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DETERMINATION OF THE OPTIMAL OBSERVATION NETWORK FOR HYDROLOGICAL STUDIES OF RIVERS OF ARMENIA

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Abstract

Hydrological observation stations are the source of accurate information necessary for the study of spatiotemporal changes of the river flow and for organizing the effective management of water resources. The paper presents the optimal observation network for hydrological studies of river flow in Armenia.

The study is based on the optimization methodology of the regime hydrological observation network developed by I.F.Karasev. Statistical, interpolation, comparison, and analogy methods were used. It was inferred that the optimal observation network for hydrological studies of river flow in Armenia will consist of 86 hydrological observation stations.

Keywords: hydrological observation station, optimal hydrological network, river flow, water resources, climate change.

Introduction

In the South Caucasus, under the conditions of global climate change, a decrease in river flow is observed. The greater demand for fresh water predicted in the future, as well as its inefficient use, dictates the development and implementation of radical measures to increase the efficiency of water resources and systems management. Based on those programs, it is necessary to have the ability to predict the quantitative and qualitative characteristics of water resources and their changes.

The source of information about water resources (quantity, quality, spatiotemporal distribution) is related to the hydrological observation stations and the results of hydrological observations and measurements carried out at these stations [1]. Prevention of natural disasters caused by droughts and floods will be impossible without the development of effective forecasting methods, which should be based on the identification of precipitation-flow relationship and statistical analysis of hydrological data of previous years.

Assessment of water resources and spatial distribution of hydrological characteristics requires a dense monitoring network, which in turn implies significant costs for the installation and operation of respective instruments. Therefore, it is necessary to have an optimal observation network for hydrological studies, which can provide information on the features of spatiotemporal changes of river flow and reduce costs in the observation network [2].

Quantitative monitoring of surface water in Armenia is currently carried out at 91 hydrological observation stations. Since 1991, the hydrological observation network has been significantly reduced, which is extremely dangerous in conditions of global climate change.

Currently, there is an established hydrological monitoring network in Armenia. Hydrological observatin stations have on the average of more than 50, in some cases more than 70 years of observation data [3]. Hydrological observation stations were installed on different rivers in different periods in order to solve different problems. However, there is still no scientific justification regarding the optimal hydrological observation network for the territory of the republic.

Regarding the determination of the optimal hydrological monitoring network various approaches and methods are found in the literature [2, 4, 5, 6], but due to the difference in the goals of designing the hydrological monitoring network, there is no single generalized methodology, particularly for the regime study of the river flow.

Conflict Setting

For water resource state assessment, as well as for resource planning, and water-related disasters prediction and prevention under climate change conditions, it is important to have an optimal observation network in order to conduct hydrological studies ensuring reliable and continuous data, which can provide information on the features of spatiotemporal changes in water flow, on the one hand, and reduce material costs in the network, on the other hand.

Proceeding from this, a goal has been set to develop an optimal observation network for hydrological studies of rivers in Armenia, based on the optimization methodology of the regime hydrological observation network developed by I.F.Karasev [7].

An optimal hydrological observation network should provide the necessary accurate data on the spatiotemporal features of the river flow and to organize effective management of water resources. The optimal observation network should be designed in a way, so that the interpolation between the data of different observation stations makes it possible to obtain reliable information for any point of the country.

Research Results

For the implementation of the work, monthly, annual, maximum discharges of 80 hydrological stations of Armenia for the 1940-2022 period, and average annual air temperature, atmospheric precipitation, relative air humidity data from 45 meteorological stations for the 1940-2022 period [3] were used. To achieve the research goal, the optimization method of regular hydrological observation network developed by Karasev was used. Besides, statistical, interpolation, comparison, and analogy methods were applied.

I.F.Karasev's method for determining and placement of the optimal monitoring network for hydrological studies of rivers enables to determine such density of the hydrological monitoring network, which will be sufficient to obtain reliable and characteristic information on spatiotemporal changes of river flow and avoid baseless material costs.

The structure of the hydrological observation network can be presented as follows: [7, 8]

Special hydrological stations study the features of the hydrological regime of a specific water object,

Regime observation hydrological stations provide regular studies of the hydrological regime of water objects,

Operational hydrological observation stations are intended for obtaining information on the current, in-situ hydrological regime of water objects.

