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Water Resources Exploitation in Bulgaria: A Water Security Perspective

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***Abstract*— This study examines the exploitation of water resources in Bulgaria within the framework of water security, with particular emphasis on the structural transformation of water supply systems and the increasing strategic role of groundwater. The analysis is based on River Basin Management Plans (2022–2027), national statistical data, and a comprehensive assessment of water abstraction dynamics across the four river basin districts for the period 2010–2024. The results reveal a clear shift from surface water dominance towards a groundwater-driven supply model, characterized by a decline in surface water abstraction from 488.3 million m³ in 2010 to 386.1 million m³ in 2024, and a relatively stable but increasingly dominant role of groundwater, which accounts for over 50% of total public water abstraction on average and reaches approximately 78–81% of drinking water supply at national level. The findings demonstrate that, despite the existence of significant reservoir infrastructure, the long-term stability and resilience of water supply in Bulgaria are predominantly sustained by groundwater resources, which function as a buffering and stabilizing component of the system.**

Keywords—groundwater, water management, water resources, water security

I. Introduction

Water resources constitute a fundamental component of natural capital and a key determinant of socio-economic development and stability, supporting ecological balance [1]. At the same time, maintaining water resource quality and quantity is considered a matter of national security in every country. Under conditions of accelerating climate change, intensifying urbanization, and increasing resource demand, water management is evolving from a traditional sectoral activity into a strategic instrument for ensuring water security [2], [3].

Water security is a complex and multidimensional concept that encompasses the capacity of a system to ensure sustainable, reliable, and sufficient access to water resources of appropriate quality to meet the needs of the population, the economy, and ecosystems, while simultaneously minimizing risks associated with water scarcity, pollution, and extreme hydrological events [4], [5], [22]. It includes both the quantitative and qualitative management of water resources, as well as effective risk management, sustainable resource use, and adaptation to climate variability [6], [17], [21]. In a contemporary context, water security is increasingly recognized as a key component of national security and sustainable development, closely interconnected with energy and food security, as well as environmental protection.

In Bulgaria, water resources are characterized by relatively limited availability and pronounced spatial and seasonal variability [7]. The long-term average annual runoff amounts to approximately 21.3 km³/year, while a significant share of the available water resources is generated outside the national territory in the form of transboundary inflow, resulting in dependence on external hydrological systems and increased vulnerability to climatic and anthropogenic factors [8], [9].

Furthermore, climate variability has led to an increased frequency and intensity of extreme events, such as droughts and floods, which directly affect both the quantity and quality of water resources [10], [21].

At the same time, different river basin districts exhibit distinct hydrological characteristics and temporal dynamics, reflecting variations in resource availability, water use patterns, and socio-economic pressures.

In Bulgaria, groundwater resources are represented by more than 170 groundwater bodies and play a strategic role in securing drinking water supply for the population. According to national statistical data (NSI), groundwater accounts for a dominant share in public water supply, reaching approximately 78–81% during the period 2014–

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2020 [11]. This confirms its critical importance as the primary source for drinking water supply at the national level, with even higher dependence observed in certain regions. Consequently, groundwater constitutes a key pillar of water security in Bulgaria. At the same time, groundwater vulnerability to overexploitation and contamination necessitates the adoption of sustainability-oriented and scientifically grounded management approaches [12], [24].

The exploitation of water resources in Bulgaria exhibits a clearly defined sectoral structure, including public water supply, agriculture (irrigation), industrial use, and energy production. Total annual water abstraction ranges between 5.5 and 6.5 billion m³, with the energy sector accounting for the largest share (60%), followed by agriculture (20–25%), industry (10–15%), and domestic water supply (10%). Despite its relatively smaller share, drinking water supply is of critical importance for water security, as it is directly linked to public health and quality of life [4], [7].

The analysis of water abstraction across river basin districts reveals substantial regional disparities. The Danube Basin District is characterized by relatively good water availability and a dominant reliance on groundwater resources. In contrast, the East Aegean Basin District exhibits the highest level of water use (approximately 2.5 billion m³/year) and a significant dependence on reservoir systems, making it particularly vulnerable to drought conditions. Although drone-based observations are promising, they are not yet widely implemented in the monitoring of available water resources in Bulgaria [14], [15].

The Black Sea Basin District is subject to strong seasonal pressure driven by tourism, while the West Aegean Basin District has more limited water resources and relies heavily on groundwater and transboundary river systems.

