Postprint: Ecological Water Requirement Thresholds for Wetlands in the Small Lake Area of Bosten Lake

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Date: 2021-12-14T00:00:00+00:00

Abstract

Wetland ecological water demand threshold represents the critical condition for qualitative changes in its ecosystem. Once a threshold is exceeded, certain material balance relationships, functions, and health of the system will be affected, while monthly-scale wetland ecological water demand threshold research facilitates optimal allocation of water resources. Targeting the landscape structure of reed marshes interspersed with open water channels in the small lake area of Bosten Lake, and leveraging the advantage of remote sensing data for synchronously acquiring large-scale information, long-term time series water surface area frequency analysis was employed to determine the monthly-scale minimum, moderate, and ideal open water area of the small lake area wetland; the evaporation pan observation method was used to calculate the monthly-scale minimum, moderate, and ideal ecological water consumption of the small lake area wetland. The results indicate that: the annual monthly average minimum, moderate, and ideal ecological water surface areas of the small lake area wetland are 14.47 km^2, 21.56 km^2, and 26.75 km^2, respectively; the minimum ecological water demands of the small lake area wetland during the growing season from March to September are 0.22$\times10^{8}$ m^3, 0.35$\times10^{8}$ m^3, 0.44$\times10^{8}$ m^3, 0.51$\times10^{8}$ m^3, 0.39$\times10^{8}$ m^3, 0.41$\times10^{8}$ m^3, and 0.28$\times10^{8}$ m^3, with the maximum occurring in June and the minimum in March, and the annual minimum ecological water demand of the small lake area wetland is approximately 3.02$\times10^{8}$ m^3; if simultaneously satisfying the dynamic water level required for reed growth as the ecological target of the small lake area wetland, the minimum ecological water demands from March to September are 0.40$\times10^{8}$ m^3, 0.52$\times10^{8}$ m^3, 0.79$\times10^{8}$ m^3, 0.86$\times10^{8}$ m^3, 2.31$\times10^{8}$ m^3, 0.41$\times10^{8}$ m^3, and 0.28$\times10^{8}$ m^3, with the maximum in July and the minimum in September, and the annual minimum ecological water demand of the small lake area wetland is approximately 5.99$\times10^{8}$ m^3. The calculation results of this study can be applied

to annual and monthly-scale inflow allocation and outflow regulation of the small lake area wetland, which is beneficial for improving regional water resource utilization efficiency and ensuring ecological sustainable development of the small lake area.

Full Text

Threshold of Ecological Water Demands for the Small Lake Wetland of Bosten Lake

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Abstract: The threshold of wetland ecological water demand represents a critical condition for qualitative changes in ecosystems. Once a threshold is exceeded, certain material balance relationships, functions, and the health of the system will be affected. Research on monthly-scale thresholds of wetland ecological water demand facilitates optimal allocation of water resources. Given the unique landscape structure of the small lake wetland of Bosten Lake, where reed marshes are interlaced with open water channels, this study leverages the advantages of remote sensing data for synchronous large-scale data acquisition. Using frequency analysis of long-term time series water surface area data, we determined the minimum, medium, and ideal open water area states for the small lake wetland at the monthly scale. The evaporation pan observation method was employed to calculate the monthly-scale minimum, medium, and ideal ecological water consumption of the small lake wetland.

The results indicate that the annual average monthly minimum, medium, and ideal ecological water surface areas of the small lake wetland are 14.47 km^2, 21.56 km^2, and 26.75 km^2, respectively. The monthly minimum ecological water demands during the growing season (March–September) are 0.41×10^{8} m^3, 0.35×10^{8} m^3, 0.44×10^{8} m^3, 0.51×10^{8} m^3, 0.39×10^{8} m^3, 0.41×10^{8} m^3, and 0.28×10^{8} m^3, respectively. If the dynamic water level required for reed growth—the ecological target of the small lake wet-

land—is also satisfied, the minimum monthly water demands during the growing season become 0.40$\times10^{8}$ m^3, 0.52$\times10^{8}$ m^3, 0.79$\times10^{8}$ m^3, 0.86$\times10^{8}$ m^3, 2.31$\times10^{8}$ m^3, 0.41$\times10^{8}$ m^3, and 0.28$\times10^{8}$ m^3, respectively. The annual minimum ecological water demand of the small lake wetland is approximately 3.02$\times10^{8}$ m^3, increasing to approximately 5.99$\times10^{8}$ m^3 when dynamic water level requirements are met. These calculated values can be applied to annual and monthly water inflow allocation and effluent regulation for the small lake wetland, thereby improving regional water resource use efficiency and ensuring sustainable ecological development.

