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Calculation of the hydrograph of the breakthrough of high mountain lakes in Uzbekistan (Examples of Ihnach-large lake)

Bekzod Khikmatov[1], Irina Dergacheva[2], Alek Starovatov[3], Fazliddin Khikmatov[4]

[1]National University of Uzbekistan named after MirzoUlugbek, Faculty of Geography and nature resources, applicant of the Department of land hydrology

[2]Scientific research hydrometeorological Institute of UZHYDROMET, senior researcher, PhD

[3]Scientific research hydrometeorological Institute of UZHYDROMET, senior researcher

[4]National University of Uzbekistan named after MirzoUlugbek, Faculty of Geography and nature resources, Department of Land Hydrology, Head of the Department, Professor, DSc. in Geography

[1]nauka@fvv.uz, [2]dergacheva_iv@ mail.ru, [3]dergacheva_iv@ mail.ru, [4]hikmatov_f@mail.ru

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Abstract

This article is devoted to the study of mud floods of a breakthrough genesis on the territory of the Republic of Uzbekistan, a description is given of a possible process of breaking through a dammed lake using the example of Lake Ihnach-large in the Pskem river basin

Keywords: *hydrology, mudflows, high-altitude lakes, mechanisms of lake breakthroughs, glacial mudflows, dangerous hydrological phenomena.*

I. INTRODUCTION

In modern conditions of intensive use of the piedmont and mountainous territories of Uzbekistan, the problem of the threat of a breakthrough of high-mountain lakes of various genesis is becoming increasingly relevant. High-mountain lakes also contains a reserve of water, which under certain conditions can have tremendous destructive power. Floods caused by the breakthrough of high mountain lakes have tremendous destructive power and capable of causing significant damage: water flooding of riverbed territories; the destruction of residential buildings, recreation areas, industrial facilities; flushing of roads and power lines; flooding or erosion of agricultural land; livestock death, human victims. Therefore, mountain lakes should be classified, as especially dangerous sources of natural disasters [1].

II. PROPOSED METHODOLOGY

The study of lakes in Central Asia has been conducting since the second half of the nineteenth century and has an almost two-hundred-year history. In the initial period, outstanding researchers from Central Asia made a huge contribution to the study of lakes: PyotrPetrovichSemyonov-Tyan-Shansky, Alexei PavlovichFedchenko, Alexei Nikolayevich Severtsov, Alexander VasilievichKaulbars, Alexey AndreevichTillo, Lev Semenovich Berg. L.S. Berg was developed and successfully used by the complex geographical method in limnology, was the establisher of modern physical geography and the initiator of landscape science. L.S. Berg considered the lake as a geographical object, reflecting the landscape characteristic, i.e., part of an integral natural complex of the entire basin. The lake, its regime is sensitive to climate change, anthropogenic impacts within the catchment area; therefore, the

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research of lakes is a multilateral task, requiring a wide approach and a variety of methods [2].

At the initial stage, the study of lakes was descriptive behavior, consisting of reconnaissance hydrographical surveys, only sometimes very limited information given about the individual characteristics of some elements of the hydrological regime of the lakes.

In the 20s of the twentieth century, the study of lakes in Central Asia began to acquire a complex character with hydrological, hydrobiological and other special observations. During this period, scientists made a huge contribution to limnological research: A.L. Borodinsky, N.P. Vasilkovsky, V.F. Gurvich, D.N. Kashkarov (1927), N.A. Kaiser, N.L. Korzhenevsky, N.G. Mallitsky (1929), S.D. Muraveisky (1960), L.A. Molchanov. N.L. Korzhenevsky (1925) performed the first generalization of materials on the hydrography of lakes in Central Asia in the work “Turkestan. Physical-geographical articles”, which provides brief information about individual large lakes and gives a list of a small number of small lakes in Central Asia.

