ANALYSIS OF THE WATER MANAGEMENT CONDITION IN THE BOZSUV DERIVATION CANAL AND STUDY OF THE OPERATING CONDITIONS OF HYDROPOWER FACILITIES

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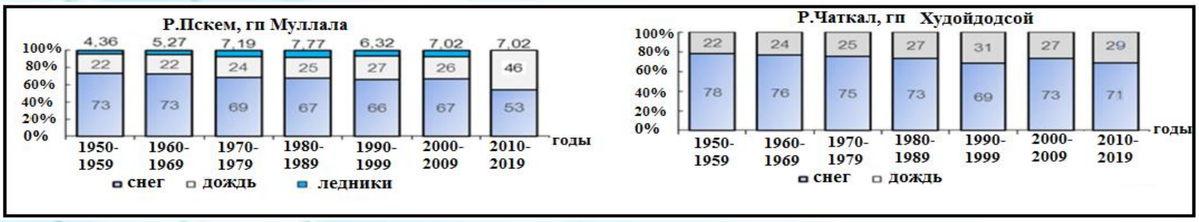
Abstract. *This article presents an analysis of the water management and hydropower conditions in the Chirchik–Ohangaron river basin. Based on the methods of reliability theory, the reliability characteristics of hydropower stations (HPPs) located on the Bozsuv derivation canal have been evaluated.*

Keywords. *Chirchik–Bozsuv, derivation canal, reliability theory, water resources.*

Introduction. The Bozsuv derivation canal is located in the Chirchik–Ohangaron river basin, where the average long-term formed water resources amount to 9.32 km³. Of these water resources, 93 percent or 8.67 km³ are formed by river waters. The main water source of the river basin is the Chirchik River, which is formed by the confluence of the Pskem and Chatkal rivers [1,2].

Due to global climate change and anthropogenic impacts on the river system, the hydrological regime of water resources at their sources is changing. That is, in the formation of water resources, the share of glaciers and snow is decreasing, while the share of liquid atmospheric precipitation is increasing (Picture 1).



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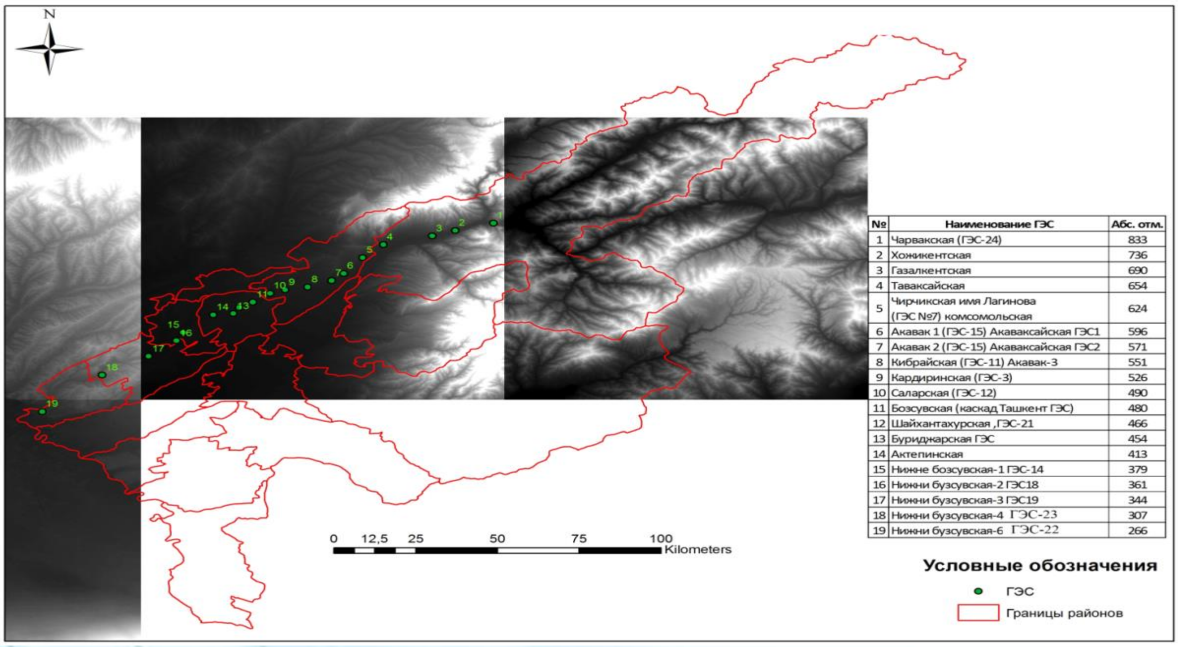
Picture 1. Factors associated with climate change affecting the formation of water flow

The results of scientific research presented in Figure 1 show that the increase in the proportion of liquid atmospheric precipitation in the formation of water resources in the river basin not only causes floods, social and environmental problems during the early spring months, but also leads to a shortage of water resources in the summer months, precisely during the peak period of the vegetation season.