Keywords: ecological water demand; threshold; frequency analysis; small lake wetland of Bosten Lake

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Wetlands are vital natural ecosystems that play irreplaceable roles in water purification, climate regulation, and biodiversity conservation. Ecological water demand thresholds serve as effective indicators of wetland water demand status [?]. Once a threshold is exceeded, certain material balance relationships, basic functions, and the health of the ecosystem will be affected. Wetland ecological water demand research involves interdisciplinary integration of hydrology, ecology, and environmental science [?], and is primarily based on water balance principles using methods such as ecohydrological analysis, ecological approaches, and remote sensing-based simulation analysis [?]. Wetland eco-environmental water demand can be divided into storage (water volume) and flux (water consumption) [?]. While storage does not require renewal, reasonable storage capacity is fundamental to maintaining normal wetland functions. Flux includes vegetation evapotranspiration consumption, net water surface evaporation, and groundwater recharge consumption [?], representing consumptive eco-environmental water demand [?]. This study calculates the consumptive ecological water demand for the small lake wetland of Bosten Lake based on this concept.

The small lake wetland of Bosten Lake is predominantly covered by reeds (*Phragmites australis*) and constitutes the main component of the Bosten Lake wetland, playing a crucial role in local economic and ecological sustainable development [?]. Previous domestic scholars have calculated the annual ecological water consumption of the small lake area using water balance methods and evaporation pan observation methods [?]. However, few studies have examined ecological water demand thresholds and monthly water demands for practical regulation. Because evaporation changes in Bosten Lake are not significantly correlated with water level changes [?], and the small lake area features fragmented water surfaces and complex channels, this study employs the ecological water surface method—an ecohydrological approach using water surface area as a hydrological parameter that considers both hydrological conditions and ecosystem health—to determine safe thresholds for ecological water demand and calculate appropriate values for the study area.

The small lake wetland is characterized by a landscape of reed marshes interlaced with open water ponds and channels. Leveraging the advantages of remote sensing data, this study uses frequency analysis of long-term water surface area time series to determine monthly-scale minimum, medium, and ideal open water areas for the small lake wetland. The evaporation pan observation method is used to calculate monthly-scale minimum, medium, and ideal ecological water consumption. Additionally, considering the dynamic water level required for reed growth during the growing season, monthly ecological water demands are calculated to provide guidance for ecological water regulation in the small lake area, thereby enhancing the ecological and economic functions of the small lake area and supporting optimal water resource allocation in the Bosten Lake basin.

1.1 Study Area Overview

Bosten Lake, once China' s largest inland freshwater lake and the largest lake in the arid inland region of Xinjiang, is located in the Yanqi Basin south of the Tianshan Mountains in Xinjiang, with geographical coordinates of 41°44 -42°14 N and 86°20 -87°26 E. At a water level of 1048.5 m, the lake has a surface area of 1210.5 km^2, an average depth of 7.5 m, and a water volume of 90×10^{8} m^3. The Bosten Lake wetland provides essential ecological functions including pollution control, detoxification, water purification, soil erosion control, biodiversity maintenance, runoff regulation, and local climate moderation [?]. The entire lake system comprises large and small lake areas (Figure 1). Water inflow to the large and small lakes can be regulated through the Baolangsumu diversion hub (the third Kaidu River diversion hub), with the east branch flowing into the large lake and the west branch into the small lake.

The small lake area is located in the southwestern part of Bosten Lake, at the intersection of the Kaidu River delta, Peacock River floodplain, and Bosten Lake littoral zone. It consists of more than ten small lakes including Dawusunnuoer and extensive reed marsh wetlands, interconnected by surface gullies, river branches, and small lake clusters. During flood periods, water overflows extensively, while in dry periods, the surface dries up and groundwater depth becomes 20–30 cm, with water depths of 10–60 cm along lake and river shores. The total area is approximately 350 km^2, forming a reed-producing wetland known as the small lake area [?]. Based on reed height, basal stem diameter, and unit area yield, the Changchun Geographic Institute of the Chinese Academy of Sciences classified reeds in the Bosten Lake small lake area into four types (Table 1).