At the end of the 20th century, the basic trends of research become an assessment of possibility of breaking through the dammed and moraine lakes, assessing the water resources of mountain lakes, and obtaining characteristics of their hydrometeorological regime. The issues of sustainability of natural dams of breakthrough hazardous lakes of various genesis, development of mathematical models of breakthroughs and calculation of breakthrough hydrographs were engaged by Yu.B. Vinogradov, G.E. Glazyrin, V.N. Razvyvich, Ya.S. Stavissky, V.I. Shatravin, I.G. Zuckerman, V.A. Keremkulov, Yu.M. Denisov, G.N. Gorelkin, D.D. Nurbaev, B.K. Tsarev, G.N. Starygin, V.N. Shamsutdinov.

The cause of increased interest in mountain lakes at the end of the last century was the breakthroughs of Issyk lakes in 1963 ZhandayevM.Zh. (1978), V.N. Vukolov (1991) and Yashinkul in 1966, Reizvikh V.N. et al. (1971). Starting from this time, breakthrough hazardous lakes of various genesis were monitoring at stationary sites, expeditionary surveys, and aero-visual exploring. Based on the results of long research work, various authors published monographs, articles, reports, developed observation methods, compiled classifications and a list of breakthrough hazardous lakes, and have been developed recommendations for monitoring their status. A new impulse to the resumption of a detailed survey of glaciogenic and dammed lakes in mountain river basins in the territory of the Republic of Uzbekistan and neighboring states was the mudflow that passed along the Shakhimardan River on July 8, 1998, caused by the breakthrough of moraine lakes, causing significant damage to the economy of Uzbekistan and resulting in human sacrifices [3].

Currently, S.S. Chernomorets (2015) M.A. Petrov (2015), E.A. Savernyuk (2016), K.S. Viskhadzhieva (2016), S.A. Erokhin (2011), E.P. Semakova (2017), Yu.A. Tarasov and others carry out research in the direction of studying glaciers, glacial lakes, glacial mudflows and their genesis in Central Asia.

Glacial, dammed and glacial lakes are potential sources of catastrophic floods, causing disaster to the lower valleys. In the territory of the Republic of Uzbekistan and adjacent territories, during the research were identified 680 lakes, the breakthrough of which threatens the national economy of Uzbekistan, Dergacheva (2018). On the territory of the Tashkent region - Chirchik-Akhangaran Basin (Fig. 1), located 265 lakes.

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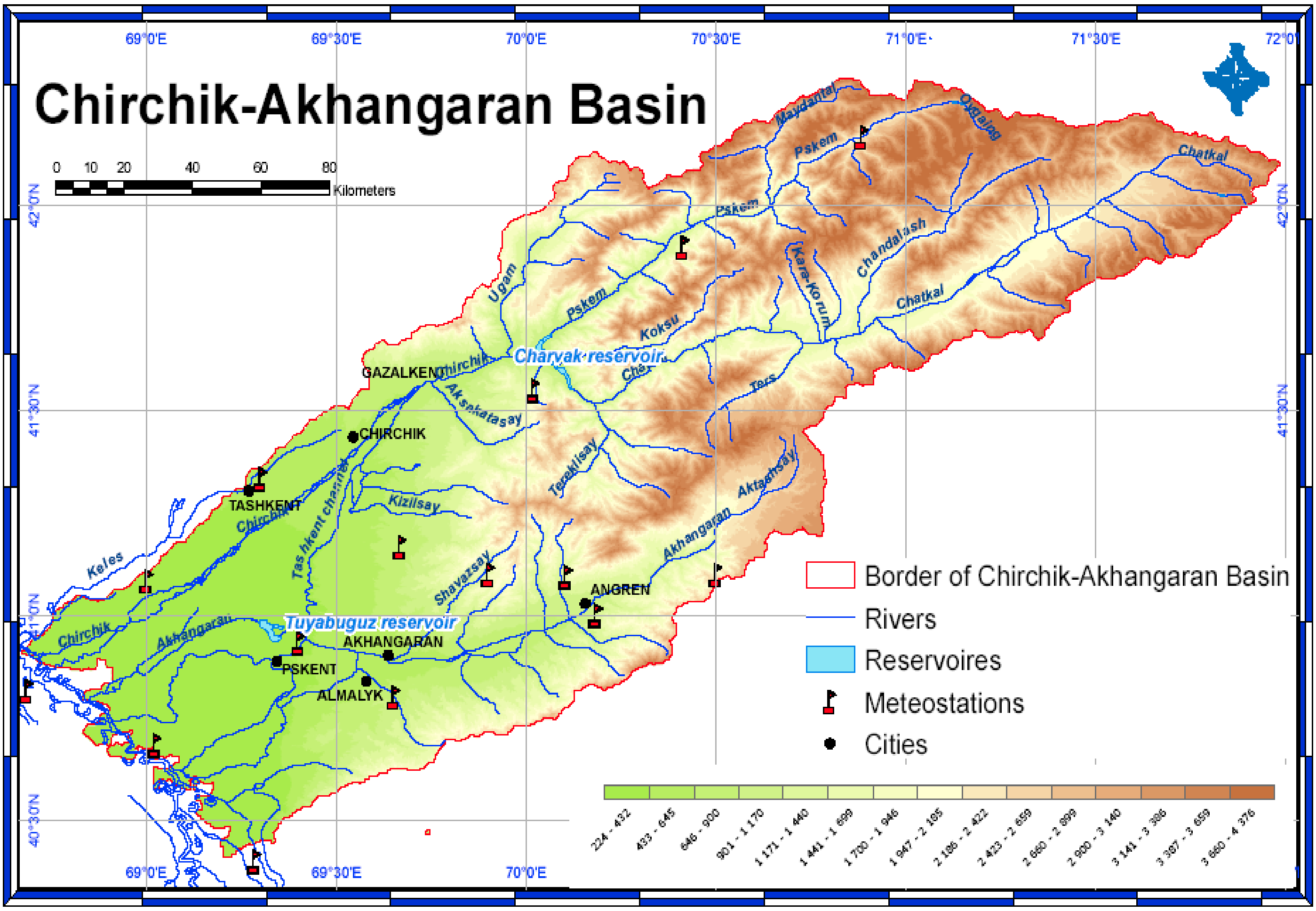

