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Comprehensive Planning Strategies for Water Resources under the Rigid Constraint System of Water Resources

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Abstract: With the intensification of global climate change and the rapid development of the social economy, problems such as water shortage and water ecological damage have become increasingly prominent. Water resources have become a key strategic resource restricting China's sustainable development. The rigid constraint system for water resources, as an important institutional innovation in national water resources management, provides a mandatory framework for comprehensive water resources planning by setting the "red line" and "bottom line" for the development and utilization of water resources. Based on the core connotation of the rigid constraint system of water resources, this paper systematically analyzes the practical challenges currently faced by the comprehensive planning of water resources in China. From four dimensions: reconstruction of planning goals, optimization of spatial layout, innovation of allocation mechanism, and improvement of control system, it proposes comprehensive planning strategies for water resources that meet the requirements of rigid constraints. To provide theoretical support and practical reference for the sustainable utilization of water resources and the high-quality development of the economy and society in our country.

1. Introduction

Water resources are the source of life, the foundation of production and the key to ecology. Their sustainable utilization is directly related to national food security, ecological security and the overall development of the economy and society. In recent years, the contradiction between water supply and demand in China has continued to intensify, and the distribution is uneven in time and space. The development and utilization rate of water resources in northern regions has exceeded the international warning line of 50%, and in some river basins, ecological problems such as river drying up and wetland shrinkage have even occurred due to excessive water exploitation. To address this situation, the revision of the "Water Law of the People's Republic of China" in 2021 explicitly proposed "establishing a rigid constraint system for water resources". In 2023, the "National Comprehensive Water Resources Plan (2021-2035)" further integrated the rigid constraint requirements throughout the planning process, marking a shift in China's water resources management from "flexible guidance" to "rigid control". Against this backdrop, how to reconstruct the comprehensive water resources planning system, making the planning not only meet the mandatory requirements of rigid constraints but also adapt to the dynamic demands of economic and social development, has become a key issue that urgently needs to be addressed in the current field of water resources management.

2. The core connotation and planning requirements of the rigid constraint system for water resources

2.1 The Core connotation of the rigid constraint System for Water Resources

The rigid constraint system for water resources refers to a system framework that takes the carrying capacity of water resources as the core and sets "unbreakable" control indicators and boundary conditions to enforce mandatory regulations on the development, utilization, conservation and protection of water resources. Its core connotation can be summarized as "three lines and one platform" [1]. Among them, the red line for water resources development and utilization is based on the available amount of water resources in a basin or region, clearly defining the upper limit of the total amount of water resources development and utilization to ensure that the intensity of water resources development does not exceed the carrying capacity. The red line for water use efficiency control is based on the advanced water use level of the industry, setting efficiency indicators such as water consumption per 10,000 yuan of GDP and the effective utilization coefficient of irrigation water for farmland, to force the transformation of water use patterns from extensive to intensive. The red line for water ecological protection aims to maintain the stability of water ecosystem functions. It demarcates protection boundaries such as ecological flow (water level) of rivers and lakes, no-extraction zones and restricted extraction zones for groundwater, etc., to prevent the degradation of water ecosystems. The water resources management and control platform, relying on big data, Internet of Things and other technologies, builds an intelligent platform integrating water resources monitoring, measurement, dispatching and supervision, achieving dynamic monitoring and precise regulation of rigid constraint indicators, and providing technical support for the implementation of planning.

2.2 Core Requirements of Rigid Constraints for Comprehensive Water Resources Planning

Under the framework of the rigid constraint system for water resources, the traditional comprehensive water resources planning model mainly based on "demand orientation" has become difficult to adapt. The planning needs to achieve "three transformations" to meet the mandatory and scientific requirements of rigid constraints. Firstly, the planning objective has shifted from "meeting demands" to "balancing supply and demand". Traditional planning often starts from the water demand of economic and social development and meets the demand by expanding water supply capacity, which easily leads to excessive exploitation of water resources. Under rigid constraints, planning needs to first clarify the upper limit of water resource carrying capacity and then optimize the layout of economic and social development based on the carrying capacity. Realize the principle of "determining cities, land, population and production based on water resources". Secondly, the planning method has shifted from "static calculation" to "dynamic simulation". Traditional planning mostly uses static hydrological data and water quotas for supply and demand balance calculation, which is difficult to reflect the impact of dynamic factors such as climate change and economic fluctuations. Under rigid constraints, planning needs to introduce tools such as hydrological models and econometric models to simulate the changes in water supply and demand under different scenarios. Ensure that the planning indicators still meet the requirements of rigid constraints during dynamic adjustments; Finally, the focus of the planning has shifted from "water supply security" to "systematic governance". Traditional planning has emphasized the construction of water supply projects, paying insufficient attention to water conservation, pollution control and ecological protection. Under rigid constraints, the planning needs to coordinate the development and utilization of water resources, conservation and protection, and water ecological restoration, and build a full-chain control system covering "water supply - water use - drainage - reclaimed water utilization". Maximize the benefits of the water resources system.

