Problems and Challenges Confronting Water Security Assurance in Xiong' an New Area Development (Postprint)

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Date: 2017-11-17T00:00:00+00:00

Abstract

The construction of the Xiong' an New Area in Hebei Province represents a millennial strategy and national priority of China, constituting a crucial measure for the centralized relief of Beijing' s non-capital functions and the advancement of coordinated Beijing-Tianjin-Hebei development. Located in the Baiyangdian region of North China, the Xiong' an New Area faces multiple risk issues and challenges concerning water scarcity, water environment, and water ecology. From the disciplinary frontiers of water security and sustainable water resource management, this article focuses on examining the primary issues of water resources, water quality, and water ecological security currently confronting the construction of the Xiong'an New Area, analyzes potential risks and their causative factors in future development, and proposes several countermeasures and recommendations to address these risks: emphasizing both increasing supply and reducing consumption while strictly controlling pollution discharge; strengthening whole-basin ecological restoration and implementing ecological water replenishment measures for Baiyangdian; and executing integrated watershed water resource management to achieve a transition from supply-oriented to demand-oriented management.

Full Text

Special Issue: Science & Technology Supporting Xiongan New Area' s Planning and Construction

Water Security Challenges and Issues in Xiongan New Area Construction

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Abstract

The construction of Xiongan New Area represents a fundamental national strategy spanning millennia and a major initiative to relieve Beijing of non-capital functions while promoting coordinated development of the Beijing-Tianjin-Hebei region. Located in the Baiyangdian region of North China, Xiongan faces multiple risks and challenges related to water scarcity, water environment, and aquatic ecology. From the perspective of water security and sustainable water resource management, this paper examines the critical issues of water resources, water quality, and water ecological security currently confronting Xiongan' s development, analyzes potential future risks and their causes, and proposes countermeasures including: balancing new source development with conservation, strictly controlling pollution discharge, strengthening whole-basin ecological restoration and ecological water replenishment for Baiyangdian, and implementing integrated water resource management to shift from supply-oriented to demand-oriented water governance.

Keywords: water resources, water security, sustainable development, Xiongan New Area
DOI: 10.16418/j.issn.1000-3045.2017.11.004

On April 1, 2017, the Central Committee of the Communist Party of China and the State Council issued a notice establishing Hebei Xiongan New Area, marking another nationally significant new area following the Shenzhen Special Economic Zone and Shanghai Pudong New Area. Positioned as a millennium-long national priority, Xiongan aims to relieve Beijing of non-capital functions, industries, and population. Its key tasks include building a world-class, green, modern, and smart city; creating a beautiful ecological environment and constructing an eco-city where water and urban areas coexist harmoniously; developing high-end and high-tech industries to attract and concentrate innovation resources; providing high-quality public services and facilities; establishing a fast and efficient transportation network with a green transportation system; advancing institutional reform to better leverage market forces in resource allocation while optimizing government functions; and expanding all-around opening-up to create a new highland for openness and international cooperation [1]. The new area's development will centrally promote coordinated Beijing-Tianjin-Hebei development and optimize the regional urban layout and spatial structure, holding major practical and far-reaching historical significance.

Xiongan New Area is planned within Baoding City in central Hebei Province [Figure 1: see original paper]. The initial phase covers approximately 100 km², the medium-term development zone about 200 km², and the long-term control zone roughly 2,000 km², encompassing Xiong County, Rongcheng, and Anxin counties plus surrounding areas—accounting for 9.0% of Baoding' s total area. Baiyangdian Lake constitutes the core region of the new area, with its water surface occupying 23.4% of the combined area of these three counties. Currently,

the region faces severe water problems: all nine inflow rivers suffer from the critical condition of "dry channels and polluted flows," with natural inflow nearly exhausted; most of Baiyangdian's water areas are classified as Class V or inferior Class V, indicating heavy pollution. Meanwhile, groundwater over-extraction is severe, with Xiong County alone having cumulatively over-extracted 6.9×10 m^3. Additionally, located in the flood detention area of the Daqing River system in the Haihe River basin, the new area' s current flood control capacity is only at a ten-year return period level, having suffered repeated flood disasters—reflected in the local saying "Baiyangdian floods nine out of ten years." Water resource shortage, serious environmental pollution, groundwater over-extraction, and flood risks constitute the main challenges to sustainable development in this region.

