Study on Comprehensive Water Price of Multi-water Resources in Ningjin County

Xiuxiu Sun¹a, Haijiao Liu²b, Mingyuan Fan²c,*, Ludong Ni¹d and Weiping Wang¹e

¹ School of Water Conservancy and Environment, University of Jinan, Jinan 250022, China
² Water Resources Research Institute of Shandong Province, Jinan 250022, China
³sunxiuxiusxx@126.com, bliuhajiao2005@163.com, cfantina715@126.com,
dnld19941121@126.com, ewangweiping126.com

* Corresponding author

Abstract. Ningjin County is located in northwest Shandong Province in the North China Plain. The water shortage can be solved if the South-to-North Water Transfer Project is completed, but the project water price is higher than the price of local groundwater and Yellow River water, so it is urgent to make the comprehensive water price of multi-water resources in this area. The water demand of non-agricultural water users in the planning year of 2020 and 2025 is forecasted based on water supply and consumption in current year of 2017, and two water supply schemes are set up respectively, four schemes totally considering the factors whether Yangtze River water will be obtained. The water prices of four schemes are calculated using weighted average model. The results show that when the transferring water replaces partial underground water in 2020, the comprehensive water prices of scheme 1 and scheme 2 are 3.21 yuan/m³ and 2.11 yuan/m³ respectively. When the transferring water replaces all groundwater in 2025, the comprehensive water prices of scheme 3 and scheme 4 are 2.92 yuan/m³ and 1.44 yuan/m³ respectively. The compensation mechanism of water price is discussed finally.

1. Introduction

Water is an indispensable resource for human survival and development, and the optimal allocation and sustainable development of water resources need reasonable water price. Ningjin County belongs to the Beijing-Tianjin-Hebei coordinated development zone. It is imperative to adjust industrial structure in the future, but the lack of water resources has seriously hindered economic development. At present, the South-to-North Water Transfer Project is in planning and construction in Ningjin County. Although Yangtze River water is conducive to relieving the imbalance between supply and demand and protecting groundwater, its water price is higher than others, which makes it at a disadvantage in competition. Therefore, it is important and urgent to study the comprehensive water price of multi-water resources in Ningjin County.

The water supply departments are enterprises in England and France, which need to guarantee cost recovery when the water price is made[1-3]. However, the water price needs to meet the full cost recovery criteria in America[4]. Two-part water price is put into practice in Japan[3]. Israel divides the water into domestic water, municipal water and water of industry and agriculture according to application, and adjusts the water prices by the actual situation[5]. In India, Australia and Canada, the
state and government is responsible for water price, but both of them do not recover the full operating costs[5-6].

Influenced by planned economy system, the water conservancy cause is social commonweal in China. The development of water price has experienced several stages as disordered period, low-cost water supply period, the period of paying attention to cost accounting and the period of transition to a reasonable water price, but a perfect pricing model for multi-water sources has not been formed. This study predicts the water consumption of non-agricultural water users in 2020 and 2025 in Ningjin County, makes four water supply schemes and calculates the water prices respectively, which provides technical support for the regional comprehensive water price reform in Ningjin County. What’s more, it is conducive to the rational use of water resources, and it can improve the government’s water management ability.

2. Geographical Position of Study Area and Water Resources Situation

2.1. Geographical Position of Study Area

Ningjin County is located in northwest Shandong Province in the North China Plain, being confined by longitudes 116° 30’ - 117° E and latitudes 37° 30’ - 37° 51’ N, 833 km² in total area. It belongs to the zone of the continental monsoon climate, and the perennial mean temperature is 12.3 °C, the average rainfall of many years is 550.1 mm. The rivers belong to the Haihe River Basin, such as Zhangweixinhe River, Ningjinxinhe River, Ningnanhe River, Ningbeihe River and Zhuijahe River. There are also 20 main drainage ditches such as Lishiguditch and Caotang Ditch, with an area of 30 km² and the total length of 249.8 km. The geographical position of Ningjin County is shown in Figure 1, and the river system is shown in Figure 2.

![Figure 1. Geographical position of Ningjin County.](image)

![Figure 2. River system of Ningjin County](image)

2.2. Water Resources Situation

Water resources in study area mainly include local water resources, foreign water resources and unconventional water resources. The local water resources include surface water resources and groundwater resources, and the total water resources in the 50%, 75% and 95% frequency years are 65.48 million m³, 44.20 million m³ and 30.37 million m³ respectively after deducting the double-calculated amount. The foreign water resources are mainly from Yellow River water, and they will include Yangtze River water in the future, the index of them is 59.4 million m³ and 12.46 million m³ respectively. Unconventional water resources include renewable water resources, brackish water resources and the water from ZhangWeixinhe River, and the water resources quantity is about 12 million m³, 5 million m³ and 15 million m³ respectively each year.