3. The current practical challenges faced by comprehensive water resources planning in our country

3.1 The connection between planning indicators and rigid constraints is insufficient

In some regions, the comprehensive water resources planning still follows the traditional indicator system, which is "disconnected" from the rigid constraint requirements. On the one hand, the total water usage and water use efficiency indicators in the planning do not strictly align with the rigid constraint red lines at the national or river basin level, making it difficult to meet the rigid control requirements. On the other hand, the planning does not give sufficient consideration to the red line of water ecological protection. Some plans only allocate ecological water as "surplus water volume", without giving priority to ensuring the ecological flow of rivers and lakes, resulting in the encroachment of ecological water and intensifying the risk of water ecological degradation.

3.2 Poor coordination in cross-regional and cross-departmental planning

Water resources have the characteristics of fluidity and systematicness. It is necessary to coordinate the planning connection between river basins and regions as well as among different departments. However, the current problem of insufficient planning coordination is prominent. The specific contradictions are shown in Table 1.

Table 1 Cross-level Collaborative Contradictions and Their Impacts

Collaborative level	Type of principal contradiction	Specific manifestations of contradictions	The influence on rigid constraints
At the basin-regional level	The planning of tributaries conflicts with that of the main stream	The main stream planning requires reducing groundwater extraction and controlling the total water usage, while the tributary planning adds new groundwater extraction projects and expands the water usage scale	This has led to the total water use in the basin exceeding the rigid red line, and problems such as excessive groundwater exploitation and insufficient ecological flow have intensified
Departmental level	Water resources planning is disconnected from other planning	The water resources planning clearly defines the upper limit of regional water usage capacity, but the territorial space planning exceeds the carrying capacity to plan industrial parks, and the industrial planning layout includes high-water-consuming projects	A situation of "conflicting plans" has emerged, making it difficult to implement rigid constraint indicators and increasing the difficulty of subsequent control and adjustment

3.3 The capacity for planning implementation and dynamic control is weak

Rigid constraints require real-time monitoring and dynamic adjustment of the planning implementation process, but the current planning implementation and control capabilities are difficult to meet the demands. First, the monitoring system is not perfect. In some remote areas, the coverage rate of water resource monitoring stations is low, making it impossible to accurately grasp the dynamics of water resource development and utilization, resulting in lagging monitoring of rigid indicators. Second, the regulatory mechanism is not flexible. The planning mostly adopts a "one-size-fits-all" control approach, lacking contingency plans for unexpected situations. Thirdly, the assessment mechanism is not sound. In some regions, the assessment of rigid planning indicators only focuses on the results while neglecting process control, leading to the phenomenon of "emphasizing planning but neglecting implementation", which affects the effectiveness of the implementation of rigid constraints.

3.4 The technical support and public participation mechanism are not perfect

The scientificity and feasibility of comprehensive water resources planning rely on technical support and public participation. However, there are obvious shortcomings at present, and the specific problems are shown in Table 2.

Table 2 Technical Support and Public Participation Issues

Supporting dimension	Supporting dimension	Specific manifestations of the problem	The influence on rigid constraints
Technical support	The accounting methods are not uniform and the models are not scientific	The calculation of water resources carrying capacity lacks a unified standard, and the parameter Settings of different models vary greatly, with the deviation of assessment results reaching more than 20%	This leads to a lack of scientific basis for the setting of rigid constraint indicators, with the indicators being too high or too low, affecting the effectiveness of control and management
Public participation	The participation channels are single and the rate of opinion collection is low	Opinions were only collected through public announcements, lacking interactive channels such as symposiums and questionnaires, resulting in a public opinion collection rate of less than 20%	The planning scheme is disconnected from public demands, and during the implementation process, it faces doubts and resistance, increasing the enforcement resistance of rigid constraints