Figure 1. Chircbasinhik-Akhangaran river basin (Tashkent region)

There are about 87 cities of republican, regional and district significance, about 200 villages and other human settlements, in which 3.5 million people live in areas of possible catastrophic flooding by Lake Ihnach-large. The largest lakes along the Pskem river are of dammed origin: Shavurkul - 3.89 million m^3, Ichnach-large - 4.8 million m^3, Ihnach-lower - 0.9 million m^3 (Fig. 1), Urungach - 1.5 million m^3, Bodakul - 4.2 million m^3. All these lakes are located in the upper reaches, through the Pskem river above the Charvak reservoir and below the reservoir, there are many human settlements, including Tashkentcity, and all of them are located in the zone of potential flooding. Currently, the assessment of the breakthrough hazard of high mountain lakes, analysis of the causes and conditions of the occurrence and formation of catastrophic floods is current importance.

In the Department of Mathematical Modeling of Hydrometeorological Processes NIGMI under the guidance of Professor Yu.M. Denisov, created a mathematical model for calculating the breakthroughfloods. Derived an equation for calculating the parameters of a breakthrough wave and for calculating the transformation of a breakthrough maximum and other characteristics of the flow down the river, according to the calculations, a hydrograph of the breakthrough and graphs of the transformation of the characteristics of the breakthrough maximum along the riverbed are constructed. In the vast majority of cases, the erosion of blockages, dams, and cofferdam enclosing reservoirs does not occur instantaneously, but with a finite, sometimes, maybe even very high speed. The duration of erosion is usually from several minutes to several days.