Main Water Security Issues and Risks in Xiongan New Area Construction

Water Resources Security Issues and Risks

Xiongan New Area is situated in the severely water-scarce Haihe River basin within the North China Plain' s Baoding region. Despite covering the "Pearl of North China" —Baiyangdian—historical records show the lake has dried up five times and currently relies on water transfers to maintain basic functions. Consequently, Xiongan' s construction and development inevitably face contradictions and problems regarding water shortage and supply, pollution and protection, ecological restoration and maintenance, and integrated water resource management, along with associated future risks and challenges. Therefore, careful and objective analysis of water security issues is required to propose scientific countermeasures to reduce or control direct and potential water security risks after the new area' s construction.

The region where Xiongan New Area is located suffers from water resource shortages, prominent supply-demand conflicts, and severe groundwater over-extraction. Baoding's multi-year average precipitation and total water resources are 566.9 mm and 2.978×10 m^3 respectively, including 1.620×10 m^3 of surface water, 2.223×10 m^3 of groundwater, and 0.865×10 m^3 of double-counted volume. In 2016, Baoding' s per capita water resources were 287 m^3, far below the internationally recognized extreme water scarcity threshold of 500 m^3 per capita. Under current development intensity, total water supply in a normal year (p=50%) is 2.809×10 m^3, comprising 1.072×10 m^3 surface water, 1.731×10 m^3 shallow groundwater, and 0.006×10 m^3 reclaimed wastewater. Total water demand in a normal year is estimated at 3.488×10 m^3, including 2.574×10 m^3 for agriculture, 0.409×10 m^3 for industry, 0.107×10 m^3 for urban living, and 0.198×10 m^3 for ecological environment, resulting in a 19% water deficit and overall water shortage status. Particularly in dry years (p=75%), the deficit rate reaches 44%, indicating severe scarcity [5]. This shortage directly causes annual groundwater over-extraction exceeding 5×10 m^3, with average

groundwater level decline rates reaching 0.55 m/year since the 1980s. According to the Hebei Provincial Government' s "Notice on Announcing Groundwater Over-extraction Areas, Prohibition Areas, and Limitation Areas in Plain Regions," most of Xiong County and Anxin County and southeastern Rongcheng County are designated as deep-layer general over-extraction areas, while all other areas are shallow-layer general over-extraction zones.

From the perspective of Baiyangdian within the new area' s planning scope, inflow has drastically decreased since the 1950s, plummeting from 1.92×10 m^3/year to 1.35×10 m^3/year—a 93% reduction. The lake has experienced continuous dry-up phenomena [6]. Water surface area has shrunk from the original 561 km^2 to 228 km^2 in 2010, a 59.4% decrease. Since the 1950s, annual rainfall in the Baiyangdian basin has shown a decreasing trend, with an average reduction of 3.42 mm/decade over the past 60 years and a total decrease of nearly 30%, with more pronounced reductions in mountainous areas with higher precipitation [7,8]. Meanwhile, temperatures in the basin have continuously risen since 1980, with the 1990s average temperature 0.6°C higher than the 1980s [7]. Therefore, climate change manifested by reduced precipitation and increased temperature is one cause of water volume reduction. Additionally, with continuously increasing industrial and agricultural water consumption, over 150 reservoirs including Wangkuai, Xidayang, Angexzhuang, and Longmen have been constructed upstream, with total storage exceeding 3.6×10 m^3, causing engineering interception to drastically reduce inflow. Research indicates that climate change and human activities contribute 40% and 60% respectively to runoff reduction in the Baiyangdian upstream source area [9]. Thus, excessive human interference constitutes the primary factor causing water resource scarcity in the Baiyangdian basin.