4. Comprehensive Planning Strategies under Rigid Constraints of Water Resources

4.1 Reconstruct the planning target system and anchor the core indicators of rigid constraints

Based on the "three lines" of rigid constraints on water resources, a four-in-one planning target system of "total quantity control - efficiency improvement - ecological protection - economic adaptation" is constructed to ensure seamless connection between the targets and the rigid constraints [2]. In terms of total control targets, based on the available water resources in a river basin or region, the total water use control indicators are decomposed to the three levels of city, county and township. The proportions of domestic, production and ecological water use are clearly defined. In water-scarce areas, the proportion of production water use needs to be controlled within a reasonable range, and the proportion of ecological water use should remain no less than a specific proportion. At the same time, unconventional water resources such as reclaimed water and rainwater are included in the total management. Set targets for the utilization of unconventional water resources to ensure that the utilization rate of unconventional water resources in cities across the country reaches the established standards in the future and alleviate the pressure on conventional water resources. In terms of efficiency improvement targets, differentiated water use efficiency indicators should be set by industry. In the agricultural sector, the focus should be on enhancing the effective utilization coefficient of irrigation water to ensure that the effective utilization coefficients of irrigation water in farmland and high-standard farmland across the country reach the corresponding standards in the future. In the industrial sector, water-saving technological renovations should be advanced, and a target for reducing water consumption per 10,000 yuan of industrial added value should be set the water consumption per 10,000 yuan of output value in high-water-consuming industries has further decreased compared to the medium-term target. Water-saving appliances have been promoted in the living sector, and the per capita daily living water consumption of urban residents has been controlled within the limited standard. In terms of ecological protection goals, priority should be given to ensuring the ecological flow (water level) of rivers and lakes. The standards for ecological flow guarantee in different seasons should be clearly defined to ensure that the ecological flow guarantee rate of the main streams in major river basins reaches a relatively high level during the dry season. Groundwater extraction no-extraction zones and restricted-extraction zones should be demarcated, and groundwater level control targets should be set. Efforts should be made to promote the water level in over-exploited groundwater areas to rise within the planning period and restore damaged water ecosystems. Set indicators such as the wetland protection rate and the area for soil erosion control to ensure that the protection rate of important wetlands across the country reaches the established standards in the future. In terms of economic adaptation goals, the industrial layout should be optimized based on the carrying capacity of water resources. A "negative list" should be formulated to prohibit the layout of high-water-consuming projects in areas with excessive water resources, promote the upgrading of the industrial structure, set a target for the proportion of water-saving industries, and ensure that the proportion of water-saving industrial enterprises and the area of water-saving agricultural demonstration zones across the country reach the corresponding standards in the future. Realize the adaptation of economic development to water resource constraints [3-4].

4.2 Optimize the spatial layout of planning and build a "basin-region" collaborative system

Based on the spatial distribution characteristics of water resources and the requirements of rigid constraints, the boundaries of administrative regions should be broken, and a planning spatial layout system featuring "basin coordination and regional collaboration" should be constructed. At the river basin level, a "one main stream and multiple tributaries" control pattern is established. Taking the river basin as the unit, the rigid constraints on the main stream and tributaries are clearly defined. The main stream focuses on ecological protection and total volume control, strictly ensuring ecological flow and controlling the water intake scale of cities along the river. The tributaries focus on efficiency improvement and industrial adaptation, with an emphasis on promoting water conservation in agriculture and water conservation renovations in industrial parks. At the same time, a water resources dispatching mechanism for the basin should be established to coordinate the water use of the upstream and downstream, as well as the left and right banks. A dynamic dispatching model of "increasing in abundance and decreasing in scarcity" should be implemented to ensure that the total water use of the main stream does not exceed the rigid red line [5]. At the regional level, a "zonal control" strategy is implemented. Based on the water resource carrying capacity of each region, the country is divided into three types of areas: "overloaded areas, near-overloaded areas, and non-overloaded areas", and differentiated planning and control are carried out. Among them, in overloaded areas, the focus is on promoting "reducing total water use", planning to close over-exploited groundwater Wells, and promoting water-saving renovations in industries. Ensure that the total water consumption during the planning period is reduced by more than a specific proportion compared to the current situation. In the critical overloading area, focus on promoting "optimizing water use structure", planning to increase the utilization of reclaimed water and adjust the planting structure to avoid entering an overloading state. In the non-overloading area, focus on promoting "moderate development and equal emphasis on protection". Under the premise of not breaking through rigid constraints, rationally plan water supply projects to support economic and social development.