Despite the available resource potential, the efficiency of water use in Bulgaria remains a significant challenge. Total water losses in the water supply and sewerage sector are estimated at approximately 1102 million m³ per year on average, accounting for about 56.8% of the total water supplied nationwide over the period 2010–2023. These losses are primarily attributed to the deteriorated water supply infrastructure and system failures, and are largely classified as real (physical) losses. This constitutes a major structural weakness of the water sector, necessitating a transformation of existing management models [3], [12], [23].

In this context, the present study aims to analyze the water use in Bulgaria through the lens of water security, with a focus on quantitative parameters of water use, regional disparities, and the role of groundwater as a strategic resource.

II. Materials and Methods

The analysis is based on data obtained from River Basin Management Plans, the National Statistical Institute (NSI), the Ministry of Environment and Water (MOEW), and the Executive Environment Agency (EEA) [2], [7], [11]. The study covers the period 2010–2024 and includes all four river basin districts in Bulgaria: Danube, Black Sea, East Aegean, and West Aegean River Basin Districts - reflecting the country's natural hydrographic structure. Based on their territorial extent, calculated from basin area distribution (Danube – 49,950 km²; East Aegean – 47,730 km²; Black Sea – 13,320 km²; West Aegean – 13,500 km²), the Danube Basin accounts for approximately 48% of the national territory, followed by the East Aegean - 35%, the Black Sea-10%, and the West Aegean - 7%, highlighting significant spatial disparities in water resource distribution [16]. The methodological approach combines comparative statistical analysis, trend analysis, and interpretation of quantitative indicators related to water abstraction, groundwater use, public water supply, and water losses. The analysis was conducted using officially reported annual data expressed in million m³/year and percentage shares (%). Comparative assessment between river basin districts was performed in order to identify regional disparities, dominant water sources, and water security vulnerabilities.

Fig. 1. Spatial distribution of river basin districts in Bulgaria.

The spatial distribution of the population was incorporated as a key factor influencing pressure on water resources [8], [12]. Additionally, an assessment of water-use efficiency was performed, alongside the identification of principal risks associated with climate variability and water stress [3].

The analyses were conducted within the broader framework of assessing water security and sustainable water resource management in Bulgaria.

III. Results and Discussion

Water resource management is directly related to the security and resilience of critical infrastructure systems. In the context of climate change and increasing environmental pressures, water security is becoming an essential component of national and regional security policies.

In accordance with the current regulatory framework, including the Water Act, the Water Framework Directive (2000/60/EC), and Decree No. 181/2009 on the designation of strategic sites of national security importance, water bodies in Bulgaria are classified into two main categories—surface water and groundwater [13], [18], [19], [20]. Surface waters comprise an extensive river network exceeding 20,000 km in length, as well as a substantial number of artificial water bodies, including more than 2,000 reservoirs.

A key component of Bulgaria's water security is represented by the 52 complex and significant reservoirs, among which those designated as nationally important for drinking water supply play a particularly strategic role [20], Table 1.

The stored volumes allocated for drinking water supply account for 83.68% of their total capacity, underscoring their critical function in maintaining the resilience and reliability of the national water supply system [10].

Within the Danube River Basin District, the reservoirs Iskar, Ogosta, Srechenska Bara, Yovkovtsi, and Beli Iskar play a central role in supplying water to large parts of Northern and Western Bulgaria, including the capital city of Sofia. In particular, Iskar Reservoir, with a storage capacity of approximately 673 million m³, provides nearly two-thirds of Sofia's drinking water demand.

TABLE 1

KEY RESERVOIRS OF NATIONAL IMPORTANCE FOR DRINKING WATER SUPPLY ACROSS RIVER BASIN DISTRICTS IN BULGARIA

Reservoir	**Key Characteristics**			
	River Basin District	***Total Storage Capacity (million m³)***	***Primary Use***	***Population Served (approx)***
Iskar	Danube RBD	520	Drinking water supply, energy	1.5–2.0 million (Sofia)
Ogosta	Danube RBD	506	Irrigation, water supply	150,000
Yovkovtsi	Danube RBD	92.18	Drinking water supply	120,000 (Veliko Tarnovo)
Srechenska Bara	Danube RBD	15.50	Drinking water supply	80,000
Beli Iskar	Danube RBD	15.45	Drinking water supply	70,000
Kardzhali	East Aegean RBD	497	Energy, water supply	100,000
Studena	East Aegean RBD	25	Drinking water supply	100,000 (Pernik)
Ivaylovgrad	East Aegean RBD	188	Energy, water supply	50,000
Asenovets	East Aegean RBD	28	Drinking water supply	60,000 (Sliven)
Batak	East Aegean RBD	310	Energy, water supply	80,000
Arda	East Aegean RBD	1077.9	Energy, water supply	100,000
Ticha	East Aegean RBD	149	Drinking water supply	200,000 (Shumen, Targovishte)
Kamchiya	Black Sea RBD	110	Drinking water supply	500,000 (Varna, Burgas)
Yasna Polyana	Black Sea RBD	35.3	Drinking water supply	250,000 (Southern Black Sea coast)
Tsonevo	Black Sea RBD	109	Water supply, irrigation	100,000
Pancharevo	West Aegean RBD	6.7	Regulation, water supply	Local significance
Hristo Smirnenski	West Aegean RBD	31	Drinking water supply	50,000
Borovitsa	West Aegean RBD	27.3	Drinking water supply	Local significance

