

HIDROLOGY

MITIGATION MEASURES AGAINST FLOOD FLOWS IN AZERBAIJAN

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Abstract

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This article is dedicated to the implementation of protective measures against floods and the methods for determining appropriate locations for embankments. The primary objective of the study is to identify scientifically grounded flood mitigation strategies. Methodologically, the study focuses on categorizing embankments based on the runoff velocity of floodwaters and the resulting hydraulic impact. The proposed measures include: The artificial dispersion of cumulonimbus rainclouds over river basins using artillery fire; The construction of a hydraulic structure at the alluvial fan of the river to divert flood flows into three separate directions; The establishment of soil embankments to resist floodwaters.

The second measure is distinguished from previously used approaches by its categorized design and enhanced structural resistance. Specifically, for debris-laden and water-stone floods, the study recommends constructing reinforced concrete embankments from the beginning to the midpoint of the alluvial fan, followed by earth embankments downstream. The rationale behind extending reinforced concrete structures up to the midpoint lies in their ability to withstand the hydraulic impact along the dynamic axis of the flood flow.

1. Introduction

Water bodies, while being an invaluable and essential part of human life, can also cause significant damage to various sectors of the economy. In particular, the destruction caused by floods is often far greater than that of regular river overflows. As is well known, with the advancement of society's productive forces, human impact on nature intensifies. One consequence of this is that erosion materials accumulated on the surface of river basins are washed into riverbeds by the season's first intense rainfalls-typically occurring in summer-ultimately forming floods that inflict widespread damage on all economic activities located in the alluvial fan. In recent years, the increasing frequency and intensity of floods have been driven by two key factors: global climate change and escalating human interference with natural systems. This growing threat underscores the urgent need for effective and scientifically sound flood control measures.

It is important to note that, despite the destructive nature of floods, they can also play a beneficial role. Floods may act as a "natural factory," contributing essential raw materials for the production of construction materials and mineral fertilizers.

Flood control measures have attracted considerable attention in various regions around the world, including the Caucasus, Central Asia, Crimea, Yalta, the Far East, the Carpathians, the Altai Mountains, the Cordilleras, and the Andes. Among these, the strategies implemented in the Caucasus and Central Asia stand out due to their relatively higher effectiveness and practical success [3, 8, 10]. In the Republic of Azerbaijan, the most severe and destructive floods are observed in the Greater Caucasus region. This reality underscores the urgent necessity of developing and applying scientifically grounded flood control measures in the country. In the modern era, comprehensive analysis of flood flows allows for the design and implementation of more effective

mitigation strategies. An evaluation of accumulated experiences in flood management reveals that, despite the application of certain preventive measures, the intensification of exogenous processes—largely driven by global warming—has increased both the frequency and severity of floods. Consequently, the demand for more advanced and robust flood control strategies has significantly grown in recent years [1, 4, 5, 6].

In earlier periods, flood protection measures—regardless of their intended purpose—primarily consisted of check dams and earthen embankments, and only occasionally of protective fences [7, 9]. In particular, the construction of check dams often required the mass cutting of forest trees, which significantly reduced vegetation cover and led to the degradation of the ecological environment.

In recent years, the increasing threat of floods caused by the transport of eroded materials during intense downpours in the mountainous regions of arid subtropical zones has underscored the growing necessity for the use of scientifically grounded engineering structures. Effective flood risk reduction in these areas increasingly depends on the implementation of well-designed, evidence-based protective infrastructure.

The objective of this study is to identify and develop scientifically substantiated flood mitigation measures. The research aims to enhance the effectiveness of protective strategies through a systematic and evidence-based approach tailored to regional hydrological and geomorphological conditions.

2. Research Methodology

The methodology involves calculating the runoff velocity of flood flows and determining appropriate new protective measures. Special attention is given to hydraulic impact assessment in order to categorize and optimize the design of flood control structures.

