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STATE POLICY OF IRAQ IN THE FIELD OF HYDRAULIC ENGINEERING STRUCTURES

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Abstract. The article attempts to analyze some aspects of Iraqi hydropower policy, examine major projects and institutional approaches, and outline challenges and ways to overcome them. It is noted that the period from 1970 to 1990 was the best period for the development of Iraqi water systems. As a result, Iraq's total electricity in 1987 was 8,538 MW. However, the 1990 Gulf War and subsequent events, especially the occupation of Iraq in 2003, interrupted this process. Three main regions of the country are indicated, where Iraq's hydropower projects are mainly concentrated. An analysis of their history allows us to conclude that they are not just engineering projects, but represent a strategic basis for the survival and development of the state, whose fate depends on the availability of water. It is noted that Iraq at this stage of development is faced with the need to reconsider its water priorities. In our opinion, the transition to more flexible water management will have a positive effect on the situation and will facilitate the efforts of the Iraqi authorities to reconstruct and modernize existing facilities. At the same time, the key importance of the foreign policy vector is emphasized, which implies reaching a comprehensive agreement with Turkey and Iran in the area of distribution of water resources in the Euphrates–Tigris river basin.

Key words: Iraq, hydroelectric power plants, hydroelectric power stations, dams, reservoirs, Mosul Dam.

Introduction. Iraq is a country with one of the world's oldest hydraulic civilizations, whose history dates back to the Sumerians and Babylonians. However, in the 21st century this civilization is facing unprecedented challenges such as political instability, transboundary redistribution of water resources, climate change, infrastructure degradation, and a lack of effective governance.

Modern Iraq's water policy is based on the operation of dams, reservoirs, and irrigation systems designed to provide energy, ensure water supply, support agricultural irrigation, and regulate flood control. However, a strategy centered on the construction and modernization of large hydraulic structures is becoming increasingly unsustainable under conditions of weak institutional systems, an intensifying resource deficit, and political fragmentation.

In recent decades, the geopolitical factor has become particularly significant. Since the sources of the Tigris and Euphrates rivers lie outside Iraq, in Turkey and Iran, the country finds itself in a highly vulnerable position with respect to the policies of its neighbors. The growing number of dams in the upper reaches of the rivers, declining precipitation, population growth, and the absence of international agreements on water balance have turned Iraq's water security into a serious regional conflict issue.

The purpose of this article is to analyze certain aspects of Iraq's policy in the field of hydraulic infrastructure, to consider major facilities and institutional approaches, and to outline challenges and possible ways of overcoming them.

Discussion. To begin with, Iraq was the first riparian country to develop engineering projects in the Euphrates–Tigris river basin. The Al-Hindiya and Ramadi-Habbania dams on the Euphrates were built in 1914 and 1951 respectively, both for flood control and irrigation purposes. However, the ecology of the river basin was fundamentally transformed when the riparian states entered the so-called "Era of Dams" in the late 1950s, which continues into the twenty-first century. In the 1950s, the Iraqi Development Board began planning irrigation and flood-control systems. Primarily, this was done to protect Baghdad, the capital, and other major cities from flooding. The first large dam (Dukan) was constructed in 1959 on the Lesser Zab River; a hydroelectric power station of the same name has been operating there since 1979. This was followed by the implementation of other projects, during which many dams were built for irrigation and electricity generation.

Because of the presence of the Tigris and Euphrates rivers, Iraq was considered relatively rich in water resources compared to neighboring countries until the 1970s. However, in the 1970s–1980s the intensive construction of hydraulic structures in Turkey and Syria led to a sharp reduction in the water flow entering Iraq. The problem became especially acute after Turkey began implementing the grand Southeastern Anatolia Project (the so-called GAP project) in 1977, which envisaged the construction of 22 multipurpose dams and 19 hydroelectric power plants. The total storage capacity of these dams amounts to 138 billion m^3 of water from the two rivers. Full implementation of the project will make it possible to irrigate 17,103 km^2 of land with a total storage capacity of 100 km^3, which is three times greater than the combined reservoir capacity of Iraq and Syria.

The dam construction programs of Turkey, Syria, and Iran forced the Iraqi government to accelerate the construction of as many of its own hydraulic facilities as possible. Overall, the period from 1970 to 1990 was the best stage in the development of Iraq's water systems. As a result, Iraq's total electricity capacity in 1987 amounted to 8,538 MW, with the Qadisiyah–Haditha dam on the Euphrates producing 600 MW, the Mosul (then Saddam) Dam producing 300–400 MW, and the Dukan Dam producing 400 MW (Kliot, 1994, p. 121). Only the so-called 1990 Gulf War interrupted this process.