In the East Aegean River Basin District, reservoirs such as Kardzhali, Studena, Ivaylovgrad, Asenovets, Batak, Arda, and Ticha are of strategic importance, serving both water supply and the energy and irrigation sectors. The Black Sea River Basin District includes reservoirs such as Kamchiya, Yasna Polyana, and Tsonevo, which are primary sources of drinking water for coastal and tourist regions characterized by pronounced seasonal water stress.

In the West Aegean River Basin District, reservoirs such as Pancharevo, Hristo Smirnenski, and Borovitsa play an important regional role in securing water resources under conditions of limited natural availability.

Despite the key role of nationally significant reservoirs in ensuring drinking water supply, the analysis of the water supply structure in Bulgaria indicates that surface water does not constitute the dominant source at the national level. Its exploitation is highly dependent on climate variability, seasonal fluctuations in runoff, and reservoir storage levels, which limits its reliability as a sustainable resource under drought conditions.

In this context, groundwater emerges as the primary strategic source for public water supply, providing between 65% and 70% of total water supply nationwide, with shares exceeding 70% in certain regions [11]. This dependence is particularly pronounced in areas with limited surface water availability or high seasonal demand, where groundwater bodies function as a buffering system, compensating for deficits in surface water resources.

A comparative assessment of reservoir systems and groundwater highlights a clear functional differentiation within the water supply system [8]. While reservoirs provide substantial water volumes and play a critical role in regulating water resources and meeting peak demand, groundwater ensures long-term stability, continuity, and reliability of water supply.

An analysis of data for the period 2010–2024 reveals a pronounced structural transformation in the composition of water used for public water supply in Bulgaria (Fig. 2).

The most significant trend is the gradual decline in the use of surface water, accompanied by a corresponding increase in groundwater abstraction, indicating a clear shift from surface to groundwater sources for public water supply and sewerage.

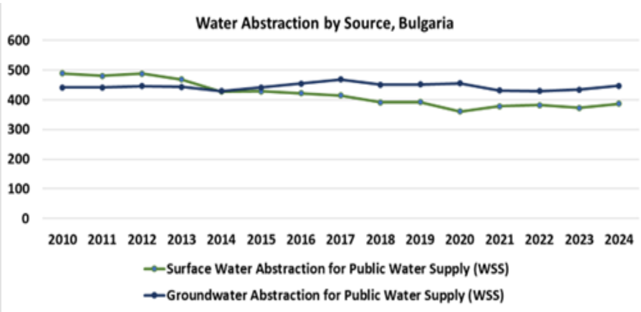

Fig. 2. Surface and Groundwater Abstraction for Public Water Supply in Bulgaria (2010–2024)

*WSS = Water Supply and Sewerage

At the beginning of the analyzed period, surface water dominated the total volume of water abstraction for public water supply, reaching 488.318 million m³ in 2010, compared to 441.094 million m³ of groundwater. However, by the end of the period, a clear restructuring of this relationship is observed. In 2024, surface water abstraction decreased to 386.12 million m³, while groundwater abstraction increased to 447.24 million m³.

Additional significance lies in the change in the relative share of the two water sources. In 2010, groundwater accounted for approximately 47.5% of the total water abstraction for public supply, whereas by 2024 its share had increased to around 53.7%. On average, groundwater constituted about 51.6% of the total water supply for drinking purposes over the entire period. This dynamic confirms the growing dependence of the water supply sector on groundwater resources.

The analysis of water abstraction dynamics for public water supply over the period 2010–2024 further reveals pronounced spatial and temporal differences among the four river basin districts in Bulgaria (Fig. 3).

