Volume 4, Issue 8 August 2026 **ISSN (E):** 2938-3757

Web of Technology: Multidimensional Research Journal
webofjournals.com/index.php/4

MATHEMATICAL MODEL OF THE WATER SUPPLY PROCESS OF PUMPING STATIONS EQUIPPED WITH AXIAL ROTARY-VANE

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Abstract
The article is devoted to the water needs of consumers of main canals during the growing season and non-growing periods. Algorithms for calculating water consumption for sections of the main channel are presented in the article.

Keywords: Main canal, water flow, optimal control, machine water lifting, algorithms, vegetative.

Introduction

The main goal of managing the annual regimes of distribution of water resources among consumers of machine water lifting systems is to determine the annual need for water resources for the planned year based on the planned areas and composition of crops, flushing, filling and water treatment, consists of irrigation regimes for plants, as well as the needs of other sectors of the national economy (industry, energy, utilities, etc.). At the same time, accounting for the hydromodule zoning of irrigated lands, forecasts of water consumption in main water intakes, features of plots and hydraulic structures are relevant scientific and practical tasks [1].

II. MATERIALS AND METHODS

The required costs and irrigated areas suspended by the m-th plot in the n-th decade of the growing season on the plots are determined as follows

$$Q_{mn}^{P} = \sum_{j \in J_m} Q_{mjn}^{P} \qquad (1)$$

$$S_{mn}^{P} = \sum_{j \in J_m} S_{mjn}^{P} \qquad (2)$$

where J_{mj} - sets of numbers of taps m- th sections of the main canal [2].

The sequence (algorithm) for calculating water flow rates for sections of the main canal is as follows:

1) At the end of the final sections of the main channel, the required discharge for the n-th decade is calculated as follows:

$$Q^{PK}_{nm_k} = Q^{P}_{nm_k}, \quad \forall m_k \in M_k, \ \forall n \in N_B \qquad \textbf{(3)}$$

2) Then, starting from the last hierarchy by hierarchy groups in the sections, the required water discharges for the n-th decade at the beginning of the sections of the main canal are calculated as follows:

$$Q^{PN}_{mn} = \frac{Q^{PK}_{mn} + QB^{P}_{Bmn} - Q^{P}_{Pmn}}{\eta_m}, \quad \forall m \in I_{i\Gamma}, \quad \forall n \in N_B \qquad (4)$$

$$Q^{P}_{Bmn} = \sum_{j \in J^B_m} \left(Q^{P}_{OBmjn} + q_{DPmjn} \right) = Q^{P}_{OBmn} + q_{DPmn}, \quad \forall m \in I_{i\Gamma}, \ \forall n \in N \qquad (5)$$

$$Q^{P}_{Pmn} = \sum_{j \in J^P_m} Q^{P}_{Pmjn}, \quad \forall m \in I_{i\Gamma}, \quad \forall n \in N_B \qquad (6)$$

$$Q^{P}_{OBmn} = \sum_{j \in J^B_m} Q^{P}_{OBmjn}, \quad \forall m \in I_{i\Gamma}, \quad \forall n \in N_B \qquad (7)$$

$$q_{DPmn} = \sum_{j \in J^B_m} q_{DPmjn}, \quad \forall m \in I_{i\Gamma}, \quad \forall n \in N \qquad (8)$$

where $Q^{PN}{}_{mn}$, $Q^{PK}{}_{mn}$ - water consumption at the beginning and end of the site, $Q^{P}{}_{Bmn}$, $Q^{P}{}_{Pmn}$ - total water consumption of required water intakes and predicted inflows, $Q^{P}{}_{OBmn}$, $qDPmn$ - total water consumption of required water intakes for irrigation and other consumers, J^B_m - set of numbers of water intakes on the site, J^P_m - set of numbers of inflows on the site, I_{iG} - set of site numbers in the group under consideration, η_m - efficiency of the m-th section of the canal, N_B - numbers of the decade of the growing season [3].

3) In groups j_{iG} in the i-th hierarchy of the structure of the main channel, the balance ratios are written as:

$$Q^{PK}_{n_{ijG}n} = \sum_{\kappa_{ijG} \in N_{ijG}} Q^{PN}_{\kappa_{ij\Gamma}n}, \quad \forall n_{ijG} \in I_{iG}, \quad \forall n \in N_B \qquad (9)$$

where $Q^{K}_{n_{ijG}}$ is the water flow at the end of the n_{ijG} -th section [3].

4) Next, the calculation is repeated in steps 2 - 3 for the next hierarchy in the structure.