3. Analysis and Discussion

It is well known that floods in mountain rivers are not only turbulent but, in some cases, possess large-scale catastrophic characteristics. While flood deposits cause significant damage to agricultural lands, they also serve as good mineral fertilizers for plants; however, these deposits disrupt the respiratory system of roots. This effect is particularly noticeable in hazelnut orchards and tobacco plantations. Such floods are observed predominantly in the Greater Caucasus region of Azerbaijan, with relatively weaker floods occurring in the Lesser Caucasus and the Nakhchivan

Autonomous Republic, except for the Jeyranchol and Lankaran natural regions. There is no river in which only one type of flood occurs. Floods in rivers vary not only across different years but also along the longitudinal profile of the river during the transport phase. Typically, muddy floods occur in the upper reaches, transitioning to debris-laden mudflows and water-stone flows in the middle reaches, and again transforming into muddy floods, especially after the alluvial fan. This pattern is explained by the slope of the terrain and the corresponding erosion law, as expressed by (Equation 1).

$$W = Av^6 \text{ or } d^3\gamma = Av^6 \quad (1)$$

In the equation W or $d^3\gamma$ —The weight of the sediment particle rolling along the bottom; the natural velocity of the flow (v); and A —the coefficient of proportionality—manifest themselves in this manner. Based on this law, rivers possess varying capacities to erode their channels.

It can be seen from the equation that the weight of the particle rolling along the bottom depends on the sixth power of the speed. That is, it is more clearly seen in the conditional ratio of plain and mountain rivers 1:5 (in catastrophic floods this ratio can be even greater). That is, the speed of the transported flood in a mountain river is equal to $1:5^6$ or $1:15625$. Therefore, mountain rivers differ from plain rivers in their great destructive properties. From this it is clear that plain rivers have the ability to transport sand, clay and silt, while mountain rivers have the ability to transport the flow of sediments rolling along the bottom. The reported rate depends more on the fall and slope of the river (table 1).

The analysis of Table 1 shows that while the average slope of the rivers varies between 40-190 ‰, the average slope of the river basin varies between 310-822 ‰. In contrast, in Balakenchay and Talachay, Damarjig, Damiraparanchay, Goychay and Agsu and Ayrichay basins, although the forest area is 29%-87%, the active effect of the forest against erosion is not felt. Since the basins of the mentioned rivers contain easily washed clay shales and the forests are weak, the slopes of the rivers in the Nakhchivan Autonomous Republic and the wide distribution of easily washed rocks cause them to become the most flood-prone rivers. In addition to the above, the large and sharp fall of the rivers, the height of the floodplains above sea level and the density of the river, ravine and goby network are also one of the main conditions.

Table 1

Morphometric characteristics of rivers

River - area	The river				Forest area in the basin, %	Density of hydrographic network, km/km ²
	length, in km	fall, in m	average slope, ‰	with the average slope of the basin ‰		
Gudiyalchay-Kupchal	47	2350	50	303	6	1
Velvelachai-Tengialti	43	2666	62	231	10	1.1
Balakenchay-Balaken	20	3031	101	492	82	0.56
Talachay-Zagatala	21	2100	100	210	87	1.25
Kurmukchay-Sarybash	12	1260	105	620	-	1.86
Kurmukchay-Ilisu	19	2280	120	590	5	1.20
Bulanigsu-Sarybash	9.4	2378	121	822	5	1.80
Kunakhaysu-Sarybash	6.1	811	133	740	5	1.53
Hamamchay-Ilisi	11	1961	126	650	17	0.90
Eyrichay-Bashdashakhil	12	1615	160	590	40	1.42
Damarciq-near the mouth	8.5	1615	190	430	31	1.42
Chukhadurmaz-near the mouth	12	1615	170	580	45	1.99
Gaynar-near the mouth	5.5	2731	184	-	67	0.92
Demiraparanchay-Gabala	23	2323	101	512	29	1.05
Goychay-Goychay	62	2356	38	-	44	0.72
Aghsu-Aghsu	37	1768	52	246	44	0.46
Levchay-Qamishli	29	1914	63	404	16	1.22
Tutxun-near the mouth	34	2142	56	377	18	1.22
Gargarchay-Aghakorpu	24	936	52	295	6	1.15
Ganjachay-Zurnabad	36	2052	43	389	21	1.1
Goshgarchay-Dashkan	15	870	58	190	5	1.13
Ordubadchay-Nusnus	12	1824	152	500	-	0.53
Gilanchay-Bist	23	1288	150	376	2	0.56
Gilanchay-Bashdize	45	1980	44	310	1	0.51
Alinjachay-Arafsa	16	1248	78	386	1	0.31
Nakhchivanchay-Garababa	36	1980	40	267	4	0.48
Jahrichay-Payiz	30	1940	48	278	2	0.41