The largest share of total water supply is attributed to the Danube River Basin District, where values range between 169.8 and 188.8 million m³/year. The maximum is observed in 2013 (188.8 million m³), followed by a gradual decline until 2021 and a slight recovery by 2024 (178.99 million m³). This trend can be interpreted as the result of a combined influence of demographic factors, improvements in water use efficiency, and climatic variability.

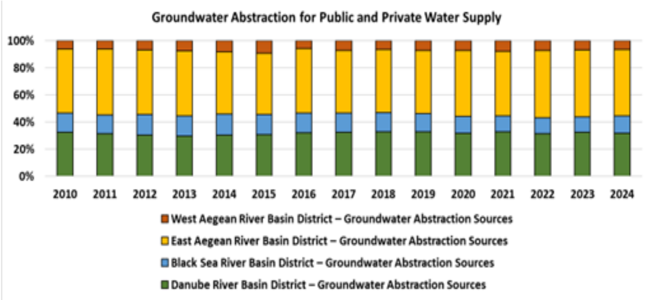

Fig. 3. Groundwater Abstraction by River Basin Districts in Bulgaria (2010–2024)

The East Aegean River Basin District ranks second in terms of water use, with values ranging between 87.5 and 101.9 million m³/year. A relatively stable trend is observed, with a slight increase during the period 2015–2017, when a peak of approximately 101.9 million m³ is reached, followed by stabilization around 95–100 million m³. This reflects sustained demand for water resources in a region characterized by high economic activity and a significant agricultural sector.

The Black Sea River Basin District exhibits the highest variability, with water use increasing from 65.5 million m³ in 2010 to a peak of 96.9 million m³ in 2020, followed by a sharp decline in 2021 (68.5 million m³) and a gradual recovery thereafter. This dynamic is directly related to the seasonal nature of water demand driven by tourism, as well as to external factors such as climatic conditions and socio-economic fluctuations.

The West Aegean River Basin District is characterized by the lowest and relatively stable values, ranging between 29.08 and 32.5 million m³/year, reflecting both limited water resources and lower levels of urbanization and industrial development in the region.

The analysis of groundwater abstraction for public and self water supply across river basin districts reveals a pronounced spatial asymmetry. The East Aegean River Basin District plays a dominant role, consistently accounting for the largest share of total groundwater abstraction throughout the analyzed period. Quantitative data indicate that groundwater abstraction in this district ranges between 251.695 and 274.427 million m³/year, with an average annual value of approximately 264.9 million m³. Its relative share in national groundwater use is estimated at approximately 46–50%. The district encompasses major urbanized areas and industrial centers, which generate high demand for water resources.

The Danube River Basin District ranks second in terms of groundwater abstraction, with values ranging between 166.418 and 187.865 million m³/year and an average of approximately 177.5 million m³. Despite its significant contribution to national water supply, its share remains noticeably lower than that of the East Aegean District.

The Black Sea River Basin District occupies the third position, with groundwater abstraction ranging between 62.228 and 84.366 million m³/year and an average of approximately 76.4 million m³. This district is characterized by higher variability, likely associated with seasonal pressures on water supply systems due to tourism and concentrated demand in coastal areas. A declining trend is observed after 2020, followed by partial recovery in 2024, indicating sensitivity to changing economic and climatic conditions.

The lowest values are observed in the West Aegean River Basin District, where groundwater abstraction remains within the range of 33.033–51.677 million m³/year, with an average of approximately 39.3 million m³. Although its share in national groundwater abstraction is limited, its regional importance remains significant, particularly given the reliance on groundwater sources in areas with constrained water availability.

The analysis of water use for public water supply across the river basin districts in Bulgaria for the period 2010–2024 reveals pronounced spatial and temporal disparities, reflecting both the natural characteristics of water resources and the socio-economic factors driving water consumption (Fig. 4).

The Danube River Basin District consistently accounts for the largest share throughout the analyzed period, with values ranging approximately between 170 and 190 million m³/year. A relatively stable trend is observed, with a slight decline during the period 2018–2021, followed by a recovery towards the end of the period.

The East Aegean River Basin District ranks second, with values ranging between 90 and 102 million m³/year. The trend is characterized by moderate variability, with a distinct peak observed around 2016–2018, followed by a stabilization phase.

The Black Sea River Basin District exhibits the highest degree of variability and dynamic change. Water use increases from approximately 65 million m³ in 2010 to a peak of around 95–100 million m³ during the period 2018–2020, followed by a sharp decline in 2021 and partial recovery in subsequent years.