The baseline data for the methodology for optimization methodology of the regime hydrological observation network developed by I.F.Karasev are: . Y - the river flow, $gradY$ - the gradient of the river flow, C_v - the coefficient of variation of the annual flow, $r(l)$ - the normalized correlation function of the annual flow, where l- is the distance between the catchment centers of observation stations, σ - the relative error of determining the annual flow.

It is necessary to determine the following criteria of the catchment area of the hydrological observation station: representative criterion, gradient criterion and correlation criterion [7].

Representative criterion of the catchment area:

The representative criterion of the catchment area is the first and main condition for the placement of the hydrological observation network. The catchment area per observation station should not be too small, otherwise the information about river flow received therefrom will not address the general zonal patterns of flow, but it will express local features only, i.e. it cannot be representative. In other words, it is necessary to determine that boundary of the catchment area which separates the azonal catchment from the zonal catchment. Azonal catchments are mostly small rivers. And the rivers with a flow identified by zonal features are mainly characterized by clear flow patterns.

Gradient criterion of the catchment area:

The gradient criterion of the catchment area indicates the minimum size of the catchment area, in which the observation stations identify the changes in the flow norm which are conditioned by geographic zonality or altitudinal zonation of climatic factors.

The gradient criterion of the catchment area is determined:

$$F_{grad} \geq \frac{8\sigma_0^2}{(gradY)^2} Y_{min}^2, \quad (1)$$

where Y_{min} is the average of the flow module, $gradY$- is the gradient of the flow module, σ_0- is the relative error of determining the annual flow.

The relative error:

$$\sigma_0 = \frac{C_v}{\sqrt{N}}, \quad (2)$$

where N is the number of observation years.

Correlation criterion of the catchment area:

The upper limit of the hydrological observation stations' optimal catchment area ~~of~~ is the correlation criterion. When the regime of a river for which there is no observation data on water flow is studied the method of hydrological analogy is widely used. This method is also applicable in cases where the river basin with data and the river basin without data are located at a small distance from each other and have similar climatic and physical-geographical conditions. Increase of the correlation criterion results in low correlation or absence of correlation at all between the observed water discharges at two hydrological stations. In the methodology developed by I.F.Karasev, the correlation criterion of the catchment area is determined by the following formula:

$$F_{cor} \leq \frac{\sigma_0^4}{a^2 C_v^4}, \quad (3)$$

where:

$$a = \frac{1}{L_0}, \quad (4)$$

where L_0- is the correlation radius.

According to I.F.Karasev's method, the optimal catchment area F_{opt} for one regime hydrological observation station should be in the following range:

$$F_{rep} < F_{grad} \leq F_{opt} \leq F_{cor}, \quad (5)$$

The optimal number of hydrological observation stations in a river basin with any F surface area is determined by:

$$N_{opt} = \frac{F}{F_{opt}}, \quad (6)$$

where N_{opt}- is the optimal number of hydrological observation stations in the given area, F- is the total area of the given area.

In order to determine the representative criterion of the catchment area, a relationship was established between the flow modules of the observation stations and the areas of their catchments (Fig. 1). Then, based on the statistical methods of Fisher and Student [9], the representative criterion of the catchment area was determined, which was 346 km^2.

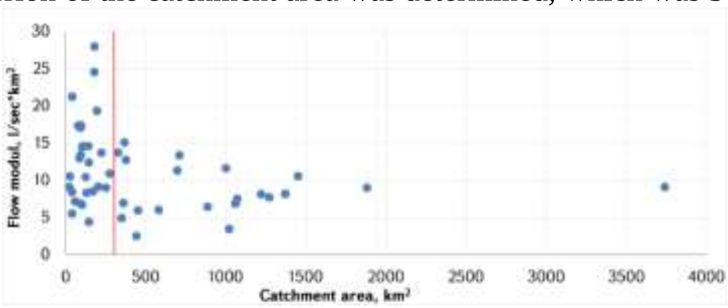

Fig. 1. Graph of the relationship between flow modules and catchment area

The gradient criterion of the catchment area is determined based on formula (1) and indicates the minimum size of the catchment area, in which the observation stations ~~are~~ identified/ highlighted the changes in the flow norm which are conditioned by geographic zonality or altitudinal zonation of climatic factors. For determination of the gradient criterion, the average value of the flow module of the territory of Armenia is determined by the GIS program [10], which is 10,8 $l/sec * km^2$. Coefficient of variation $C_v = 0{,}30$ and relative error $\sigma_0 = 0{,}032$ of average annual discharges is calculated for 59 hydrological observation stations.