Floodplains in the rivers of our republic are mainly located at altitudes above 1800 m above sea level and have an area of up to 75 km² [9].

The average effect of a complex of factors determines the formation and strength of the hydraulic shock of a flood. Thus, the magnitude of the hydraulic shock of a flood depends, among other factors, on the fall of the river and the height of the stream. It is known that a particle in the form of a plume located at the bottom of the river bed or its front (front) part P_l is subjected to a hydrodynamic pressure force. The force of the flow is proportional to the speed of friction with the bottom. It is expressed by the following equation (formula 2).

$$P_l = a \frac{\gamma}{g} v_{dib\ bas} \cdot \Omega \quad (2)$$

a -proportionality coefficient; γ -specific gravity of water; g -gravity acceleration; v bottom-initial velocity of bottom sediments; Ω -indicates the

cross-sectional area of the particle perpendicular to the flow direction.

It should be noted that, depending on the length of the rivers and the absolute height of the floodplains, floods have different speeds in the upper, middle and lower reaches [2, 11]. Thus, if we take the conditional runoff speeds of the flood, taking into account the lower, middle and upper reaches of the river, as 3 m/s, 4 m/s and 5 m/s, respectively, then the duration of the flood transport corresponding to its dynamic strength will also be different (table 2).

Analysis of table 2 indicates that the flood velocity in the upper course of the Valvalachay river, over a distance of 6 km, reaches 5 m/s with a runoff of 20', while in the middle course, over 30 km, the velocity is 4 m/s with a runoff of 125'. In the lower course, covering 7 km, the velocity decreases to 3 m/s with a runoff of 39%, requiring a total time of 3 hours and 4 minutes.

Table 2

The duration of the flood transport

River - area	length, in km	upstream			midstream			downstream			total duration, hours, minutes.
		length, in km	speed, m/sec	duration, hours, minutes	length, in km	speed, m/sec	duration, hours, minutes	length, in km	speed, m/sec	duration, hours, minutes	
Gudiyalchay-Kupchal	47	1-7	5	23'	8-40	4	138'	41-47	3	39'	200'
Velvelichay-Tengialti	43	1-6	5	20'	7-36	4	125'	37-43	3	39'	184'
Balakenchay-Balaken	20	1-3	5	11'	3-10	4	29'	11-20	3	56'	96'
Talachay-Zagatala	21	1-3	5	10'	3-10	4	29'	11-21	3	61'	100'
Kurmukchay-Sarybash	12	1-3	5	10'	3-10	4.5	26'	11-12	4	50'	86'
Kurmukchay-Ilisu	19	1-3	5	10'	4-9	4.5	22'	10-19	3	56'	88'
Bulanigsu-Sarybash	9.4	1-2	5	7'	3-7	4.5	19'	7-9.4	4	10'	36'
Kunakhaysu-Sarybash	6.1	0-1	5	3'	2-4	4.5	11'	5-6.1	4	9'	23'
Hamamchay-Ilisu	11	1-2	5	7'	3-5	4.5	11'	6-11	3	33'	51'
Eyrichay-Bashdashaqil	12	1-3	5	10'	4-7	4.5	15'	8-12	3	28'	53'
Damarchig-near the mouth	8.5	1-2	5	7'	3-6	4.5	15'	7-8.5	4	10'	32'
Chukhadurmaz-near the mouth	12	1-2	5	7'	3-8	4.5	22'	9-12	4	17'	46'
Gaynar-near the mouth	5.5	0-1	5	3'	2-3	4.5	7'	4-5.5	4	10'	20'
Demiraparanchay-Gabala	23	1-6	5	20'	7-15	4	146'	16-23	3	44'	210'
Goychay-Goychay	62	1-15	5	50'	16-50	4	46'	51-62	3	67'	163'
Aghsu-Aghsu	34	1-10	5	33'	11-21	4	41'	22-34	3	72'	146'
Levchay-Qamishli	29	1-10	5	33'	11-21	4.5	59'	22-29	4	33'	125'
Tutxun-near the mouth	37	1-12	5	40'	13-28	4.5	29'	28-37	4	39'	108'
Gargarchay-Aghakorpu	24	1-10	5	33'	11-17	4	62'	18-24	3	29'	124'
Ganjachay-Zurnabad	36	1-12	5	40'	13-27	4	11'	28-36	3	50'	101'
Goshgarchay-Dashkan	15	1-6	5	20'	7-9	4.5	15'	10-15	3	33'	68'
Ordubadshay-Nusnus	12	1-5	5	17'	6-9	4.5	26'	10-12	3	17'	60'
Gilanchay-Bist	23	1-12	5	40'	13-19	4.5	12'	20-23	3	12'	64'
Alinjachay-Arafsa	16	1-6	5	20'	7-11	4.5	19'	12-16	3	28'	67'
Nakhchivanchay-Qarababa	36	1-10	5	33'	11-25	4.5	56'	26-36	3	61'	150'