In general, dozens of medium- and small-capacity reservoirs, as well as a number of more or less large catchment dams, are scattered across Iraq. Three main regions of the country can be distinguished where Iraq's hydraulic structures are primarily concentrated:

1. The mountainous and hilly region of the governorates (muhafazat) of Dohuk, Erbil, Kirkuk, and Sulaymaniyah.
2. The region of the eastern valleys in the governorates of Diyala, Wasit, and Maysan.
3. The Western Desert region in the governorates of Anbar, Najaf, and Muthanna.

There are 17 dams in the northern regions, 5 in the eastern regions, and 11 small and medium dams in the Western Desert (Mukhalad et al., 2019, p. 283).

Irrigation projects include several categories such as dams, barrages, canals, drainage systems, pumping stations, regulators, and reservoirs. Iraq has six major operating dams, five of which are located in the Tigris basin and one in the Euphrates basin (Mukhalad & Al-Ansari, 2021, p. 35). In addition, a system was created on the Euphrates River to control flooding. This system includes the Ramadi Dam and Lake Habbaniya. Other systems on the Tigris River included regulators, canal systems, the Tharthar Lake project, and the Samarra Dam (Issa et al., 2013, p. 14618).

A relatively new use of dams is their capability to generate energy. For this purpose, dam reservoirs are used as storage basins for hydroelectric power plants (HPPs). Energy production and trade are relatively profitable uses of dams; therefore, most dams (and all major ones) are equipped with HPPs, even if their primary purpose is different. Iraq's hydroelectric power plants belong to storage-type hydraulic structures. In such HPPs, river water is stored in reservoirs during periods of high flow or when energy needs can be met by other power plants. When energy demand increases, or river flow is particularly low, the stored water can be released through HPP turbines to convert potential energy into electricity (Bremer, 2013, pp. 6–7).

The most critical problems faced by major reservoirs in Iraq include liquefaction in the foundations of the Mosul Dam, landslides and the consequences of earthquakes at the Derbendikhan Dam, as well as essential maintenance and rehabilitation requirements for almost all dams. Below, using several hydraulic structures as examples, we will consider the key trends in this area in Iraq.

As already noted, the first large dam built under the targeted program by the French company Dumez-Ballot was the Dukan Dam–the only large concrete arch dam in Iraq. The dam is a concrete arch structure set into limestone and dolomite rock, with gravity support blocks located in a narrow, steep gorge. It is situated on the Lesser Zab River in the Dukan area, 65 km southeast of the city of Sulaymaniyah (Dokan and Derbendikhan Dam Inspections, 2006, p. 32).

As can be seen from the table provided, the largest dam in Iraq is the Mosul Dam. It is also the second largest dam in the Middle East and the only dam on the main course of the Tigris River in Iraq. The first studies regarding the construction of a dam in this area began back in 1953. Over a quarter of a century, geological surveys of the area were carried out for the development of the dam project, which was repeatedly revised. The very possibility of construction was often questioned, since gypsum formations beneath the proposed dam posed a serious safety risk.

Ultimately, a project proposed by a Swiss consulting company was approved, and in January 1981 construction began by a German-Italian consortium. The dam was inaugurated on July 7, 1986. The project consists of a main embankment 3,600 meters long, representing an earthfill dam with a clay core. The maximum height of the dam is 100 meters, and the operational level is 330 meters above sea level. The minimum operational level is 300 meters above sea level, below which the dead storage volume of the reservoir is 2.95 billion m^3, and the useful storage volume is 8.16 billion m^3.

The dam includes four Francis turbine power units on the right bank, with a total capacity of 750 MW, located at the foot of the dam, as well as two diversion structures. At full capacity, the facility holds about 11.1 cubic kilometers of water and supplies electricity to 1.7 million residents of Mosul. Construction of this hydraulic structure on a karst foundation with a clay core was completed in 1986. However, serious defects were discovered that very same year. Water leakage from the lower part of the dam body became particularly noticeable. Periodic collapses occurred, forming sinkholes, as it was revealed that the depth of the gypsum formations reached not 100, but 300 meters, making the structure highly vulnerable.