Vegetation in the Bosten Lake reed marsh area exhibits water-related distribution characteristics from the lake shore toward the center. Areas with water depths of 0–30 cm are dominated by *Phragmites australis* communities; 30–50 cm depths by *Typha orientalis* communities; 50–80 cm depths by floating plants such as *Nymphaea tetragona*, *Nymphoides peltatum*, and *Potamogeton distinctus*; and depths exceeding 80–120 cm by submerged plant communities dominated by algae. Areas deeper than 120 cm generally have no vegetation [?]. Water level determines the area of different landscape types in the reed zone [?].

1.2 Research Methods

This study calculates ecological water demand thresholds for the small lake area using the wetland eco-environmental water demand model based on the ecological water surface method [?] and the evaporation pan observation method [?].

1.2.1 Determination of Minimum, Medium, and Ideal Ecological Water Surface Areas Ecological water surface area refers to the water surface area corresponding to different health statuses of the ecosystem [?]. By analyzing the frequency distribution of long-term time series water surface area data, the minimum, medium, and ideal ecological water surface areas can be identified. Water surface areas that appear with high frequency are considered well-adapted by the wetland over the long term and represent the most acceptable conditions for the ecosystem; the water surface area with the highest frequency within the high-frequency range is taken as the ideal water surface area. The minimum ecological water surface area represents the water area required to maintain the wetland' s existence and is included in the low-frequency small water surface area range. The medium water surface area falls within the medium-frequency range. By calculating the ratio of minimum, medium, and ideal ecological water surface areas to the multi-year average water surface area, ecological water surface coefficients are determined. Multiplying each month' s multi-year average water surface area by these coefficients yields the monthly minimum, medium, and ideal water surface areas [?].

1.2.2 Evaporation Pan Observation Method for Calculating Small Lake Area Ecological Water Consumption Evapotranspiration (ET) in the small lake area of southwestern Bosten Lake is calculated using the evaporation pan observation method. Based on different land cover classification areas, measured evaporation intensity data, and relevant coefficients, the ecological water consumption of the Bosten Lake small lake area is determined [?, ?]. The small lake area is classified into open water (including floating and submerged plants), surface water reed areas (including reed types I, II, and III and cattail), and non-surface water reed areas (including type IV dryland reeds) [?, ?]. Due to the complex terrain of the small lake area, which comprises more than ten interconnected small lake clusters with overflow during floods and drying during droughts, establishing an area-volume curve is difficult. The study assumes constant storage in the small lake area and does not consider wetland storage in the ecological water demand calculation, focusing only on water demand flux —i.e., water consumed by the small lake area, including water surface evaporation, seepage, and plant transpiration minus precipitation. The mathematical expression is:

$$E = E_0 + E_1 + E_2 - P + K \cdot I$$

where E is total water consumption in the small lake area (m^3), E_0 is water consumption in the open water area (m^3), E_1 is water consumption in the surface water reed area (m^3), E_2 is water consumption in the non-surface water reed area (m^3), P is monthly precipitation (m^3), K is the soil permeability coefficient (dimensionless), and I is the seepage slope (dimensionless).

Since the soil permeability coefficient and seepage slope are difficult to obtain, and the small lake area surface consists of Quaternary alluvial and lacustrine deposits with fine-grained sub-sandy soil and sub-clay alternating layers that have low permeability [?], with permeability coefficients between 3.75–20.00 m · d^{-1} [?], the study adopts the mean groundwater seepage value from the Zhalong wetland [?] and sets the seepage loss ($K \cdot I$) at 0.18 mm · d^{-1}.

Additionally, because reeds are the dominant species in the small lake area and serve as the ecological target, their growth process requires consideration of changing inundation depths, which necessitates accounting for water storage changes in the small lake area as part of the ecological water demand. The water requirement for maintaining dynamic water depth is calculated by multiplying water depth by area. Assuming the small lake area is a columnar body without topographic variation (where increased water depth does not change surface area), and based on monthly water depth change data for the reed area and the small lake area of 350 km^2, water storage is calculated. Water required to maintain depth is not consumed (i.e., storage does not require renewal and can be accumulated sustainably). For example, maintaining 0.05 m depth requires 0.175$×10^{8}$ m^3, and increasing to 0.10 m depth requires an additional 0.175$×10^{8}$ m^3 rather than a total of 0.35$×10^{8}$ m^3. Therefore, the monthly water volume needed to maintain different water depths is shown in Figure 4.