The water source of the Bozsuv derivation canal is the Chirchik River. From the upper pool of the Gazalkent dam on the Chirchik River, an average of 180 m³/s of water is diverted into the derivation canal.

The hydropower stations (HPPs) located on the Chirchik River and the derivation canal form the Chirchik–Bozsuv cascade of HPPs. The construction of these HPPs began in the 1930s of the last century.

The total energy capacity of the Chirchik–Bozsuv cascade of HPPs amounts to 1200 MW. The Bozsuv derivation canal consists of 16 HPPs with a total design capacity of 315 MW (Figure 2). The HPPs located along this tract are technologically outdated, and their actual operating capacity is 190 MW.



Picture 2. GIS map showing the location of the Chirchik–Bozsuv cascade of hydropower stations (HPPs)

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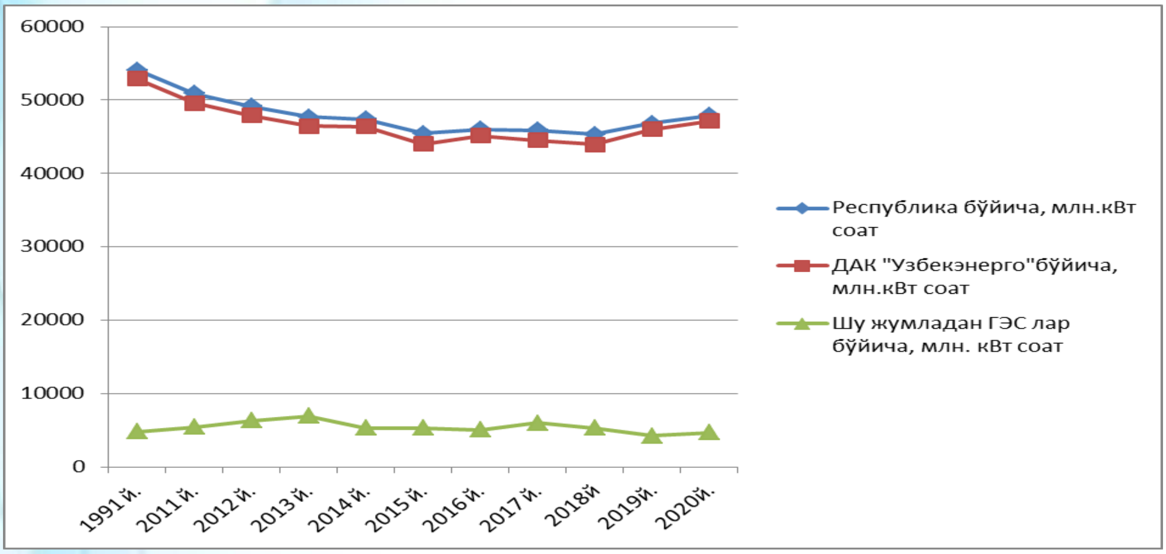
In our country, 11.6 percent of the annual electricity produced comes from hydropower stations (HPPs). Of this amount, the Chirchik–Bozsuv cascade of HPPs accounts for 89 percent (Figure 3).

At present, it is planned to reconstruct the HPPs located along the Chirchik–Bozsuv tract and equip them with modern units.



Picture 3. Dynamics of electricity generation by hydropower stations (HPPs)

Based on the methods of reliability theory, we determine the technical condition and quantitative reliability characteristics of the Lower Bozsuv HPP-22 and Lower Bozsuv HPP-23 hydropower stations located on the Bozsuv derivation canal. Analytical expressions are used for the quantitative characteristics of reliability [3]

$$P(t) = \exp(-\int_0^t \lambda(t)dt) = 1 - \int_0^t f(t)dt \qquad (1)$$

$$q(t) = 1 - P(t) \qquad (2)$$

$$f(t) = \frac{dq(t)}{dt} = -\frac{dP(t)}{dt} \qquad (3)$$

$$\lambda(t) = \frac{f(t)}{P(t)} \qquad (4)$$

Here: — probability of the object operating without requiring repair; — probability of object failure; — change in the density of failure probability; — failure rate over time.

We assume that the dynamic processes related to the operating mode of the Lower Bozsuv HPP-22 and HPP-23 hydropower facilities on the derivation canal vary according to an exponential law. Therefore, we express formulas (1–4) for the exponential law as follows:

$$P(t) = \exp(-\lambda t) \quad (5)$$

$$q(t) = 1 - \exp(-\lambda t) \quad (6)$$

$$f(t) = \lambda \exp(-\lambda t) \quad (7)$$

$$\lambda(t) = \lambda \quad (8)$$

In this case, the time until the loss of operational capability of the Lower Bozsuv HPP-22 object follows an exponential distribution law. The buildings and structures of this HPP were repaired in 2016; however, the technological equipment and units were not repaired: $\lambda = 2{,}5 \cdot 10^{-5}$, $t = 87600$ hours (10 years).