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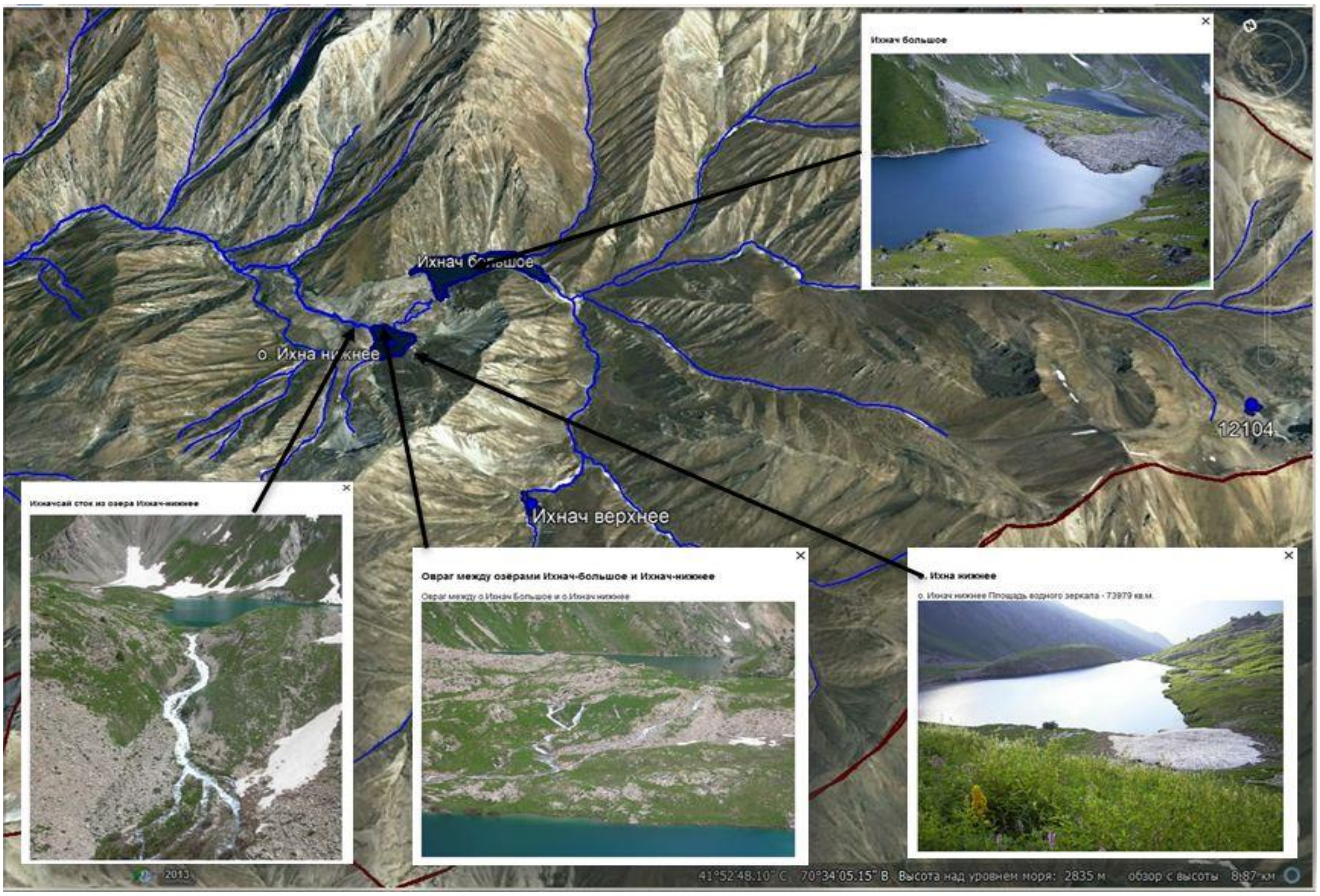

Figure 2. Ihnach river basin (Tashkent region)

III. RESULT ANALYSIS

As an illustration of the calculation of the disruptive discharge of the dammed lake, a model example of this calculation for Lake Ichnach-large is given.

The water-balance equation of the dammed lake taken in the form:

$$F(z_в(t))\frac{dz_в(t)}{dt}=Q_n(t)-Q_p(t), \qquad (1)$$

The calculation carried out for a rectangular gap.

$$P(z_в(t),z_{1p}(t),t)=B_p(t)\left[z_в(t)-z_{1p}(t)\right], \qquad (2)$$

$$Q_p(t)=\frac{4}{3}\sqrt{\frac{g}{2}}B_p(t)\left[z_в(t)-z_{1p}(t)\right]^{\frac{3}{2}}. \qquad (3)$$