3. Analysis of Water Supply and Demand in Current Year

The total water supply was 133 million m³ in 2017 according to the Annual Report of Water Resources in Ningjin County. The surface water resources quantity was 81.634 million m³, among them the local surface water quantity was 5.014 million m³ and Yellow River water quantity was 76.62 million m³. And the groundwater resources quantity was 51.47 million m³, among them the
quantity of shallow groundwater was 50.24 million m$^3$ and deep groundwater was 1.23 million m$^3$. In addition, the quantity of reused water, saline water and rain and flood resources of Zhangweixinhe River that was taken by local people themselves was about 30 million m$^3$, which was not the part of the annual report.

From the present situation of water using, the water supply mode for resident living, secondary and tertiary industry is mainly based on public pipe network, with self-well water supply partially. The ecological water is taken from rivers and public pipes. And the water sources of primary industry are various, including groundwater, Yellow River water, surface water and unconventional water. From water utilization structure, the rate of agricultural water use (122.0394 million m$^3$) was the largest, which accounts for 91.68% of total water consumption; and the rate of ecological water use (0.3 million m$^3$) was the least, which only accounts for 0.22% of total water consumption. And the quantity of domestic water, industry water and urban water accounted for 7.20%, 0.89% and 0.37% of total water consumption respectively.

4. Water Supply Allocation for Non-agricultural Water Users in Planning Year

The implementation of the comprehensive water price reform in this region is mainly for non-agricultural water users with high water using rate. And the water configuration is the prerequisite for water-price accounting. It is predicted that the quantity of water intake of non-agricultural water users will be 15.81 million m$^3$ in 2020 and 21.24 million m$^3$ in 2025 in the county under the premise of preferential use of transferring water. The water intake forecast is shown in Table 1.

| Water Sector | 2020 | 2025 |
|--------------|------|------|
| Public Water Supply | | |
| Ningjin Water Plant | 9.33 | 14.39 |
| DaLiu Water Plant | 5.11 | 6.85 |
| Self-well Water Supply | | |
| Urban and Rural Life | 0.488 | 0 |
| Industry | 0.647 | 0 |
| Tertiary Industry | 0.235 | 0 |
| Total | 14.44 | 1.37 |

Make two water supply schemes respectively at the planning year of 2020 and 2025 based on this result. When the foreign water replaces partial underground water in 2020, scheme 1 is that Yangtze River water replaces the groundwater of 6.68 million m$^3$, scheme 2 is that considering the delay of engineering operation on Yangtze River, Yellow River water replaces the groundwater of 6.68 million m$^3$. When the foreign water replaces all groundwater in 2025, scheme 3 is that considering the maximum indicator of Yangtze River water, water intake quantity of Yangtze River water is 11.87 million m$^3$, scheme 4 is that considering the delay of engineering operation on Yangtze River, Yellow River water replaces the groundwater of 10.103 million m$^3$. See Table 2 for details.
5. Accounting Methodology of Water Price

5.1. The Unit Prices of Different Water Sources and Water Supply Modes
At present, there are three water supply sources for non-agriculture in Ningjin County, and the unit price of each water source can be composed of raw water price, water resource fee (tax) and engineering water price. What needs to be explained is the raw water price of Yangtze River. The Yangtze River water implements the two-part water price system, of which the basal water price is 1.09 yuan/m³, the measurement water price is 1.15 yuan/m³. The fundamental water fee must be paid before the water is consumed according to the basal water price and the water quantity promised by the intake area, which makes the raw water price of Yangtze River change greatly with the used amount of Yangtze River water.

In the two scenarios of the planning year of 2020 and 2025, the actual water intake of Yangtze River in scheme 1 is 7.01 million m³, and the actual water intake of Yangtze River in scheme 3 is 12.46 million m³ considering the route loss at 4.7%. The raw water price can be calculated according to the formula \( p = 1.15 + 1.09 \times (1246/W) \), where \( p \) is the raw water price of Yangtze River water, the unit is yuan/m³, and \( W \) is the water intake quantity of Yangtze River, the unit is 10,000 m³. The water intake quantity of Yangtze River in Scheme 2 and Scheme 4 is 0, thus the raw water price is the basal water price of 1.09 yuan/m³. What’s more, the regional comprehensive water price refers to the water price of water supply project, rather than the household water price in this paper. See Table 3 for details.

| Water Supply Sources | Raw Water Price | Water Resource Fee (Tax) | Engineering Water Price | Water Supply Price |
|----------------------|----------------|--------------------------|------------------------|--------------------|
| Yellow River         | 0.12           | 0.40                     | 0.28                   | 0.80               |
| Groundwater          | 0              | 6.00                     | 0                      | 6.00               |
| Yangtze River        |                 |                          |                        |                    |
| Yellow River         | 3.09           | 0.40                     | 1.96                   | 5.45               |
| Groundwater          | 1.09           | 0                        | 0                      | 1.09               |
| Yellow River         | 2.24           | 0.40                     | 1.96                   | 4.60               |
| Groundwater          | 1.09           | 0                        | 0                      | 1.09               |