4.3 Innovate the water resource allocation mechanism to achieve efficient utilization under rigid constraints

Break through the traditional "supply based on demand" allocation model, and build a water resource allocation mechanism that "determines demand based on water and acts in accordance with water availability", to enhance the efficiency of water resource utilization under the framework of rigid constraints. Firstly, establish a dual allocation mechanism of "total quantity control + quota management". At the total quantity control level, based on rigid constraint indicators, decompose the total water resources to each industry and each user. At the quota management level, formulate water consumption quotas that match the rigid constraints. The water consumption quotas for high-water-consuming industries must not exceed the national advanced level. Agricultural irrigation quotas are dynamically adjusted based on climatic conditions and crop varieties to ensure that "the total amount does not exceed the limit and the quota does not exceed the standard" [6-7]. Secondly, we will promote the reform of market-based water resource allocation, improve the water resource fee collection system, and implement progressive surcharges for water use exceeding the total amount and quota. Different parts of the excess quota will be charged at corresponding proportions to force users to save water. We will explore the trading of water resource usage rights, establish water resource trading platforms within river basins, and allow water-saving enterprises to transfer the saved water to water-deficient enterprises for a fee. Promote the flow of water resources to high-efficiency areas. Finally, strengthen the allocation of unconventional water resources, incorporate reclaimed water, rainwater and desalted seawater into the water resource allocation system, clarify the rigid requirements for the utilization of unconventional water resources, give priority to the use of reclaimed water in urban greening, road cleaning, industrial cooling and other fields, ensure that the proportion of reclaimed water usage reaches the set standards, and plan and construct seawater desalination projects in coastal areas. Ensure that the proportion of desalinated seawater production in the total water consumption of coastal cities in the future reaches the set standard, and reduce the reliance on conventional water resources [8].

4.4 Improve the planning and control system to ensure that rigid constraints are effectively implemented

Build a full-chain control system of "monitoring - assessment - adjustment - evaluation", strengthen the rigid constraints in the process of planning implementation, and ensure that the planning goals are achieved on schedule. In terms of building an intelligent monitoring and supervision platform, data resources from hydrological stations, water intake monitoring stations, groundwater monitoring Wells, etc. are integrated. By applying Internet of Things and big data technologies, real-time monitoring of water resource development and utilization, water use efficiency, and water ecological conditions is achieved. A "space-ground-air" integrated monitoring network is established to conduct dynamic monitoring of key river basins and key areas. Regular water level monitoring should be carried out in groundwater over-exploitation areas to ensure that rigid indicators are controllable and manageable [9-10]. In terms of establishing a dynamic assessment and adjustment mechanism for planning, an assessment of the implementation of the comprehensive water resources planning should be conducted every three years, with a focus on the completion of rigid indicators such as total water use, water use efficiency, and ecological flow. If the planning indicators do not match the rigid constraints due to factors such as climate change or economic development, the adjustment procedures should be initiated promptly. In case of special climate years, the production water use quota can be temporarily adjusted to give priority to ensuring domestic and ecological water use. However, the adjustment range must be approved by the superior administrative department to ensure that it does not exceed the overall rigid constraints. In terms of improving the planning assessment and accountability mechanism, the rigid constraint indicators of water resources will be incorporated into the performance assessment system of local governments, and a "one-vote veto system" will be implemented. For regions that fail to meet the rigid indicators such as total water use control and water use efficiency improvement, the approval of new water withdrawal projects will be suspended. An accountability system will be established, and units and individuals who illegally approve water withdrawal or use water in excess will be held accountable in accordance with laws and regulations. For regions that have continuously exceeded the rigid constraints on total water consumption, the main responsible persons of local governments will be summoned for talks and held accountable to ensure that the rigid constraints are effectively implemented.

5. Conclusion

This article conducts research on the comprehensive planning under the rigid constraint system of water resources, clearly stating that this system takes "three lines and one platform" as the core and puts forward "three transformation" requirements for the planning. At the same time, it is pointed out that the current planning faces challenges such as insufficient connection of indicators, poor coordination, weak control, and imperfect technology and public participation. Based on this, strategies are proposed from four dimensions: goal reconstruction, spatial optimization, configuration innovation, and management improvement, along with supporting policy, technical, and financial guarantees. In the future, it is necessary to further study the flexible regulation of rigid indicators under extreme weather conditions, deepen the application of technologies such as digital twins in planning, explore market-oriented cross-regional collaborative mechanisms, promote water resources planning and management to better adapt to rigid constraints, and facilitate the sustainable utilization of water resources and high-quality economic and social development.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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