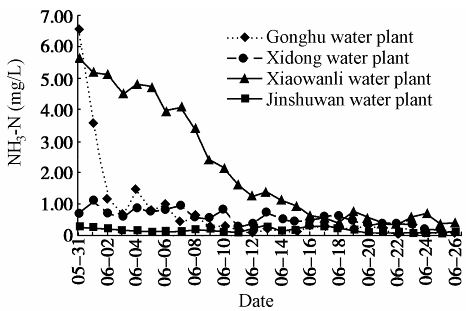


**Figure 5** Variation of $NH_3$-N in water plants in Wuxi, since water diversion in 2007

## 3.2 Improving Taihu Lake and river network environment through water diversion

With the trial of the water diversion from the Yangtze River to Taihu Lake, the Taihu Basin Authority (TBA) makes full use of water resources from floods and accelerates the water exchange between Taihu Lake and the river network to improve the water quality in Taihu Lake, which is the largest and most important untreated water source for the cities of Shanghai, Suzhou and Wuxi.

In the past six years, this diversion has improved the water environment by connecting the main water system with the regional river network and enhancing the flow throughout.

Since 2002, the TBA has transferred nearly $11.3\times10^9$ $m^3$ of water from the Yangtze River to the Taihu Basin, $5.1\times10^9$ $m^3$ of which has been transferred to Taihu Lake (Figure 3). The water level of Taihu Lake is normally 3.0-3.4 m. There are water level differences between Taihu Lake and the downward reaches of the river network, accelerating the drainage of Taihu Lake water downstream. The period of the exchange of water has decreased from 300 d to 250 d. The key indicator of eutrophication in Taihu Lake is total phosphorous (TP), the mean concentration of which decreased from 0.10 mg/L in 2000 to 0.069 mg/L in 2003 (Figure 6). The organic pollutant indicator is potassium permanganate, whose mean concentration also decreased from 5.28 mg/L in 2000 to 4.30 mg/L in 2003 (Figure 7). The area of eutrophication in Taihu Lake has been reduced by 13%, the growth of phytoplankton has been significantly restrained and plants that indicate better water quality have appeared in Gonghu Lake. The quality of water at the water supply source has improved by one to three classes. The flow velocity in the receiving river network has increased from 0.1 m/s before the water transfers to 0.2-0.3 m/s afterwards, and the water of the river network has been fully exchanged once. Through the diversion, the water quality of rivers and lakes that receive water has improved and the percentage of monitoring sections with water quality higher than class III (according to the $COD_{Mn}$ and $NH_3$-N) has increased by 20%.

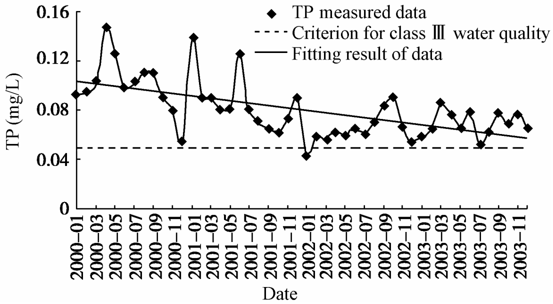


**Figure 6** Variation of TP in Taihu Basin from 2000 to 2003

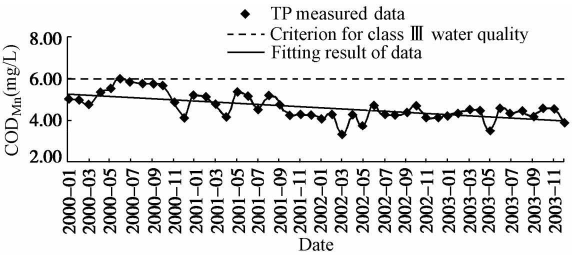


**Figure 7** Variation of $COD_{Mn}$ in Taihu Basin from 2000 to 2003

## 3.3 Ensuring the security of water supply through water diversion with risk decision

During the process of the water diversion from the Yangtze River to Taihu Lake, the TBA implemented scientific research on the optimal distribution to ensure secure flood control and water supply as well as an improved aquatic environment in the basin.

Since the trial, the TBA has actualized the security of flood control and the water supply and improved the water quality, the water environment, and the ecology through such methods as intensifying water resources monitoring, pre-alert systems and decision-making, controlling the water level of Taihu Lake before the flood season so that flooding remains only a moderate risk, and integrating flood dispatching with water resources transfers.

The summer of 2003 saw the highest temperature in 50 years and the worst drought in 30 years in the Taihu Basin. By regulating and dividing water resources, the water for daily use and production as well as ecological circulation were guaranteed, and the needs for the basin's shipping, electric power, fisheries and tourism were satisfied. Moreover, the water transfer increased the water body's self-purifying capacity and meliorated the water quality of Taihu Lake and the basin's river network.

During the main flooding period of 2004, the Taihu Basin experienced continuously hot season and was attacked by several typhoons, including Mindule, Rananim and Talim. After the period of intermittent drizzles in the rainy season, the levels of rivers and lakes were continuously low, followed by a severe drought. According to scientific analysis and risk management decisions based on flood situations, the Changshu pumping station was opened and a total volume of $0.31\times10^9$ $m^3$ of water was diverted, of which $0.18\times10^9$ $m^3$ of water flowed into Taihu Lake, relieving the drought and ensuring water supply security.

## 4 Conclusions

With an area of less than 0.4% of China and less than 0.6% of the national water resources, the Taihu Basin produces 12% of the country's GDP, and indicates a trend of accumulation of wealth. Water management is an eternal topic of concern in the Taihu Basin. We should establish and perfect water management support systems by monitoring, forecasting, regulating, protecting and maintaining the health of rivers and lakes, and, especially, by enhancing the capability of managers to tackle crises and risks.

(1) The water resources capacity in the Taihu Basin is very small, and water shortages caused by high levels of pollution are serious. Dissensions over water matters, particularly in relation to pollution, often occur in the river basin. The multi-annual mean water resources only amount to $17.7\times10^9$ $m^3$, while water usage reaches $35.6\times10^9$ $m^3$—a big difference between supply and demand. With the rapid development of the economy, the demands for water in large and moderate-sized cities increase continuously. In view of the limited water supply and severe water pollution, in other words of the conflict between water supply and demand, measures must be taken to expand the area of water use and to develop water transfers into the basin from regional rivers and lakes in order to restore water resources quickly and resolve the problem of water shortage.

(2) The optimal solution is to improve the efficiency of water resources distribution, that

is, on the one hand, to reasonably resolve the water usage conflicts among all departments and trades, and on the other hand to impel all departments and trades to use water economically and efficiently. It is very important to comprehensively plan to ensure the security of the flood control systems, the water supply, and the water ecology when water transfers are carried out in the area, whether there is plenty of water or a shortage of water caused by pollution.

(3) It is an era that calls for the maintenance of healthy lakes and active rivers. Water projects such as the water diversion from the Yangtze River to Taihu Lake are playing an important role. Basin authorities should seek sustainable development of the environment, the economy, and society, as well as understanding the characteristics of water resources, aquatic ecology, economic development, and the relationships between all of these, in order to clearly determine the objective to manage healthy rivers and plan for water quality and quantity. They should also strengthen their social management skills and ability to serve the public, and promote harmonious relationships between human beings, water systems and natural ecosystems.

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