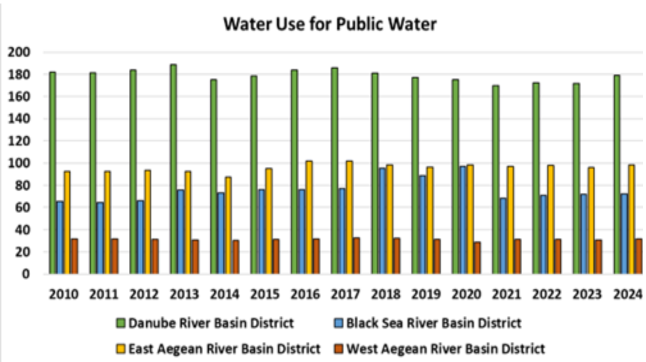

Fig. 4. Regional distribution of water use for public water supply in Bulgaria by river basin districts (2010–2024).

The West Aegean River Basin District is characterized by the lowest and relatively stable values, ranging between 28 and 33 million m³/year.

The East Aegean River Basin District is thus established not only as the region with the highest groundwater abstraction but also as the most vulnerable in terms of risks related to overexploitation, declining groundwater levels, and deterioration of chemical status. The district includes seven reservoirs designated as strategic objects of national security importance—Kardzhali, Studena, Ivaylovgrad, Asenovets, Batak, Arda, and Ticha—which further reinforces its significance within the national water management system. The combination of high groundwater abstraction and the concentration of key water infrastructure underscores the critical role of the East Aegean District and highlights its strategic importance for ensuring water security in Bulgaria. In this context, the sustainable management of groundwater bodies—including control of abstraction, monitoring of quantitative and chemical status, and mitigation of anthropogenic pressures—represents a key priority in national water policy.

In the context of increasing climate variability, intensifying anthropogenic pressure, and structural imbalances in water use, the future management of water resources in Bulgaria is defined by the need to transition toward an integrated and adaptive management framework. The growing role of groundwater as a strategic resource for ensuring long-term water security is becoming increasingly evident, necessitating the implementation of stricter monitoring regimes, enhanced control over water abstraction, and effective protection of water quality. At the same time, the modernization of water supply infrastructure and the reduction of losses within water supply and sewerage networks represent key priorities for improving the efficiency of water use.

Regional disparities in the availability and consumption of water resources require the application of differentiated management approaches tailored to the specific hydrological and socio-economic characteristics of individual river basin districts. Particular attention should be given to the East Aegean River Basin District, where the high concentration of water abstraction and strategic infrastructure increases the risk of overexploitation and resource degradation.

IV. CONCLUSIONS

The present study identifies a clear structural transformation in Bulgaria's water supply model, characterized by a gradual transition from the dominance of surface water resources to an increasing reliance on groundwater. In this context, groundwater emerges as a primary strategic component of the water supply system, long ensuring -term stability, reliability, and resilience under conditions of growing climatic uncertainty. Although surface waters and reservoir infrastructure continue to play a significant role, their effectiveness is increasingly constrained by their high sensitivity to seasonal variability and climate change.

The analysis of the 2010–2024 period reveals a pronounced spatial differentiation in water use patterns, with the East Aegean River Basin District clearly dominating in terms of groundwater abstraction, accounting for approximately 46–50% of the total national groundwater use. The combination of intensive groundwater exploitation and the concentration of seven strategically significant reservoirs defines the region as a critical node within the national water security system, while simultaneously increasing its vulnerability to overexploitation, declining groundwater levels, and deterioration of chemical status.

At the regional scale, distinct hydrological and management characteristics are observed across the river basin districts. The Danube River Basin District demonstrates relatively stable water availability and resource security; the Black Sea River Basin District is characterized by high seasonal variability driven by tourism-related pressures; and the West Aegean River Basin District exhibits limited water resources and strong dependence on local groundwater sources. This heterogeneity necessitates the implementation of region-specific, adaptive water management strategies tailored to the unique hydrological and socio-economic conditions of each basin [1], [2].

Furthermore, the high level of water losses within the distribution network (50–60%) is identified as a major systemic vulnerability, significantly reducing water use efficiency and intensifying pressure on strategic water resources. In this regard, improving infrastructure efficiency, alongside the sustainable management of groundwater resources, constitutes a critical priority for ensuring long-term water security in Bulgaria.

The findings may support decision-making related to sustainable water resource management, monitoring systems, and long-term water security planning. Future research may focus on digital monitoring technologies, groundwater quality assessment, satellite and drone-based observations, and predictive water risk modeling.

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