With Xiongan' s establishment, Xiong County, Rongcheng, Anxin County, and surrounding urban areas will achieve new leaps in construction and economic development. Over 80 central enterprises including CNPC, Datang, and Shenhua, along with some universities, have formulated development strategies, expecting more than 100,000 people to relocate soon, eventually forming a Type II large city supporting 2-2.5 million people. This massive influx of enterprises and population will further increase water consumption for production and living. Although the South-to-North Water Diversion Project allocates 5.5×10 m^3 of clean water annually to Baoding after 2015, alleviating recent water pressure, a water resource gap of 0.6×10 m^3 annually is still projected for the long term, making the water shortage situation hardly optimistic with human interference becoming more prominent.

Water Quality Security Issues and Risks

During the 1950s-1960s, Baiyangdian basin had excellent water quality and served as the main drinking water source for surrounding residents. Since 1970, water quality in inflow rivers and the lake area gradually deteriorated, primarily to Class III (light pollution). From the 2000-2015 Hebei Provincial Environ-

mental Quality Bulletin, by 2000 the basin had reached heavily polluted status, with most water areas classified as Class V or inferior Class V, far worse than the Class III water quality target for functional zones, suitable only for agricultural irrigation. Exceeding pollutants include chemical oxygen demand from production and living sources and nutrients like total phosphorus and nitrogen. The most severe pollution occurs at the Fu River inflow mouth and in Anxin County' s Duancun and Nanliuzhuang areas, with water quality remaining at inferior Class V year-round, followed by waters around densely populated villages. Additionally, based on groundwater quality monitoring data from 2001-2010 by the Hebei Provincial Institute of Environmental Geology and Baoding Monitoring Center, among 17 groundwater wells in Xiong County, Rongcheng, and Anxin, only 7 wells (41%) met Class I-III standards, while 10 wells (59%) were Class IV and V, with Xiong County showing the most serious groundwater contamination [10].

Unregulated discharge of urban production and living wastewater, economic activities of lake residents, and agricultural soil erosion are the main causes of water quality deterioration. For decades, over 300 high-energy-consumption and high-pollution enterprises including papermaking, wool textile printing and dyeing, leather manufacturing, down processing, and non-ferrous metal smelting have been distributed upstream and in surrounding towns, discharging large amounts of untreated wastewater directly into Baiyangdian. Since 1980, natural clean water replenishment has been scarce, with inflow sources primarily coming from surrounding urban sewage. According to the 2015 Hebei Provincial Environmental Status Bulletin, the Juma and Cao Rivers are inferior Class V water bodies, the Xiaoyi River is Class IV, while the other six rivers have dried up. The Fu and Tang Rivers have become perennial sewage channels for Baoding City, with wastewater discharge reaching 1×10 tons/year. Baiyangdian pollution has attracted high-level central government attention. Since 1990, governments at all levels have invested nearly 10 billion yuan to address basin water pollution, integrating and upgrading heavily polluting enterprises and eliminating nearly 58% of backward production capacity, while implementing storm and sewage separation, sewage interception and renovation, and constructing 41 new sewage treatment plants. After years of governance, water quality deterioration has been basically controlled and pollution loads entering the lake have decreased. However, 2007 pollution source census data shows total chemical oxygen demand and ammonia nitrogen loads entering the lake were 9,221 t/year and 2,720 t/year respectively, still far exceeding the lake' s environmental capacity in normal years (chemical oxygen demand: 6,214.7 t/year; ammonia nitrogen: 232 t/year) [11].