The relative error was determined by formula (2). The flow gradient of the territory of Armenia was determined by the GIS program [10] and it is equal to 0,057 $l/sec * km^2$.

Plugging the results into equation (1), the value of gradient criterion of the catchment area is 294 km^2.

The correlation criterion determined by formula (3) is responsible for the upper limit of the optimal catchment area of hydrological observation stations. In order to determine the correlation criterion of the catchment area, a correlation matrix [11] was built between the correlation coefficients of the annual discharges of the observation stations and the distance between the catchment centers of the observation stations (Fig. 2). To this end, for 59 hydrological observation stations the geometric centers of the catchments and their geographical coordinates were determined using the GIS program. According to I.F.Karasev's method, it is proposed to determine the linear distance between the centers of the catchment area of observation stations, while we proposed to apply a new approach, the relief distance between the centers of the observation stations catchment area, determined by GIS program [10].

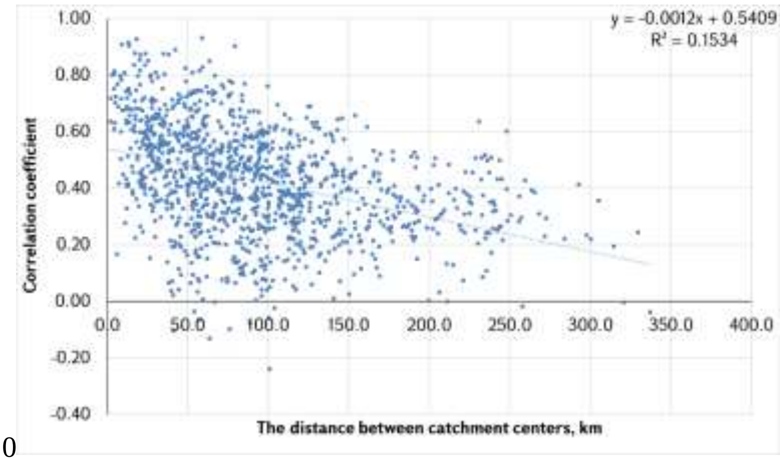

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Fig. 2 Graph of the relationship between the distances of the catchment centers of the observation stations and the correlation coefficient of the annual discharges

The resulted field of points can be approximated by a linear function if the catchment basins are located in the neighborhood. In our conditions, the catchment basins are located in the neighborhood, and the approximation can be made with a linear function. As a result, the value of the flow correlation radius (L_0) is 451 km (Fig. 2).

Let's make a grouping of points with an interval of 20 km and calculate the mean square deviation of those points with respect to the mean (Fig. 3).

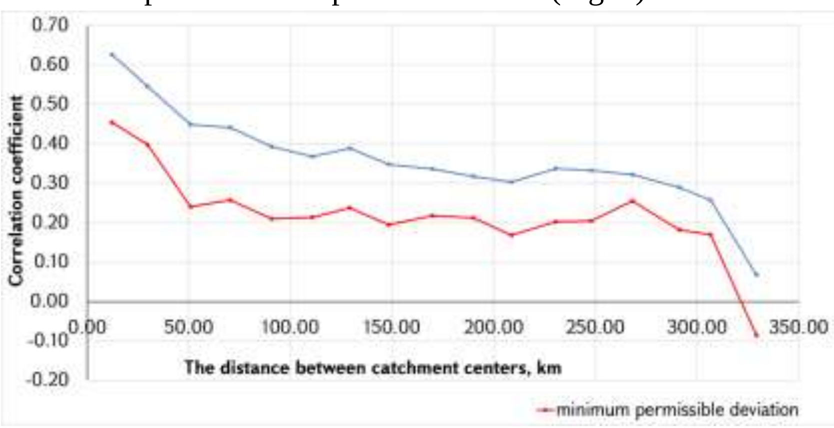

Fig. 3 Determination of the flow correlation radius (L_0) with an averaged range of ∆L=20 km

Taking into account the obtained results, the value of the flow correlation radius (L_0) was taken as 323 km. Based on the obtained data by using formula (3) the correlation criterion of the catchment basin area (F_{cor}) was calculated, which is equal to 15 km^2. The result indicates that in the case of Armenia, the correlation criterion is almost insignificant for determining the optimal catchment area.