The monthly water consumption for open water areas, surface water reed areas, and non-surface water reed areas is calculated separately using the formula:

$$E_i = C_i \cdot A_i \cdot \alpha_i \cdot \beta_i \cdot \gamma_i \cdot 30$$

where C_i is monthly water surface consumption (mm), A_i is the area of open water, surface water reed, or non-surface water reed zones (km^2), α_i is the evaporation conversion coefficient (ratio of large water surface evaporation to evaporation pan values, 0.53) [?], β_i is the plant correction coefficient (ratio of marsh reed area evapotranspiration to open water evaporation, 1.2) [?], and γ_i is dryland reed water consumption. Since reed water consumption is similar to that of terrestrial crops, the actual water consumption per unit area of crops in the Yanqi Basin is used as a reference: 750 mm · a^{-1} [?].

Through remote sensing data interpretation and literature data collection, the areas of different classifications in the Bosten Lake small lake area are obtained. Multiplying these by relevant coefficients, water consumption for each category is calculated and summed to obtain total lake water consumption.

1.2.3 Calculation of Small Lake Area Ecological Water Demand The small lake area consists of open water and reed marsh wetlands with complex terrain. Based on the above research and reed growth conditions in the Bosten Lake small lake area, reed inundation depths are determined [?, ?]. Monthly water depth conditions in the small lake area are as follows: January–February require no ponding; March requires 10 cm depth to supplement water for thawing; April requires 20 cm depth to facilitate reed germination and growth; May–June maintain 30 cm depth to promote growth (optimal reed depth); July maintains 55 cm depth (favorable for reed height growth) with one mid-season drainage to control pests and diseases, after which water is replenished to 55 cm depth, consuming more water; August maintains 55 cm depth with early-month drainage; September requires no ponding.

1.2.4 Remote Sensing Extraction of Open Water Area in Bosten Lake Small Lake Area Remote sensing images were downloaded from the United States Geological Survey (USGS) website (http://glovis.usgs.gov). High-quality images from Landsat TM/ETM+/OLI for the study area from 1990–2019 were selected, with 185 scenes meeting quality requirements for March–November. Using ENVI 5.1 software, the Normalized Difference Water Index (NDWI) was applied to extract open water areas, where values > 0 are classified as water and values < 0 as non-water [?, ?].

2.1 Determination of Minimum, Medium, and Ideal Water Surface Areas for Small Lake Ecological Water Demand

Literature data [?, ?, ?, ?] and Landsat imagery interpreted in this study were compiled and analyzed. Frequency statistics were performed on annual average water surface areas from 1990–2019. The frequency distribution shows that high-frequency water surface areas occur within 43.1–50.3 km^2, with a frequency count of 43.1 km^2 being most frequent, which is taken as the ideal standard water surface area. Medium-frequency water surface areas appear within 36.0–43.1 km^2, with 41 km^2 having the highest frequency, taken as the medium standard. Minimum water surface areas occur in the low-frequency small-area range, with 21.5–28.7 km^2 remaining, where 22 km^2 appears most frequently, taken as the minimum ecological water surface area. The multi-year average water surface area of Bosten Lake small lake area is 41.76 km^2, from which minimum, medium, and ideal ecological water surface coefficients are derived. The average monthly water surface areas of Bosten Lake small lake area are shown in Table 2. Due to ice and snow cover in winter, water surface extraction is difficult; December uses November values, while January and February use March values. Using ecological water surface coefficients and monthly water surface areas, monthly minimum, medium, and ideal water surface areas are determined (Table 3). The annual average minimum ecological water surface area is 14.47 km^2, the medium is 21.56 km^2, and the ideal is 26.75 km^2.