Despite repeated geological studies, the extent of gypsum dispersion and the degree of liquefaction in the dam foundations were not properly assessed. Bathymetric surveys of the Mosul Reservoir showed that its useful storage volume decreased from 8.16 to 7.597 billion m^3, and its total storage volume decreased to 9.967 billion cubic meters (Mukhalad et al., 2019, pp. 114, 116).

Concerns about the instability of the structure led to large-scale restoration and rehabilitation work after the U.S. invasion of Iraq in 2003. In 2014, the dam was briefly seized by ISIS militants. After its liberation, the issue of the dam's foundation became a central topic in global media coverage. In 2016, Iraqi scientists and engineers sounded the alarm about the condition of the dam, as the risk of its collapse had increased catastrophically as a result of military operations. According to their forecasts, in the event of the dam's failure, vast territories, including the cities of Mosul and Baghdad, would be submerged, and more than one million people would die (Mosul dam engineers warn it could fail at any time, 2016).

After the defeat of ISIS, the Iraqi Ministry of Water Resources began restoring and rebuilding the destroyed sections of the facility and resumed the dam's maintenance program. In March 2016, a contract was also signed with the Italian company Trevi to perform grouting, preparation, and maintenance work on the dam. Repair work began in October 2016 and was completed in June 2019 (Mukhalad & Al-Ansari, 2021, pp. 40–41). The total cost amounted to 535 million USD, of which the U.S. government paid about 125 million USD and the Iraqi government 410 million USD. During this period, about 41,000 m^3 of cement grout–equivalent to 26,700 tons of solid material–was injected into the ground (Mosul Dam rehab project wins award for work done deep in Iraq's conflict zone, 2022).

The Mosul Dam project staff, after undergoing relevant training under the guidance of foreign specialists, received qualifications enabling them to take responsibility for maintenance, grouting, and operation of the dam. Grouting operations are now carried out using a significantly modernized system. In addition, modern stations and equipment are used for preparing and pumping cement mixtures. Eighteen new drilling machines have been put into operation, 11 of which are electric and the rest diesel-powered. All operations are computerized (Al-Ansari et al., 2021, pp. 114–115).

The Haditha Dam is the only dam on the Euphrates River within Iraqi territory and is currently the second largest reservoir dam after the Mosul Dam. It is one of the most important and successful dams in terms of its role in controlling discharges on the Euphrates River, as well as the successful design and unique technical procedures adopted during its construction. The project for this dam was conceived in the late 1960s; construction began in 1977 and was completed in 1988. The dam embankment was designed by the "Hydroproject" Institute of the USSR Ministry of Energy, while its power station and equipment were designed and built by various Yugoslav companies (Adamo et al., 2018, p. 79).

The dam is located about 270 km northwest of Baghdad and about 14 km northwest of the city of Haditha. It is an earth-fill dam. Its length is 9,064 m; the crest width is 40 m, while the maximum base width exceeds 200 m depending on the riverbed elevation. The maximum height is 57 m from the deepest point of the riverbed, and the crest elevation is 154.00 m above sea level (Sissakian et al., 2022, p. 5). Among the Haditha Dam structures, the hydroelectric power station occupies an important place; it includes six Kaplan turbines with a total capacity of 570 MW. It is worth noting that the Haditha Dam currently faces serious operational difficulties due to the significant depletion of the Euphrates River flow (Al-Ansari et al., 2015, p. 16).

The Haditha Dam, with an area of 235,000 km², is the last reservoir on the Euphrates River within the cascade of dams that includes the Keban and Karakaya Dams in Turkey, as well as the Tabqa and Tishrin Dams in Syria. Compared to the Mosul Dam, the Haditha Dam has more successful projects and measures in terms of foundation treatment, particularly in overcoming the problem of karstification. The measures implemented at the Haditha Dam proved to be more successful than those achieved at the Mosul Dam (Mukhalad & Al-Ansari, 2021, p. 59).

In addition to the Haditha Hydropower Plant, several impoundment reservoirs (Al-Habbaniyah, Ar-Razzazah, etc.) and low-head barrage dams (Ar-Ramadi, Al-Fallujah, Al-Hindiya, etc.) have also been built on the Euphrates River, making it possible to supply water to irrigation canals.

The Duhok Dam, due to its location in Iraqi Kurdistan, is controlled by the authorities of the Kurdish autonomous region.