Having the data of the three criteria for determining the optimal catchment area and in setting them in formula (5) the optimal catchment area corresponding to one regime hydrological observation station is determined:

$$F_{rep}`\ 346\text{km}^2 < F_{grad}`\ 294\text{km}^2 \leq F_{opt}`\ 346\text{km}^2 \leq F_{cor}`15\text{km}^2$$

It has been accepted by us, that the optimal catchment F_{opt} for one regime hydrological observation station is equal to the representative area F_{rep} of the catchment, which is 346 km^2.

Based on the obtained results and using equation (6), the optimal number of observation stations for the hydrological studies of the flow of rivers in Armenia was calculated, which equals to 86.

Conclusion

In order to study the zonal features of spatiotemporal changes in the flow of rivers of Armenia, one regime observation station should cover a catchment area of at least 346 km^2, and the optimal observation network for hydrological studies of rivers should consist of 86 hydrological observation stations. The existing hydrological observation network in Armenia is sufficient to provide reliable and continuous data for water resources state assessment and their planning, under climate change conditions, and forecasting and early warning of water-related disasters.

Thus, to tackle specific problems new hydrological observation stations can be established.

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ՀԱՅԱՍՏԱՆԻ ԳԵՏԵՐԻ ՀԻԴՐՈԼՈԳԻԱԿԱՆ ՈՒՍՈՒՄՆԱՍԻՐՈՒԹՅՈՒՆՆԵՐԻ ՕՊՏԻՄԱԼ ԴԻՏԱՑԱՆՑԻ ՈՐՈՇՈՒՄ

Միսակյան Է.Է.
Ակադեմիկոս Ի.Վ. Եղիազարովի անվան Ջրային հիմնահարցերի և հիդրոտեխնիկայի ինստիտուտ

Գետային հոսքի տարածաժամանակային փոփոխությունների ուսումնասիրության և ջրային ռեսուրսների արդյունավետ կառավարում կազմակերպելու համար անհրաժեշտ ճշտության տեղեկատվության աղբյուր են հանդիսանում հիդրոլոգիական դիտակետերը: Աշխատանքում ներկայացվում է Հայաստանի գետերի հոսքի հիդրոլոգիական ուսումնասիրությունների օպտիմալ դիտացանցը: Ուսումնասիրության հիմքում դրվել է Ի. Կարասևի մշակած ռեժիմային հիդրոլոգիական դիտացանցի օպտիմալացման մեթոդաբանությունը: Օգտագործվել են վիճակագրական, միջարկման, համադրման, նմանակման մեթոդներ: Հայաստանի գետերի հոսքի հիդրոլոգիական ուսումնասիրությունների օպտիմալ դիտացանցը բաղկացած կլինի 86 հիդրոլոգիական դիտակետից:

Բանալի բառեր. հիդրոլոգիական դիտակետ, օպտիմալ հիդրոլոգիական դիտացանց, գետային հոսք, ջրային ռեսուրսներ, կլիմայի փոփոխություն:

ОПРЕДЕЛЕНИЕ ОПТИМАЛЬНОЙ НАБЛЮДАТЕЛЬНОЙ СЕТИ ДЛЯ ГИДРОЛОГИЧЕСКИХ ИССЛЕДОВАНИЙ РЕК АРМЕНИИ

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Гидрологические наблюдательные пункты являются источником точной информации, необходимой для изучения пространственно-временных изменений речного стока и организации эффективного управления водными ресурсами. В статье представлена оптимальная сеть наблюдений для гидрологических исследований речного стока Армении. Исследование было основано на методологии оптимизации режимной сети гидрологических наблюдений, разработанной И. Карасевым. Использовались методы статистики, интерполяции, сравнения и аналогии. Оптимальная наблюдательная сеть для гидрологических исследований речного стока в Армении будет состоять из 86 гидрологических наблюдательных пунктов.

Ключевые слова: гидрологический наблюдательный пункт, оптимальная гидрологическая сеть, речной сток, водные ресурсы, изменение климата.
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