The lake area is home to approximately 364,800 residents engaged primarily in aquatic planting and aquaculture, directly discharging about $(11.68\text{-}29.20)\times10$ m^3/year of domestic sewage. Large amounts of bait 投放 and extended breeding periods increase total nitrogen and phosphorus concentrations, accelerating eutrophication. Meanwhile, the upstream basin has long been in a severe soil erosion area, with annual losses of about 1.6×10 t. Large quantities of

residual pesticides and fertilizers directly enter water bodies, with nitrogen and phosphorus inputs accounting for 51% and 34.1% of total inputs respectively, causing lake eutrophication. Additionally, sewage from Baiyangdian' s inflow system, lake water pollution, and pesticide/fertilizer residues in soil infiltrate groundwater through precipitation leaching, causing serious groundwater contamination. Furthermore, to support tourism development, untreated sewage is stored in upstream sewage reservoirs, representing a significant potential source of groundwater pollution.

Xiongan's construction will be a rapid urbanization process, with 1.6 million new permanent residents expected by the end of the 13th Five-Year Plan period, further increasing total domestic sewage and industrial wastewater discharge. Even if all urban sewage undergoes centralized treatment meeting the national highest standard of Grade A (GB18918-2002) for municipal wastewater treatment plant effluent, the effluent quality still far exceeds Baiyangdian' s functional zone water quality standards—Grade A discharge standards for chemical oxygen demand and total nitrogen are 50 mg/L and 15 mg/L respectively, not only higher than Class III water functional zone standards (25 mg/L and 1.0 mg/L) but even exceeding Class V standards (40 mg/L and 2.0 mg/L) [12,13]. Therefore, without clean water replenishment, Baiyangdian water quality will remain primarily Class V or inferior Class V, in a eutrophic state. Additionally, urban area expansion will increase urban initial rainwater non-point source pollution loads, creating a severe situation of combined lake and external pollution.

Water Ecological Security and Risks in New Area Construction

From the late Qing Dynasty to the Republic of China period, Baiyangdian covered over 1,000 km² with good ecological conditions and abundant aquatic resources. Lake fishermen lived primarily on fishing, as reflected in local sayings: "If Donghu (local name for Baiyangdian) doesn' t supply fish and crabs, Baoding fish market won' t open" and "West Lake (Baiyangdian) carp is the best under heaven." Since 1980, prolonged dry-ups and severe water pollution, especially five consecutive years of dry-up from 1983-1988 and eight consecutive years from 1997-2004, have caused devastating ecological damage. Data shows that over the past 50 years, phytoplankton and zooplankton species have decreased from 129 and 95 to 99 and 37 respectively, with pollution-intolerant species significantly reduced while pollution-tolerant species and cyanobacteria representing eutrophication have increased dramatically. Benthic invertebrates decreased from 35 to 17 species [14]; fish resources dropped from 63 to 25 species, showing "miscellaneous and miniaturization" trends; vascular plants decreased from 34 species across 26 families to almost only reeds; wild birds and mammals decreased to 190 and 14 species respectively, particularly with only 52 bird species in 1992 [15], recovering only after water replenishment projects like the Yuecheng-to-Baiyangdian transfer in 2004. Additionally, since the 21st century, Baiyangdian has experienced multiple large-scale fish kill events due to pollution, particularly in 2000, 2001, 2006, 2012, 2014, and 2016.

Since the 1960s, Baiyangdian basin has entered a dry period, with upstream reservoir interception causing sharp reductions in inflow water volume, compounded by sharply increased sewage loads, resulting in tremendous damage to the aquatic ecosystem and severe habitat degradation and biodiversity loss. Since Baiyangdian' s refilling in 1998, Hebei Province has addressed the issue from both water transfer and pollution control perspectives. Between 1981-2008, nearly 30 artificial water replenishments were conducted with total water transfer of 1.45×10 m^3. The Yuecheng-to-Baiyangdian water transfer project was completed in 2004, transferring 1.6×10 m^3 from the Haihe River' s Yuecheng Reservoir; in 2016, the Yellow River-to-Baiyangdian water transfer project began construction, planning to divert 2.55×10 m^3 annually from Puyang' s Huanghe Qucun Gate. Additionally, after South-to-North Water Diversion implementation, part of the local water source was replaced and surplus in 2015, providing regulation space for Baiyangdian ecological water replenishment plans. Pollution control aspects were detailed in Section 2.2.