New spillway gates at the Derbendikhan Dam were installed between 1989 and 1990 after they were dismantled in 1988 due to the Iran–Iraq War. During the war, the spillway and substation were damaged by bombings. The power station was also damaged by airstrikes in 1990. In 2007, the World Bank launched a project worth USD 35.36 million to repair the Derbendikhan and Dukan dams. Repairs to the Derbendikhan Dam cost USD 18.85 million and were completed in 2013 (World Bank Group, 2015, pp. 1–3). At present, the Derbendikhan Dam and hydropower plant are under the control of the government of the Iraqi Kurdish autonomous region, which, in practice independently of Iraq's central authorities, determines both the future prospects of this facility and, in general, the hydropolicy of the territories under its control.

Recently, hydropower initiatives undertaken by Iran have also posed certain risks to this dam. The fact is that Iran has begun implementing a large-scale water project known as the "Tropical Water Project," which includes 14 dams and 150-kilometer diversion tunnels on the Sirvan and Zmkan rivers to transport water to rural areas in the south of the country. The total capacity of all planned dams is about 1.9 billion m³. As a result of the project's full implementation, approximately 77% of the natural catchment area of the Derbendikhan Dam will be lost (Rashid & Mohd Anuar, 2022, pp. 2704–2705).

Since 2000, there have been plans to build the Makhoul Dam on the Tigris River, with completion initially expected by 2007. However, the U.S. occupation of Iraq in 2003 resulted in the suspension of the project. Only in May 2021 did the Iraqi government resume construction of the Makhoul Dam and its hydroelectric power plant (with a capacity of 250 MW). This construction, scheduled for completion in 2026, is the largest infrastructure project in Iraq in the 21st century. It is expected that a water reservoir with a volume of three billion cubic meters will subsequently be created, where water can be stored for use during periods of drought and water scarcity.

However, construction is progressing very slowly due to the challenging terrain and lack of sufficient water. At the same time, the structural complexity of the facility increases economic costs. It should also be taken into account that the structure, like several other hydraulic facilities in Iraq, is located on gypsum layers, which leads to karstification of the subsurface and, consequently, increases the safety risks for the dam. The point is that there is a significant likelihood of gypsum dissolution, which in turn may cause water seepage into the ground (Abbas, 2022, pp. 5, 22).

Construction of this dam also threatens to flood nearby archaeological sites and displace populations in three administrative units between the provinces of Kirkuk and Salahaddin. Particular concern is associated with the possible flooding of the ruins of the city of Ashur (the capital of ancient Assyria), which is included in the UNESCO World Heritage List, as well as 184 other heritage sites. It will also cause large-scale changes in the fragile ecosystems of the Tigris River. Thus, the Iraqi authorities are forced to sacrifice values of the historical past in order to avoid a looming catastrophic future caused by the country's rapidly declining water resources. It is assumed that more than 3 billion cubic meters of water will be stored in this reservoir, mainly for irrigation purposes (Istepanian & Raydan, 2021).

It should be noted that three strategically important dams are located in Iraqi Kurdistan: Dukan, Derbendikhan, and Duhok, the first two of which provide 30% of Iraq's water reserves. The water strategy of the Kurdistan Regional Government focuses on the construction and reconstruction of dams, largely at the expense of downstream parts of the country. Since 2014, Kurdish officials have proposed adding 245 small dams and barrages on the province's rivers. In 2022, the KRG announced plans to build four major reservoirs, reportedly without any consultation with Baghdad. The KRG's water strategy risks increasing local tensions in Iraq (Hall & Harper, n.d.).

As already noted above, in addition to large hydraulic structures, dozens of small and medium reservoirs and dams are also in operation in the country. Below we have compiled a table reflecting the indicators of some of Iraq's small and medium-sized dams.

Table 1

Characteristics of Some Small and Medium-Sized Dams in Iraq (adapted from Mukhalad & Al-Ansari, 2021, pp. 60–64; Mukhalad et al., 2019, pp. 285–288)

Name and Location of the Dam	Type of Dam	Storage Capacity	Length and Height of the Dam	Date of Full Commissioning
Harava (Sulaymaniyah Province)		0.764 million m³	Length 115 m Height 22.5 m	2007
Azmar Valley Dams (Sulaymaniyah Province)				2006
Hasachay (Kirkuk Province)	Earth-fill embankment with a clay core	46.36 million m³	Length 2,360 m Height 58 m	2014
Kashkan (Duhok Province)		1 million m³	Length 270 m	
Shirin (Duhok Province)	Earth-fill embankment	1.325 million m³	Length 426 m	2008
Vand (Diyala Province)	Earth-fill embankment	37,82 млн м3	Length 1,342 m Height 24 m	2013
Belkana (Kirkuk Province)	Earth-fill embankment	0.89 million m³	Length 277 m	2013