2.2 Monthly Ecological Water Demand Calculation

Monthly evaporation pan data and rainfall from the Tashidian hydrological station (Figure 1) were obtained from hydrological yearbooks and calculated as multi-year monthly averages. Using minimum, medium, and ideal water surface areas, seepage loss, multi-year monthly average evaporation pan observations, and monthly average rainfall, and considering the relationship between large water surface evaporation and evaporation pan observations, monthly minimum, medium, and ideal water surface consumptions are calculated (Table 3). Annual minimum, medium, and ideal water surface consumptions (including groundwater seepage) are 0.24\$×10^{8}\$ m^3, 0.30\$×10^{8}\$ m^3, and 0.37\$×10^{8}\$ m^3, respectively. Using the multi-year average reed area of 319.4 km^2 [**?**] and assuming reed evapotranspiration at 80% of the multi-year average value, reed water consumption is calculated based on the relationship between reed water consumption and evaporation pan observations. Monthly minimum, medium, and ideal reed wetland water consumptions are shown in Table 3, with annual minimum, medium, and ideal reed wetland water consumptions (including groundwater seepage) of 2.85\$×10^{8}\$ m^3, 3.83\$×10^{8}\$ m^3, and 4.80\$×10^{8}\$ m^3, respectively. The sum of water surface consumption and reed consumption (including groundwater seepage) represents the ecological water flux for the small lake area. The small lake area growing season (March–September) minimum, medium, and ideal ecological water fluxes are 0.22\$×10$^{\{8\}-0.86\times10}${8}\$ m^3, 0.29\$×10$^{\{8\}-1.21\times10}${8}\$ m^3, and 0.37\$×10$^{\{8\}-1.10\times10}${8}\$ m^3, respectively. Assuming constant storage in the small lake area, the annual minimum, medium, and ideal ecological water demands are 3.02\$×10^{8}\$ m^3, 4.07\$×10^{8}\$ m^3, and 5.10\$×10^{8}\$ m^3, respectively.

2.3 Monthly Water Demands Considering Dynamic Water Levels

According to existing research [**?**, **?**] and reed growth conditions in the Bosten Lake small lake area, reed inundation depths are determined as follows: January–February require no ponding; March maintains 10 cm depth to supplement water for thawing; April maintains 20 cm depth to facilitate reed germination and growth; May–June maintain 30 cm depth to promote growth (optimal reed depth, optimizing reed density and height); July maintains 55 cm depth to promote growth (favorable for reed height), with one mid-season drainage to control pests and diseases, after which water is replenished to 55 cm depth, consuming more water; August maintains 55 cm depth with early-month drainage; September requires no ponding.

Without considering topographic variation in the small lake clusters and assuming the small lake area is a columnar body where water depth increases without changing surface area, water storage is calculated based on monthly water depth change data for the reed area and the 350 km^2 area of the small lake area. Water required to maintain depth is not consumed (i.e., storage does not require renewal and can be accumulated sustainably). For example, maintaining 0.05 m depth requires 0.175\$×10^{8}\$ m^3, and increasing to 0.10 m depth requires an additional 0.175$×10ˆ{8}$ m^3 rather than a total of 0.35$×10ˆ{8}$ m^3. Therefore, the monthly water volume needed to maintain different water depths is shown in Figure 4. The annual water demand for dynamic water levels in the small lake area is 2.98$×10ˆ{8}$ m^3, with higher demands during the growing season drainage period, corresponding to peak monthly values in July in Figure 4. To meet both reed growth water consumption and dynamic water level requirements, the small lake area total annual water demand is calculated. The growing season monthly minimum, medium, and ideal ecological water fluxes are 0.40$×10^{{8}−0.86×10}{8}$ m^3, 0.52$×10^{{8}−1.21×10}{8}$ m^3, and 0.69$×10^{{8}−2.60×10}{8}$ m^3, respectively. The small lake area annual minimum, medium, and ideal ecological water demands are 5.99$×10ˆ{8}$ m^3, 8.07$×10ˆ{8}$ m^3, and 10.09$×10ˆ{8}$ m^3, respectively.

3 Discussion

To better reflect intra-annual variation in ecological water demand and meet wetland requirements, this study calculates ecological water demand at the monthly scale, clarifying water needs for each month to facilitate optimal water resource allocation and improve water use efficiency. Without considering dynamic water level requirements for reeds, the small lake area annual minimum, medium, and ideal ecological water demands are 3.02$×10ˆ{8}$ m^3, 4.07$×10ˆ{8}$ m^3, and 5.10$×10ˆ{8}$ m^3, respectively, which falls within the range of 2.68$×10^{{8}−4.96×10}{8}$ m^3 calculated using water balance methods [?] and is consistent with multiple studies cited by Li Jibing [?], indicating that the results are reasonable and monthly ecological water demands are credible. Water allocation for the small lake area can be based on the calculated monthly minimum, medium, and ideal ecological water demands, enabling targeted water distribution and improving water use efficiency.