A core objective of Xiongan New Area is to "create a beautiful ecological environment and build an eco-city where water and urban areas coexist harmoniously." As an important ecological barrier for Xiongan's sustainable development, maintaining stable water replenishment, improving basin water environment conditions, and ensuring healthy aquatic ecosystem development are particularly crucial. From an engineering perspective, water transfer reservoirs are located in water-scarce Haihe and Yellow River basins, and replenishment faces many uncertainties due to climate conditions and transit losses, with effects not necessarily significant. Although the South-to-North Water Diversion provides more regulation space for replenishment plans, water transfer' s primary purpose is ensuring residential production and living water use, not direct replenishment, with detailed water resource allocation planning and joint operation with local water yet to be developed and implemented.

Additionally, the new area is located in a low-lying plain at the downstream end of nine rivers, with low current flood control capacity. Major floods in the past century occurred in August 1939, August 1956, August 1963, August 1996, and July 2012. Consequently, Xiongan New Area construction also faces high flood and waterlogging disaster risks due to its downstream location.

Key Water Issues Requiring Focused Discussion in Xiongan New Area Construction

Xiongan New Area construction will inevitably face water security challenges. From the perspective of key water issues and fundamental work needed, we must first identify water supply, quality, ecological, and flood control security issues, then estimate direct and potential water security risks and stresses during construction, before proposing water security strategies and recommendations for ensuring "water-city integration" in the eco-city construction. Therefore, we emphasize research and understanding of three fundamental issues:

1. **Re-investigation of water issues in Xiongan New Area and its connected basins.** Key aspects include: available water quantity and water resource carrying capacity, such as current water supply and shortage issues; river and lake pollution and water quality conditions; flood and drought disasters and defense standards, particularly flood control and drought resistance capacity and assessment; current river and lake ecological status and main issues, especially investigation and analysis of biodiversity in the Baiyangdian water system.
2. **Analysis of water security risks and causes during Xiongan construction.** Main contents include: analysis of construction scale and water demand, such as water and socio-economic development planning; risk analysis of water resource shortage, particularly highlighted water supply-demand contradictions and supply risks; pollution risk analysis, such as highlighted water environment and non-point source risks; biodiversity degradation risk analysis, including risks from water shortage, pollution, and ecological issues; and internal waterlogging and drought risk analysis, particularly flood risks in the low-lying downstream area.
3. **Water security safeguard countermeasures for Xiongan's "water-city integration" construction.** Focus areas include: water supply security measures such as water-saving and water-transfer projects and joint allocation of multiple water sources including unconventional water; water quality security measures including pollution control, industrial structure adjustment, and environmental management; water ecological security measures including river, lake, and wetland protection and restoration projects, ecological water replenishment, and river-lake connectivity; flood security measures including flood and drought disaster early warning and forecasting and disaster reduction systems; and comprehensive strategies for Xiongan' s "water-city integration" water security, including integrated ground-sky monitoring systems, river chief systems, medium- and long-term water system comprehensive management planning and post-evaluation, and institutional innovation for water security.

Policy Recommendations

Implement Integrated Water Resource Management and Shift from Supply to Demand Management to Ensure Xiongan's Water Security

Located in a water-scarce region, Xiongan faces water security threats from climate change, urban development, and population and economic growth from both supply and demand perspectives. We recommend implementing basin-wide integrated water resource management to shift from supply-oriented to demand-oriented management, using the "three red lines" of total water use control, water use efficiency, and functional zone pollution limits as constraints, adhering to the principle of "determining city size, land use, population, and production by water availability," and reasonably advancing development scale

and population capacity in different stages. Simultaneously, enhance government water resource management functions and capacity building, formulate and improve water-related laws and regulations, increase funding for research and education, promote technological innovation in water-related research and management, improve public participation and water-saving awareness, effectively reduce disturbances to water resource systems from climate change and human activities, and lower water security risks.