Table 1 (continuance)

Shevasur (Kirkuk Province)		4.45 million m³	Length 333 m Height 26 m	2016
Bahiri (Kirkuk Province)		0.38 million m³	Height 18 m	
Mandalay (Diyala Province)	Earth-fill embankment	3.63 million m³	Length 1,315 m Height 14 m	2004
Shihabi (Wasit Province)		0.8 million m³	Length 275 m Height 9 m	
Dwairij **(Maysan Province)**	Concrete	1.87 million m³	Length 510 m Height 9.5 m	2015
Khusub (Najaf Province)		4.2 million m³	Length 1,050 m Height 11 m	2005 г.
Horan (Anbar Province)		4.9 million m³	Length 650 m Height 14 m	
Rutba (Anbar Province)	Earth-fill embankment	32 million m³	Length 848 m Height 19 m	1981
Al-Ubayla (Anbar Province)	Earth-fill embankment	4 million m³	Length 500 m Height 11.5 m	1973
Abyad (Anbar Province)	Earth-fill embankment	25 million m³	Length 448 m Height 20 m	2002
Um al-Tarfat (Anbar Province)	Earth-fill embankment	7 million m³	Length 990 m Height 11.6 m	1982
Shibayjah (Anbar Province)	Earth-fill embankment	8 million m³	Length 720 m Height 10.5 m	1977
Hussainiya (Anbar Province)	Earth-fill embankment	6 million m³	Length 512 m Height 13.25 m	1976
Al-Aghri (Anbar Province)	Earth-fill embankment	6 million m³	Length 525 m Height 11 m	1974
Rahalya (Anbar Province)	Earth-fill embankment	4 million m³	Length 440 m Height 13 m	1982

As can be seen from the information provided, a significant number of small and medium-sized dams were built in Anbar Province, in the so-called Western Desert. These structures generally do not include hydroelectric power plants and function as reservoirs within the framework of irrigation policy. From the very name of the region, it is clear that this part of Iraq is particularly deprived of precipitation and requires artificial irrigation. It is easy to notice that these dams were mainly built in the 1970s–1980s. Unfortunately, after 2003 the construction of such facilities in the Western Desert practically ceased.

Overall, negative trends can be observed with regard to Iraq's small and medium-sized dams. Some dams in mountainous and hilly areas have been partially or completely destroyed due to high waves. As a result of poor technical maintenance, sediment accumulates in the reservoirs, rendering them ineffective. Political instability and civil wars have also had an adverse impact on the condition of these structures.

A review of the history of the construction and operation of Iraq's hydraulic structures allows us to conclude that they are not merely engineering facilities but represent the strategic foundation for the survival and development of a state whose fate depends on access to water. Since the 20th century, dams, barrages, and hydroelectric power plants have become instruments of industrial and agricultural breakthroughs, energy security, and modernization across all spheres of public life. However, in recent decades these structures have come under pressure from numerous negative factors. The deteriorating hydrological situation–synchronized with climate change–the aging of infrastructure, political fragmentation, and the absence of coordinated international mechanisms for managing transboundary water resources not only neutralize the achievements of previous periods but also create fundamental problems that threaten the existential foundations of Iraqi statehood.

Conclusion. At the current stage of its development, Iraq faces the need to reconsider its water priorities. The strategy relying on large-scale construction of new dams has exhausted its potential. Instead, a shift toward more flexible water management is required, including the reconstruction and modernization of existing facilities, digitalization of monitoring systems, the introduction of water-saving technologies in agriculture, and the development of small and local water storage systems.

The foreign policy dimension remains key. Without a comprehensive interstate water agreement with Turkey and Iran that takes into account the interests of all parties, Iraq's efforts will have limited effectiveness. It is also necessary to strengthen the legal framework, establish decentralized water resource management systems, and involve local communities.

Iraq's experience clearly demonstrates that in the 21st century water becomes not only an economic resource, but also a socio-political one, requiring comprehensive, sustainable, and coordinated policies. Solving Iraq's water problem is simultaneously a matter of national security, regional stability, and human survival amid the global climate crisis.

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