The average speed of watercourse through the closing gap u_p equal to:

$$u_p(t)=\frac{Q_p}{P}=\frac{4}{3}\sqrt{\frac{g}{2}}\sqrt{z_в(t)-z_{1p}(t)}, \qquad (4)$$

the average depth of closing gap h_{pc} and its wetted perimeter χ_p is:

$$h_{pc}=\frac{P}{B_p}=z_в(t)-z_{1p}(t), \qquad (5)$$

$$\chi_p(t)=B_p(t)+2\left[z_в(t)-z_{1p}(t)\right]. \qquad (6)$$

The correlation between the width of the closing gap B_p and the mark of its bottom z_{1p}. For a rectangular closing gap, it follows from the corresponding differential equations:

$$\frac{dz_{1p}}{dt}=-a_p(t); \qquad \frac{dB_p}{dt}=2a_p(t). \qquad (7)$$

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Find from the first equation a_p and substitute it into the second equation, we get:

$$B_p(t) = B_{p0} + 2(z_{1p0} - z_{1p}). \quad (8)$$

B_{p0} and z_{1p0} – initial values of the considered quantities.

Equality (8) allows opening the expression (6) for the wetted perimeter of the closing gap:

$$\chi_p = (B_{p0} + 2z_{1p0}) + 2(z_в - 2z_{1p}). \quad (9)$$

The expression of the erosion intensity in the closing gap for $z_в(t) - z_{1p}(t) \succ s^*_{p0}$ is following:

$$a_p(t) = \frac{2}{3}\sqrt{2g}\left\{K_{pt}\frac{2}{3}\sqrt{2g}\left|\sqrt{z_в - z_{1p}} - \sqrt{s^*_{p0}}\right| + \frac{\nu}{\left[(B_{p0} + 2z_{1p0}) + 2(z_в - 2z_{1p})\right]} \times \right.$$
$$\left. \times\left[K_{ph}\frac{[B_{p0} + 2(z_{1p0} - z_{1p})]}{(z_в - z_{1p} + s^*_{p0})} + 4K_{pB}\frac{(z_в - z_{1p} + s^*_{p0})}{[B_{p0} + 2(z_{1p0} - z_{1p})]}\right] - \right\}\left(\sqrt{z_в - z_{1p}} - \sqrt{s^*_{p0}}\right)$$

(10)

For $z_в(t) - z_{1p}(t) \le s^*_{p0}$:

$$a_p(t) = 0. \quad (11)$$

Next, it is necessary to determine the area of the lake water mirror, depending on the level mark, and set the initial conditions.

The bathymetric plan of the Ihnach-large and Ihnach–lower lakes and the curve of the areas of the Ihnach–large lake are shown in Fig. 3.

