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Hydrology

Primary Reasons for Frequent Natural Disasters on Earth (on the Example of Georgia)

Robert Diakonidze*, Davit Kereselidze*, Jumber Panchulidze*, Levan Tsulukidze*, Irakli Kvirkvelia*

* *Tsotne Mirtskhulava Water Management Institute, Georgian Technical University, Tbilisi, Georgia*

(Presented by Academy Member Ramaz Khurodze)

The paper presents the analysis of the natural disasters that have become more common on Earth due to climate change, on the example of Georgia. Special attention is focused on erosion-debris flow events, floods, waterfalls, landslides and deformation processes in riverbeds. Preventive measures against natural disasters and ways of their implementation are presented. Based on the natural conditions in Georgia, we recommend using the so-called Swiss-made anti-debris flow elastic type nets that are reusable and relatively low in cost. *© 2023 Bull. Georg. Natl. Acad. Sci.*

climate changes, natural disaster, debris flow, waterfalls, glaciers, landslide processes, erosion

Floods, landslides, and erosion-debris flow events are among the many natural disasters that occur on Earth and cause significant ecological and, consequently, economic losses for humanity. Georgia is not an exception.

Today, the world's leading scientists unanimously recognize that climate change is the main cause of frequent natural disasters on our planet, and the rise in temperature is due to the thermal effect caused by thermal gases release into the atmosphere. To a certain extent, we agree with this viewpoint; nonetheless, we believe that there may be other factors contributing to climate change. Acknowledgment of this viewpoint is conditioned by the matter of the Earth's glaciation. We think that one of the main factors of climate change is the Earth's rotation around its axis, and the processes resulting from it lead to climate changes on the planet. It is necessary to determine which of the two reasons mentioned above plays a decisive role.

It is important to highlight the various factors of climate change, such as: increase in the average air temperature of the Earth; melting of glaciers caused by thermal effect; formation of high-intensity abundant atmospheric precipitations in a short period of time (for example, often the monthly norm of precipitations falls within one or two days); concurrence of high-intensity abundant rainfall with glaciers accelerated melting.

All above-mentioned, caused by climate change problems, affect the environment's ecological sustainability in different doses, including water-

falls, floods, activation of erosion-debris flow and landslide processes, etc.

We will now share information about a few of them. Abundant and intense precipitation and glacier's rapid melting (in regions where glaciers are widespread) lead to the formation of a critical amount of surface runoff and is a precursor to the formation of various natural disasters. Similar events often occur in Georgia, especially on waterways and ravines originating from the southern slopes of the Great Caucasus.The excessive amount of surface water runoff triggers erosion, debris flow, landslides, slope reduction in riverbeds, rock collapse and various ecological issues.The combination of these factors leads to the creation of debris flows. Accelerated rates of erosion-debris flow processes are especially observed in areas where the prerequisites for its formation, such as deforestation and other factors are present. Frequent, abundant and intense precipitation leads to a critical increase in water runoff volumes on the Earth's surface, which is already reflected in oceans and sea levels rise.

In prone landslide zones, when the gravitational weight of water-saturated soil reaches a critical limit, the landslide becomes active and begins to move. The speed of its movement depends on multiple natural factors (geological, hydrological, hydraulic, climatic, etc.).

There are various problems caused by climatic factors, among which should be noted floods and waterfalls, erosion-debris flow events, accelerated deformation processes in riverbeds, and the so-called landslide of the bed slopes. Uncommon is the collapse of a part of the glacier body, which often leads to the river bed blocking and the formation of a natural dam. (Similar cases were noted in Georgia in 2014 in Gergeti in the basin of the Tergi River, and on August 3, 2023, in the right tributary of the Chanchakhi River, when a part of the glacier "Buba" broke off.) Water accumulates in the upper pool of the natural dam and, when in a certain period of time, the gravitational weight of the detached ice, rock debris, or a mass brought by a landslide, reaches a critical limit, and, the amount of water, collected in the upper pool reaches the energy, sufficient for the assembled sediment (mass) dislocation, a natural dam is breached, and solid sediment takes the form of a debris flow stream.It begins moving. In these conditions, turbulent debris flow with destructive power is formed.