Corresponding to the velocity distributions of the floods, in Talachay, runoff values of 10', 10', 61' and a time of 1 hour 21 minutes are recorded; in Kurmukchay, runoff values of 6', 22', 56' and 1 hour 14 minutes; in Damardzichay, 7', 15', 10', and 32 minutes; and in Gaynar, 3', 7', 10' and 20 minutes are observed. Similar patterns have been noted in other flood-prone rivers. Comparable studies were also conducted in the 1970s [7, 9]. However, global climate changes during those years were not as pronounced as in recent times.

The amount of water collected in different intensities in the upper, middle and lower reaches of the river basins is also different according to

the relative velocity distribution of the flood. Thus, during intense downpours of 1, 2, and 3 mm/min. in the 172.3 km² elementary basin area of the upper reaches of the Gudyalchay River, 1 mm/min. 172 thousand m³, 2 mm/min. 345 thousand m³ and 3 mm/min. 517 thousand m³ of water are collected, while in the corresponding intensive downpours of 344.6 km² of the middle reaches, 345 thousand m³, 689 thousand m³ and 1084 million m³ of water can be collected, and in the total flow of 517 km² up to the Kupchal settlement, 517 thousand m³, 1034 million m³ and 1551 million m³ of water can be collected [5]. A similar situation is observed in Talachay and other

ivers. Thus, in the 45.3 km² elementary area of the upper reaches of the Talachay, 45 thousand m³, 91 thousand m³ and 136 thousand m³ are collected at the corresponding intensities of heavy rains, in the 90 km² elementary basin area of the middle reaches 90 thousand m³, 181 thousand m³ and 273 thousand m³, and in the 136 km² elementary areas of the total flow up to the Zagatala water gauging station downstream 136 thousand m³, 272 thousand m³ and 408 thousand m³ of water are collected. The above-mentioned require the implementation of appropriate flood control measures.

Unfortunately, until recent years, flood control measures were taken after the occurrence of floods. The assessment of the cause of the flood is also of great importance in terms of the effectiveness of the dam to be built. Thus, it is natural that there is a difference between the measures taken to combat them, as compared to mud floods, due to the diversity of water-stone and mud-stone floods. While earth dams and narrow concrete dams are sufficient on the banks of rivers where mud floods pass, other floods require the construction of large hydrotechnical structures. Taking into account the above, some of the measures that will be effective in minimizing the impact of floods include the following: Although the measures taken to combat floods require large financial resources, they are required to control floods and reduce the damage caused as much as possible. As of modern times, the state of flood studies does not respond to the solution of water management issues. Therefore, there is a great need to take effective control measures.