Thus, the planned modes of operation of sections of the main canal are calculated to meet the needs of all consumers, which are characterized by the following set:

$$\Omega^{BP}_{M} = \left\{ \begin{matrix} \left[m, \ Q^{PN}_{mn}, \ Q^{PK}_{mn}, \ Q^{P}_{Bmn}, \ Q^{P}_{Pmn}, \ Q^{P}_{OBmn}, q^{P}_{DPmn}, \ S^{P}_{mn} \right], \\ \forall m \in M, \ \forall n \in N_B \end{matrix} \right\} \qquad (10)$$

Here , $Q^{PN}{}_{mn}$, $Q^{PK}{}_{mn}$ – water discharge at the beginning and end of the plot, $Q^{P}{}_{Bmn}$, $Q^{P}{}_{Pmn}$ total water discharges of water intakes and tributaries, $Q^{P}{}_{OBmn}$, $q^{P}DPmn$ – total water consumption for irrigation and other consumers, $S^{P}{}_{mn}$ – irrigated areas of agricultural crops suspended on plot m for decade n of the growing season [4, 7].

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The head required (planned) water flow $Q^{NP}_{m_g n}$, corresponding to the initial section of the canals of the machine water lifting system for decades of the growing season, is the required flow for all consumers of the canal. Here m_g - is the number of the initial section of the main channel.
Determining the need for water resources by consumers of the main canal in the non-vegetation period is similar to that for the growing season. The only difference is that instead of irrigation regimes for crops, leaching rates of irrigation of saline lands by types of salinization, the irrigation rate of grain and other crops during the non-vegetation period and the rates of water charging irrigation are used.
For the non-vegetation period, leaching regimes for saline areas are determined according to the types of salinity i, in which leaching rates are set in each flushing irrigation j, irrigation norms for cereals and the norm of water-charging irrigation W_{ikjP}, the timing of irrigation, i.e. start t_{ikjN}, end t_{ikjK} and watering duration $T_{ikj} = t_{ikjH} - t_{ikjK}$. The leaching rate, the irrigation rate for cereals during the non-vegetation period and the rate of water-charging irrigation W_{ikP} are determined as the sum of leaching and irrigation rates, i.e. $W_{ikP} = \sum_{j=1}^{N_i} W_{ikjP}$
For planning water resources for each type of saline lands, ten-day flushing hydro and irrigation modules are calculated. A ten-day leaching hydromodule is the required specific water consumption (l/s/ha) supplied evenly for flushing saline lands in a given decade of the non-vegetation period. A ten-day irrigation module is the required specific area (ha/irrigation) irrigated in a given decade of the non-vegetation period [5].
The algorithm for calculating the planned water supply regimes for sections of the main canal for the non-vegetation period, to provide flushing irrigation of saline lands, irrigation of grain water-charging irrigation of all outlet consumers is characterized by the following set.

$$\Omega^{NBP}_{M} = \left\{ \begin{matrix} \left[m,\ Q^{NP}_{mn},\ Q^{KP}_{mn},\ Q^{P}_{Bmn},\ \ Q^{P}_{Pmn},\ \ Q^{P}_{OBmn}, q^{P}_{DPmn},\ \ S^{P}_{mn} \right], \\ \forall m \in M,\ \forall n \in N_{NB} \end{matrix} \right\} \qquad (11)$$

Here $Q^{PN}{}_{mn}$, $Q^{PK}{}_{mn}$ - are the water discharge at the beginning and end of the canal section, $Q^{P}{}_{Bmn}$ $Q^{P}{}_{Pmn}$ - are the total water discharges of water intakes and tributaries, $Q^{P}{}_{OBmn}$, $q^{P}DPmn$ - are the total water discharges for irrigation and other consumers, $S^{P}{}_{mn}$ -are the irrigated areas of agricultural crops, suspended on the site m for the decade n outside the growing season, N_{NB} - are the numbers of the decade of the growing season [3, 6].
The elements of the set (11) are calculated on the basis of the saline lands leaching regimes, crop irrigation during the non-vegetation period, according to the saline land area structure, the structure of grain and other crops irrigated during the non-vegetation period.
With the calculation of all elements of the sets (10) - (11) according to the above algorithm, the problem of determining the planned needs in the annual planning of irrigation of irrigated lands is solved.

III. CONCLUSION

Algorithms for calculating the water demand of consumers of the main channel during the growing and non-vegetative periods make it possible to improve the operating modes of the system objects, reduce the loss of water consumption, and in the process of water consumption receive, store and accumulate energy resources and the necessary information, distribution in the system increases the performance of system objects by increasing the speed processing.

The developed method for calculating water supply modes at pumping stations, which ensures the supply of the required amount of water to consumers, is designed to improve water supply in machine water lifting systems using modern information technologies, its implementation will help in the construction of canals, pumping stations, barrier structures and water outlets, as well as in ensuring timely supply the required amount of water to consumers with minimal losses of water and energy resources during the growing season.

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