This study considered the dynamic water depth requirements for reed growth as the ecological target in the small lake area, including water volumes needed to satisfy dynamic water levels in the ecological water demand accounting. The dynamic water depths were determined based on the following research: although reeds are widespread, they are hygrophytic plants that generally grow in shallow water with suitable depth ranges; both excessively low and high water depths constrain reed growth [?, ?]. Reeds can survive in water depths of -0.6 to 1.0 m, with dominant vegetation primarily reeds in the 0–0.4 m range. Reed seedlings grow best in shallow water, and as they mature, their water tolerance increases along with vegetation coverage. At an average water depth of 0.3 m, reeds reach optimal growth conditions with peak density and coverage; average density and coverage decrease on both sides of this peak, while average height and stem diameter increase with water depth. Reed height increases with water depth because as large emergent plants, they must extend above water to obtain CO_2 and light for photosynthesis and transport O_2 to roots for respiration and rhizosphere oxidation. Common reed stems reach maximum height at 55 cm water depth, and biomass begins to decrease at 80 cm depth. Reed water adaptability depth is 45$±$20 cm [?, ?], but should not exceed 70 cm.

This study accounted for water volumes needed to maintain dynamic water depths. However, actual reed growth in the small lake area does not follow dynamic water level allocation; typically, one winter or spring irrigation is applied, followed by irrigation when water is available during the growing period and no irrigation when unavailable, with drainage occurring after rather than during the growing season. This actual approach saves water but does not meet reed ecological water requirements. Based on these results and practical considerations, eliminating mid-season drainage during the growing period could reduce water consumption, saving approximately 0.87$×10^{8}$ m^3 of water.

4 Conclusions

This study targets the reed wetland in the small lake area and provides a reasonable accounting of ecological water demand by considering reed growth water consumption, water surface evaporation, groundwater seepage, and intra-annual dynamic water level requirements during the growing season. Monthly-scale results facilitate intra-annual water resource allocation.

1. The small lake area annual minimum, medium, and ideal ecological water demands are 3.02$×10^{8}$ m^3, 4.07$×10^{8}$ m^3, and 5.10$×10^{8}$ m^3, respectively. During the growing season (March–September), monthly minimum ecological water demands are 0.41$×10^{8}$ m^3, 0.35$×10^{8}$ m^3, 0.44$×10^{8}$ m^3, 0.51$×10^{8}$ m^3, 0.39$×10^{8}$ m^3, 0.41$×10^{8}$ m^3, and 0.28$×10^{8}$ m^3, respectively; medium demands are 0.52$×10^{8}$ m^3, 0.44$×10^{8}$ m^3, 0.59$×10^{8}$ m^3, 0.75$×10^{8}$ m^3, 0.68$×10^{8}$ m^3, 0.69$×10^{8}$ m^3, and 0.48$×10^{8}$ m^3, respectively; and ideal demands are 0.76$×10^{8}$ m^3, 0.69$×10^{8}$ m^3, 0.86$×10^{8}$ m^3, 1.10$×10^{8}$ m^3, 0.86$×10^{8}$ m^3, 0.69$×10^{8}$ m^3, and 0.48$×10^{8}$ m^3, respectively.

2. If dynamic water level requirements for the ecological target plant (reed) during the growing season are met, the small lake area annual ecological water demand increases to 5.99$×10^{8}$ m^3. Monthly minimum ecological water demands during the growing season become 0.40$×10^{8}$ m^3, 0.52$×10^{8}$ m^3, 0.79$×10^{8}$ m^3, 0.86$×10^{8}$ m^3, 2.31$×10^{8}$ m^3, 0.41$×10^{8}$ m^3, and 0.28$×10^{8}$ m^3, respectively; medium demands are 0.52$×10^{8}$ m^3, 0.69$×10^{8}$ m^3, 1.21$×10^{8}$ m^3, 1.10$×10^{8}$ m^3, 2.60$×10^{8}$ m^3, 0.54$×10^{8}$ m^3, and 0.48$×10^{8}$ m^3, respectively; and ideal demands are 0.86$×10^{8}$ m^3, 1.21$×10^{8}$ m^3, 2.31$×10^{8}$ m^3, 2.60$×10^{8}$ m^3, 2.98$×10^{8}$ m^3, 0.76$×10^{8}$ m^3, and 0.48$×10^{8}$ m^3, respectively.

3. The calculated results can be used for annual and monthly water inflow allocation and effluent regulation in the small lake wetland, providing a

basis for improving regional water resource use efficiency and ensuring sustainable ecological development of the small lake wetland.

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