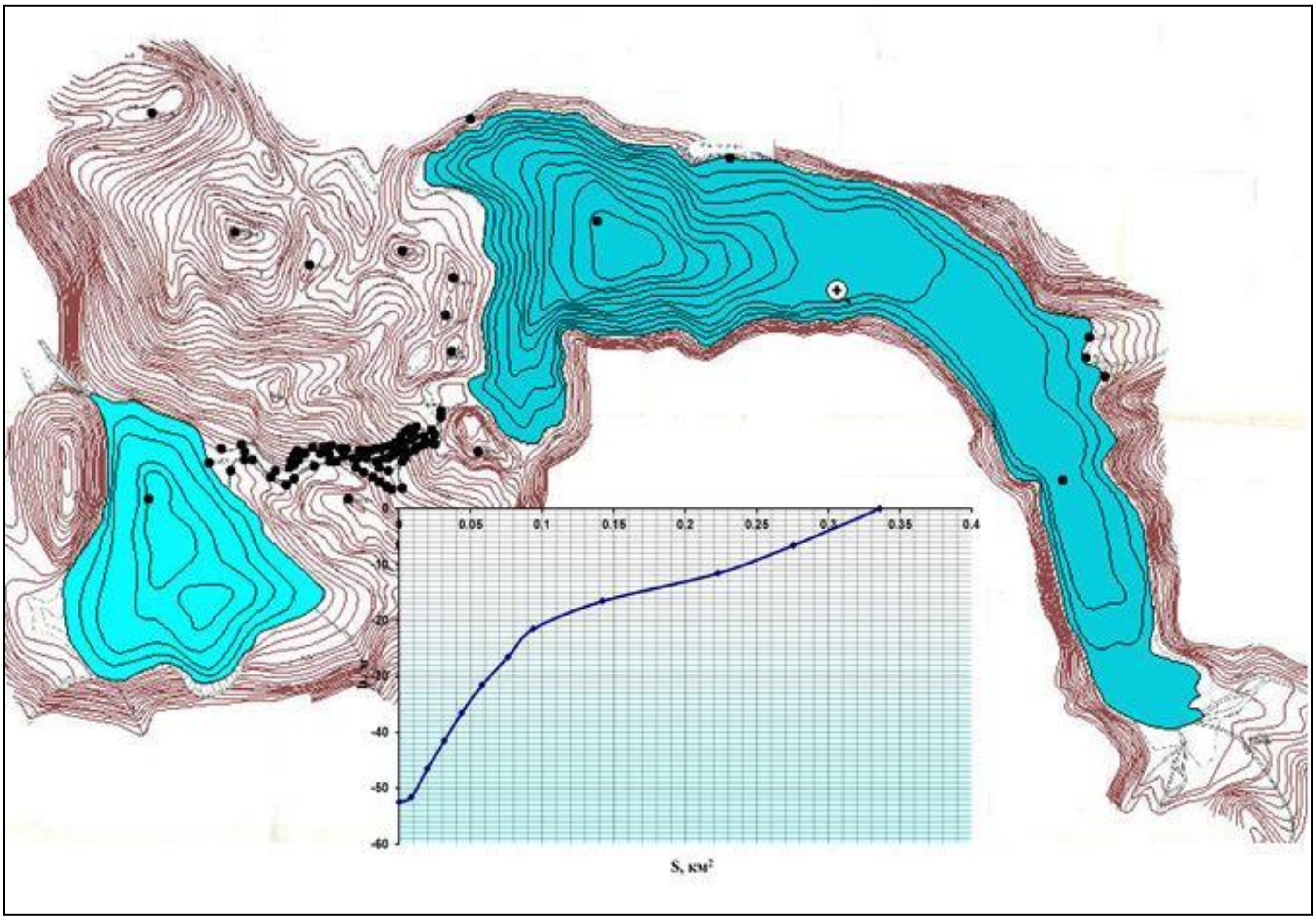

Figure 3. The bathymetric plan of the Ihnach-large and Ihnach–lower lakes and the curve of the areas of the Ihnach–large

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In equation (1), which includes this area, includes only its value, and not its shape.

Therefore, the shape of the area in this statement of the problem does not affect the calculation results and, with its given distribution in height, the volumes of the flood lakes will be the same.

The calculation results shown in Figures 3 and 4.

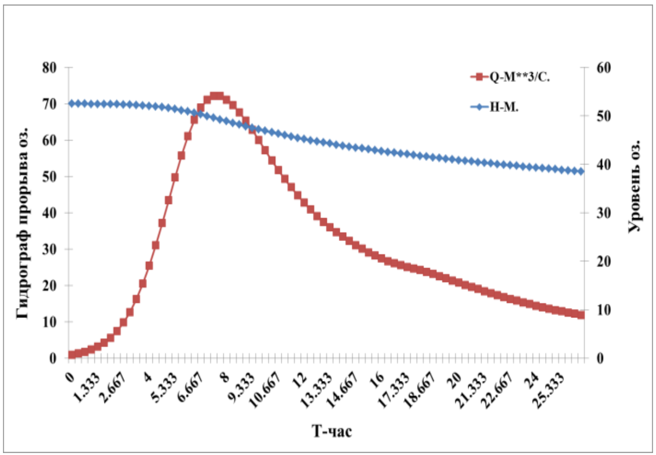

Figure 3 – Model calculation of the characteristics of the breakthrough of Lake Ihnach-large.