We calculate the probability of failure-free operation of the Lower Bozsuv HPP-22 using formula (5):

$$P(t) = \exp(-\lambda t) = \exp(-2{,}5 \cdot 10^{-5} \cdot t);$$

$$P(87600) = 0{,}112 .$$

We calculate the probability of object failure using formula (6) $q(87600) = 0{,}89$.

2. We calculate the probability of failure-free operation of the Lower Bozsuv HPP-23 using formula (5). This object was repaired in 1981. Currently, its technological parts have become unusable. Therefore, we determine the time until loss of operational capability according to the following exponential law $\lambda = 3{,}5 \cdot 10^{-5}$, $t = 87600$ hours (10 years).

We calculate the probability of failure-free operation of the object using formula (5): $P(t) = \exp(-\lambda t) = \exp(-3{,}5 \cdot 10^{-5} \cdot t)$;

$$P(87600) = 0{,}047 .$$

We calculate the probability of object failure using formula (6): $q(87600) = 0{,}953$.

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The calculation results show that the probability of failure of the Lower Bozsuv HPP-22 within 10 years is , and the probability of failure of the Lower Bozsuv HPP-23 within 10 years is (Figure 4)

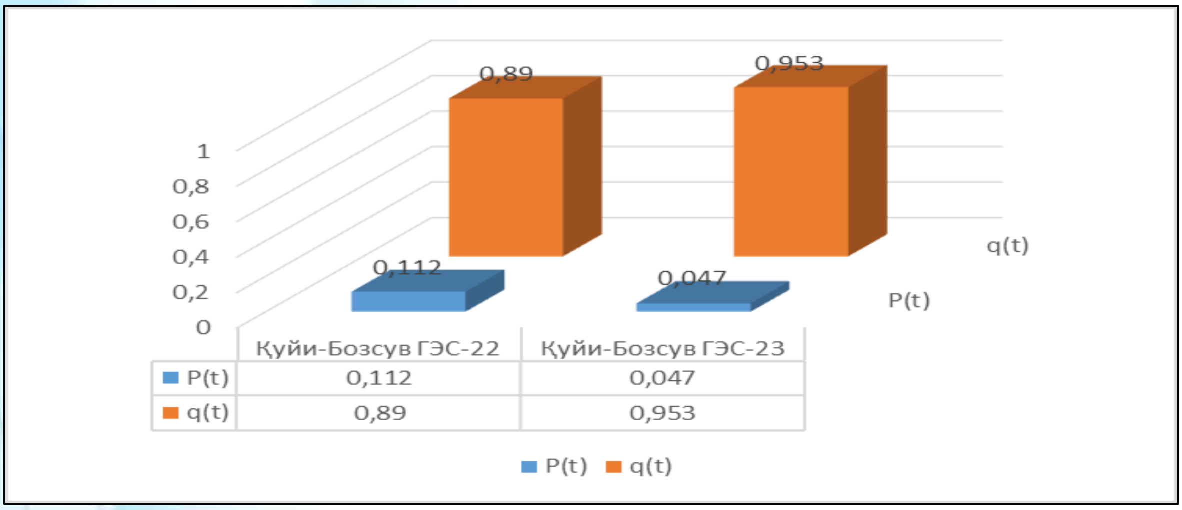

Figure 4. Quantitative Indicators of Reliable Operation of the Lower-Bozsuv HPP-22 and Lower-Bozsuv HPP-23 Hydropower Facilities

According to the results of the analysis of the reliability characteristics of the hydropower plants located along the Bozsuv diversion canal (see Figure 4), the probability of failure-free operation of the **Lower-Bozsuv HPP-22** facilities over the next ten years is **0.112**, while the probability of failure is **0.89**.

For the **Lower-Bozsuv HPP-23** facilities, the probability of failure-free operation over the next ten years is **0.047**, and the probability of failure is **0.953**.

These results clearly show that the technological components of the Lower-Bozsuv HPP-23 are considerably outdated, and its reliability level is much lower compared to that of the Lower-Bozsuv HPP-22. Therefore, it is necessary to carry out modernization and refurbishment of HPP-23, including the replacement of obsolete equipment and machinery.

Conclusion

Based on the conducted research, the reliability parameters of the hydropower plants along the Bozsuv diversion canal were analyzed. The calculation results show that:

- For the **Lower-Bozsuv HPP-22**, the probability of failure-free operation within ten years is **0.112**, and the probability of failure is **0.89**;
- For the **Lower-Bozsuv HPP-23**, the probability of failure-free operation within ten years is **0.047**, and the probability of failure is **0.953**.

The analysis indicates that it is advisable to develop scientifically based measures to improve the efficiency of water use and enhance the reliability of the hydropower facilities along the Bozsuv diversion canal.

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