5.2. The Calculation of Regional Comprehensive Water Price

5.2.1 Weight Average Model. It is assumed that \( m \) water sources and \( n \) water supply modes should be considered in the calculation of regional comprehensive water price, and the weight average model of regional comprehensive water price is \( p = \sum_{i=1}^{m} \sum_{j=1}^{n} p_{ij} W_{ij} (\sum_{i=1}^{m} \sum_{j=1}^{n} w_{ij})^{-1} \). Where \( p_{ij} \) was the
water price of i single water source under the j water supply mode, and \( w_{ij} \) was the water supply quantity of i water source under the j water supply mode.

5.2.2 The calculation of regional comprehensive water price. The regional comprehensive water prices of four schemes are calculated by the weight average model according to water configurations in Ningjin County. Finally it is gained that the water price is 3.21 yuan/m\(^3\), 2.11 yuan/m\(^3\), 2.92 yuan/m\(^3\), 1.44 yuan/m\(^3\) respectively. See table 4.

| Planning Year | Scheme | Water sources       | Water Supply Quantity (×10\(^6\) m\(^3\)) | Water Price (yuan/m\(^3\)) | Comprehensive Water Price (yuan/m\(^3\)) |
|---------------|--------|---------------------|-------------------------------------------|-----------------------------|-----------------------------------------|
| 2020          | Scheme 1 | Yellow River water  | 7.76                                      | 0.80                        | 3.21                                    |
|               |        | Yangtze River water | 6.68                                      | 5.45                        |                                         |
|               |        | Groundwater         | 1.37                                      | 6.00                        |                                         |
|               | Scheme 2 | Yellow River water  | 14.44                                     | 0.80                        |                                         |
|               |        | Yangtze River water | 0                                         | 1.09                        | 2.11                                    |
|               |        | Groundwater         | 1.37                                      | 6.00                        |                                         |
|               | Scheme 3 | Yellow River water  | 11.87                                     | 4.60                        | 2.92                                    |
|               |        | Groundwater         | 0                                         | 6.00                        |                                         |
|               | Scheme 4 | Yangtze River water | 21.24                                     | 0.80                        |                                         |
|               |        | Groundwater         | 0                                         | 1.09                        | 1.44                                    |

6. Compensation Mechanism of Water Price
The so-called price compensation mechanism, commonly known as price subsidy, sets different prices for different users, some of which are lower than the cost, and some of which are higher than the cost. Above all, Ningjin County should establish the water price compensation mechanism as soon as possible combining the reform of water price.

There are three ways of water price compensation: clear-sighted subsidies, hidden subsidies, and the way between them. The clear-sighted subsidies refer to government subsidy for water users with money directly on the basis of considering the relationship between water price and market supply and demand. The hidden subsidies are that subsidize water users in the form of lower water charges. The way between them means take quantitative restriction for hidden subsidies. The implementation of comprehensive water prices will inevitably promote water saving and increase water use efficiency. It is difficult to implement clear-sighted subsidies for all water users. So it is recommended to implement a limited amount of hidden subsidies firstly, and then gradually transit to the stage of full implementation. It is critical to determine the standard of compensation anyway.

The scientific and rational system of readjusting the price should be created and the special funds for regional comprehensive water price compensation should be set up. What’s more, water uses should promote water saving to reduce costs and increase benefit, thus the water price reform can be implemented energetically and reliably.

7. Conclusion and Suggestions
The water supply quantity is 133.3 million m\(^3\) in total in current year of 2017 in Ningjin County, of which the water supply quantity of surface water accounts for 61.33%, and the water supply quantity of groundwater accounts for 38.67% of the total water supply. Agricultural water accounts for the largest proportion, accounting for 91.68% of total water consumption. It is predicted that the quantity of water intake of non-agricultural water users will be 15.81 million m\(^3\) in 2020, and the quantity of water intake of non-agricultural water users will be 21.24 million m\(^3\) in 2025.
In the two scenarios of the planning year of 2020 and 2025, two water supply schemes are made respectively considering the factors whether Yangtze River water will be obtained. Then using the weighted average calculation model, the water price corresponding to each scheme is calculated to be 3.21 yuan/m$^3$, 2.11 yuan/m$^3$, 2.92 yuan/m$^3$ and 1.44 yuan/m$^3$ respectively. It is recommended to implement a limited amount of hidden subsidies firstly, and then gradually transit to the stage of full implementation.

In the future, it is necessary to strengthen the research on the water price for special industries with high water consumption such as bathing, car washing and purified water, and water prices should be formulated according to the types of households. In addition, it is important to popularize use of flood and rain, play the role of the adjustable effect of many years of groundwater and study the scheme of groundwater recharge of Zhangweixinhe River.

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