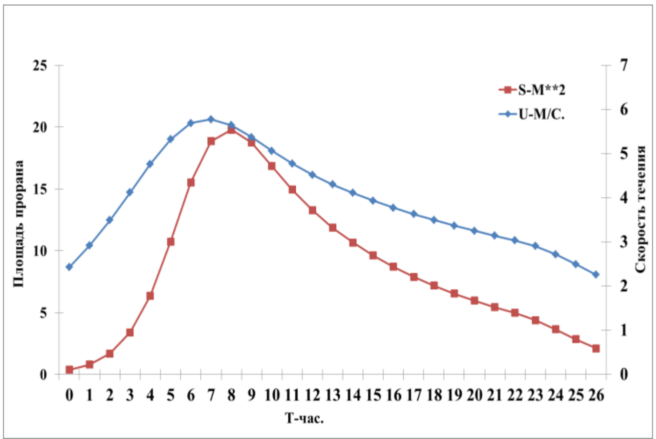

Figure 4 – Model calculation of the characteristics of the breakthrough of Lake Ihnach-large.

In the case of Lake, Ihnach-large overflow occurs only at maximum filling over the dam body, therefore, the highest water level in the dam lake in it at the initial moment of the breakthrough. The analysis shows that the maximum discharge through the closing gap passes eight hours after the start of the breakthrough, and the maximum speed occurs after 7 hours. The values of the calculated characteristics are close in order of magnitude to the observed values for lakes of the indicated capacity.

IV. CONCLUSION

The main factors determining the damage from the breakthrough of the lakes are:

- area of the lake, which substantially determines the shape of the breakthrough hydrograph (flow rate rise rate, maximum flow rate);
- the amount of water in the lake, that could be discharged as a result of a breakthrough;
- the character of the dam, on which the rate of increase in the breakthrough depends;
- the character of the riverbed along which the flood rushes (the spreading rate of the flood wave depends on the shape of the channel, and the presence of loose material in the channel can lead to the formation of thick mudflow even in the case of a relatively small volume of water discharged from the lake that has broken through);
- Infrastructure and population of the territory located along the river (the more developed the riverbed territory, the more damage is possible).

The genetic type of lakes is the most important criterion for their breakthrough hazard.

From the correct determination of the cause of formation of the lake the accuracy of predicting its state depends, that is, it will be a breakthrough hazard or not.

The most studied type includes lakes of the dammed group. Dammed lakes well known, as they have existed for many decades, cataloged and shown on a maps. Lakes of this group divided into four types: dammed-tectonic (landslide), dammed-mudflow, and dammed-landslide and dammed-snow avalanche. The formation of dammed-tectonic or

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dammed-landslide type lakes are associated with earthquakes.

After grand landslides of mountain slopes caused by seismic shocks, powerful dam dams form on the bottoms of valleys, above which significant masses of water accumulate from several hundred thousand to hundreds of millions of cubic meters. For example, Lake Karatoko (48.8 million m^3) and Lake Sarychelek (493 million m^3).

The runoff from the dammed-landslide lakes occurs both surface and underground, for example, from Lake Ihnach-large. As the lake develops, underground runoff replaced by surface runoff. The transition of one form of runoff to another is usually accompanied by catastrophic breakthroughs of lakes (Lake Yashinkul in 1966), therefore breakthrough hazardous –dammed-landslides are lakes with underground runoff. On some dammed-landslide lakes, surface runoff appears only at their maximum filling (Ihnach-large).

Breakthroughs of dammed-landslide lakes occur superficially through erosion gaps. The costs of watercourses, in this case, reach from several hundred to the first thousand cubic meters. Compared to moraine-glacial lakes, dammed-landslides erupt much less frequently, but their breakthroughs are more destructive.

Dammed-mudflow lakesformed on the bottoms of mountain valleys, above the thick blockages formed by mudflow outcrops when they leave the valleys of the side tributaries.As, for example, a temporary lake was formed because of a landslide in the Akhangaran river basin in the summer of 2006. Within a short time (from several hours to several days), the lacustrine bathtub overflows and surface overflow begins through the dam bridge and its erosion. A gap is formed in the body of the dam, through which the lake is completely or partially emptied. The flow rate of the breakthrough flow reaches several hundred cubic meters [58].

Under extreme conditions - a sharp increase in air temperature, intense atmospheric precipitation, a large accumulation of snow in the mountains, earthquakes, almost all mountain lakes are breakthrough hazards. Therefore, in all densely populated mountain valleys, that have lakes in the upper reaches, it is necessary to identify areas of potential damage by catastrophic floods and accept measures to reduce the risk of its impact.

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