The debris flow events are often triggered by large amounts of water accumulation in the glacier body, which may occur in crevasses or at the glacier base. Accumulation of a large amount of water in the glacier body is facilitated by various processes taking place on the glacier, including the temperature regime. When the volume of water in the body of the glacier reaches a critical limit, the glacier begins to move, and so-called "glaciological debris flow" with great speed and colossal destructive power occurs. In addition to the above, the reason of glacier movement may be an earthquake or a heavy mechanical impact.

Due to the various environmental problems caused by climate change, taking into account the physical and geographical conditions of Georgia, we offer measures that, in our opinion, are necessary to implement:

- As the danger of natural disasters has dramatically increased due to climate change in the 21st century, Georgia's network of hydro-meteorological stations has to be expanded. The network expansion is required even due to the ineffectiveness of existing hydro-meteorological data, as it cannot meet today's needs, which, as we mentioned above, is caused by a sharp change in climate.
- In ecologically vulnerable areas across the country, it is crucial to install remote notification devices due to the nature of the expected danger. These devices will enable us to take preventive measures against natural disasters in advance. Permanent monitoring of glaciers is also crucial.

- In higher education institutions, hydrological sciences and training of engineers-hydrologists should be reinstated. The government agency's requirement for an engineer-hydrologist to evaluate projects seems unreasonable as hydrologist engineers have not been trained by higher education institutions for over 20 years. However, students of the mentioned specialty study the necessary subjects in a complex manner, such as general hydrology, climatology-meteorology, geography, geology, hydrogeology, soils, etc. Knowledge of all these subjects allows hydrologists to competently assess expected natural disasters and to plan appropriate measures for their prevention.
- In the light of current events, it is imperative to provide urgent training to approximately 40-50 hydrologists across Georgia with sufficient education for disaster management (Preparatory course training can be carried out based on I. Javakhishvili Tbilisi State University and research institutes of the Technical University of Georgia).
- Every local self-government body in Georgia needs to set up an environmental safety service that takes into account the natural hazards present in each district or region. The number of staff units in this service should correspond to the specific conditions of the area.
- All regions of Georgia (especially vulnerable regions) must be equipped with anti-natural disaster devices and appropriate equipment to implement a proper response shortly. It would be good to purchase at least two helicopters and base them in Kutaisi (for western Georgia) and Tbilisi (for eastern Georgia).
- The particular services established within the self-government of the regions of Georgia must have a “drone” flying machine equipped with the appropriate software equipment and well-trained specialists who should be able to use them. All of this will allow us to periodically (especially during abundant and intense rainfall) identify expected natural disasters and take preventive measures promptly.

We can say with certainty that preventing natural disasters will cost the state much less than taking measures after the disaster. If these recommendations are followed, human casualties can be avoided.

In order to carry out preventive measures against natural disasters, it is necessary to be guided by appropriate scientific research. The studies we have recently carried out will significantly support working out measures against natural disasters for the conditions of Georgia: in the field of erosive-debris flow processes, we have set up the empirical dependence for calculating the predictive values of the maximum costs of debris flow [1-3] and water runoff [4-6]. These studies make it possible to calculate, with acceptable accuracy, the predictive values of debris flows and maximum water costs. Below, we present the new empirical relationships, which are discussed in detail in the scientific publication [1,3].

The calculation dependence of the debris flow cost has the following form:

$$Q_{df} = 0.06 \cdot N + 2.0, \quad (1)$$

when $N \leq 1000$ mln.W

$$Q_{df} = 0.08 \cdot N + 45, \quad (2)$$

when $N \geq 1000$ mln.W, where Q_{df} – debris flow rate, m^3/sec.

N denotes potential capacity of the water catchment, mln.W, it can be calculated with a simple dependence

$$N = YQH \approx 10000 \text{ kgp} \cdot \text{m/sec} \approx 10000 \text{ QHW},$$

where: N is water catchment capacity, W;
Y – unit volumetric weight of water, kg/m^3;
Q – average water consumption, m^3/sec;
H – average height of the catchment basin, m.