Develop New Sources and Save Water, Scientifically Allocate Water Resources to Ensure Xiongan' s Water Supply

Under new construction conditions, we recommend recompiling water resource planning and allocation schemes, accurately accounting for dynamic changes in external water transfers and upstream reservoir storage under different climate conditions. Closely integrate with industrial layout and urban planning to rationally allocate external water sources, comprehensively promote water-saving measures throughout the new area, compress agricultural planting scale, adjust planting structure, and promote pipe irrigation, sprinkler irrigation, and canal system renovation to improve agricultural water use efficiency and canal water utilization efficiency. Promote industrial transformation and upgrading, eliminate high water-consuming and heavily polluting production capacity, improve industrial water recycling rates, reduce water consumption per 10,000 yuan of GDP, and implement urban residential water-saving measures. Under the premise of ensuring water security for Baoding and Xiongan, rationally allocate water for Baiyangdian ecological restoration and groundwater replenishment, strictly control local water resource development and utilization rates, improve water use efficiency, and ultimately achieve scientific allocation and joint operation of external transfers, local water, groundwater, and reclaimed water reuse to ensure Xiongan' s water supply security, improve lake water environment, and enhance resilience to basin climate change.

Strictly Implement Pollution Red Line Management and Control Point and Non-point Source Discharge to Ensure Xiongan' s Water Quality Security

Although Baiyangdian' s current water resources and ecological environment quality are better than Beijing' s, pollution remains severe and resource-environment carrying capacity has exceeded limits. Additionally, new production and domestic sewage after the new area' s completion will further aggravate regional water environment deterioration. Therefore, water quality security in Xiongan should prioritize Baiyangdian water environment improvement as a key early-stage construction task.

1. Implement the strictest water functional zone pollution red line management, strengthen interception and treatment of factory and domestic sewage around the lake area, upgrade sewage treatment capacity and

processes, and implement biological retention measures to ensure final discharge into Baiyangdian meets Class V surface water standards or better.

2. Eliminate aquaculture in Baiyangdian and relocate scattered residential villages in the lake area to the shore, strengthening centralized treatment of rural production and living "three wastes."
3. Effectively protect upstream water source conservation areas through planting structure adjustment, ecological restoration, and solid waste management to reduce pesticide and fertilizer application and soil erosion, effectively controlling agricultural non-point source pollution.
4. Adopt urban low-impact development design concepts to promote sponge-functional green new city construction, reducing urban development impacts on Baiyangdian's water environment.
5. Formulate reasonable Baiyangdian tourism planning, clarify development direction, strengthen investment in green tourism facilities, and reduce tourism's impact on the lake's water environment.

Strengthen Whole-Basin Ecological Restoration and Baiyangdian Ecological Water Replenishment to Ensure Aquatic Ecological Security

Baiyangdian's repeated dry-ups have caused devastating damage to the aquatic ecosystem. To ensure aquatic ecological security and build a beautiful eco-city, we recommend the following planning from a sustainable development perspective:

1. Formulate Baiyangdian whole-basin aquatic ecological protection and restoration plans, dividing different regional aquatic ecological functions.
2. Screen indicator biological species in the water system and Baiyangdian area to determine suitable environmental flow processes and ecological water levels for species survival and ecosystem integrity maintenance.
3. Scientifically formulate upstream water project ecological operation schemes, maintain perennial river ecological base flow, and develop Baiyangdian ecological water replenishment schemes under different inflow conditions.
4. Strengthen biological habitat restoration and protection, creating suitable living, breeding, and growth environments for aquatic organisms through pollution control and artificial restoration; for significantly reduced species, restore or increase populations through artificial breeding and release to improve and optimize aquatic ecosystem community structure.
5. Minimize encroachment on water areas and disturbance to aquatic ecosystems from Xiongan construction and tourism development, establish protected areas in ecologically fragile zones, rationally plan urban land

use, promote urban river-lake system connectivity, and ultimately achieve "water-city integration."

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Acknowledgments: This paper benefited from discussions with Academician Liu Changming and other domestic scholars and experts, to whom we express sincere gratitude.

Note: Figure translations are in progress. See original paper for figures.