The maximum water consumption can be calculated with a simplified dependence

$$Q_t = \frac{P}{T} t \upsilon b \alpha \varphi \quad m^3/\text{sec}, \quad (3)$$

where P is precipitation of reporting provision (mm), T – duration of precipitation (hr), t – current time – from the beginning of the flow (hr), υ – speed of the flow (m/sec), b – width of the catchment area (km), α – runoff coefficient, φ – adjustment coefficient of the runoff hydrograph.

As for implementing practical engineering measures against natural disasters, we should approach them from different angles and consider their efficiency, quality and cost. In this regard, considerable experience have the research institutes of the Technical University of Georgia, including Tsotne Mirtskhulava Institute of Aquaculture (this organization has been devoted to developing measures to combat natural disasters and studying debris flow since its establishment during the post-Soviet era. Additionally, it has been recognized as a primary center for individuals from various Western European countries to enhance their theoretical and practical knowledge), and the Institute of Hydrometeorology. Many models of debris flow control structures have been developed in the mentioned institutes [7-9]. Despite all of the above, after getting acquainted with the existing types of debris flow protection structures, we concluded that for the conditions of Georgia, where the origin of debris flows mainly occurs on small tributaries of large rivers, it is appropriate to recommend elastic debris flow prevention nets, an improved version of which was developed in Switzerland [10]. It is worth mentioning that a similar anti-debris flow model was developed at the Georgian Hydrotechnic and Reclamation Scientific Research Institute in the 20th century. Unfortunately, there is no documentation available to verify this information.

Conclusions

To date, it is no longer in doubt and it has been proven that climate change on the Earth has led to the activation of various ecological problems, including floods, waterfalls, erosion-debris flow events, deformation of riverbeds and river slopes, landslides, glaciers rapid melting and, under certain conditions, their partial collapsing, solid rocks eroding, fall, fracturing, etc. This work provides an account of natural disasters and their effects on the environment. It also offers a list of recommended actions to mitigate the impact of natural disasters in Georgia, as well as highlighting the latest scientific advancements within the country.

Engineering measures against natural disasters (debris flows) presented in this study can be used in Georgia and other countries with similar physical and geographical conditions.

For Georgia's conditions, where debris flows mainly occur on small tributaries of large rivers, it is appropriate to recommend elastic anti-debris flow nets, the latest model of which has been developed in Switzerland.

ჰიდროლოგია

დედამიწაზე გახშირებული ბუნებრივი სტიქიების ძირითადი მიზეზები (საქართველოს მაგალითზე)

რ. დიაკონიძე*, დ. კერესელიძე*, ჯ. ფანჩულიძე*, ლ. წულუკიძე*, ი. კვირკველია*

** საქართველოს ტექნიკური უნივერსიტეტი, ცოტნე მირცხულავას სახ. წყალთა მეურნეობის ინსტიტუტი, თბილისი, საქართველო*

(წარმოდგენილია აკადემიის წევრის რ. ხუროძის მიერ)

ნაშრომში წარმოდგენილია დედამიწაზე კლიმატური ცვლილების ფონზე გახშირებული ბუნებრივი სტიქიების ანალიზი საქართველოს მაგალითზე. განსაკუთრებული ყურადღება გამახვილებულია ეროზიულ-ღვარცოფულ მოვლენებზე, წყალდიდობებზე, წყალმოვარდნებზე, მეწყრულ მოვლენებსა და მდინარეთა კალაპოტებში მიმდინარე დეფორმაციულ პროცესებზე. წარმოდგენილია სტიქიების საწინააღმდეგო პრევენციული ღონისძიებები და მათი განხორციელების გზები. საქართველოს ბუნებრივი პირობებიდან გამომდინარე, მიზანშეწონილად მიგვაჩნია, რომ ღვარცოფული ნაკადების საწინააღმდეგოდ გამოყენებულ იქნეს შვეიცარიაში წარმოებული ე.წ. ელასტიკური ტიპის ბადეები, რომლებიც მრავალჯერადია და მათი თვითღირებულება დაბალია.

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