One of the measures is to organize the fragmentation of cumulonimbus clouds formed over the river basin with artillery fire in order to reduce the flood in mountain rivers. This measure consists in reducing the amount of precipitation falling on the river basin to a safe level. The proposed method can be cheaper than the construction of protective dams along the river and other anti-flood measures. There is a great need to clean the channels with bulldozers at the beginning of the spring and autumn seasons every year. The use of this method creates conditions for the passage of muddy floods from the rivers. This can also lead to a relative reduction in damage to farms. This method can be used for rivers flowing through the Greater and Lesser Caucasus.

Another measure to reduce the speed of the flood and the damage caused by it is to build a hydraulic structure at the head of the confluence that divides the flood flow into 3 parts. The main

part of the flood is discharged through the channel, and the remaining part is discharged through flood channels on the right and left sides. The purpose of using the method is to reduce the hydrodynamic impact of the flood in 3 directions. It is appropriate to use this method in rivers with muddy-stony and water-stony floods. The riverbeds should be cleaned before the flood at the beginning of the spring-autumn seasons. The cleaned flood materials should be transported to stone quarries and converted into efficient use in the form of construction materials. Such an approach allows for a comparative reduction in damage to agricultural areas. The use of the method plays a significant role in reducing the peak level of the flood. This method can be applied to flood rivers flowing through the southern slope of the Greater Caucasus, the Lesser Caucasus, and the territories of the Nakhchivan Autonomous Republic.

The next method is to organize regular cleaning of the riverbeds of rivers with muddy floods with bulldozers every year before the spring and autumn floods and floods. This method can be used in rivers flowing from the Lankaran Natural Region, Jeyranchol and Gobustan.

The mentioned control measures can be divided into groups of low, medium and high effectiveness.

1. Low-efficiency control measures include (annually) cleaning of the riverbed, especially the area of the flood cone, and maintaining a stable channel system.

2. Medium-efficiency control measures include the protection of natural forest cover along the river, the construction of artificial embankments, and regular cleaning of blockages in the channel caused by floodwaters.

3. High-efficiency control measures include the construction of dams and forest reclamation works by category.

The above-mentioned group of control measures should be divided into current and prospective periods and differ in the degree of flood hazard depending on the physical and geographical characteristics of the area.

4. Conclusion

1. Studies show that the need for new methods is explained by the simplicity of the previous ones, their temporary practical significance, their failure to fully meet the requirements of the modern era, and the intensive erosion of river basin surfaces due to global climate change.

2. It has been established that the fact that flood flows mainly pass through rivers at night

leads to their not being observed in the camera. This requires that new methods applied for flood protection be based on hydrological calculations and empirical equations.

3. Calculations show that the construction of flood protection dams also depends largely on the fall of the river. Thus, the fall of the river determines the hydraulic impact of the flood. It is important to build dams with a flat trapezoidal reinforced concrete structure that will sit along the confluence of rivers with a large fall.

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AZƏRBAYCANDA SEL AXINLARINA QARŞI MÜBARİZƏ TƏDBİRLƏRİ

C.H.Məmmədov

Xülasə. Məqalə seldən mühafizə üçün qoruyucu tədbirlərinin görülməsi və ona müvafiq bənd yerlərinin müəyyən edilməsi üsullarına həsr olunmuşdur. Tədqiqatın məqsədini elmi cəhətdən əsaslandırılmış mübarizə tədbirlərinin müəyyən edilməsi, metodiki həlli isə sel axınlarının qaçış sürətini və hidravliki zərbəni nəzərə almaqla, bəndlərin kateqoriyalarının müəyyən edilməsi təşkil edir. Tədbirlərdən birincisi çay hövzəsi üzərindəki topa yağışlı buludların top atəşi ilə parçalanması, ikincisi çayın gətirmə konusunda sel axımını 3 istiqamətə ayıran hidrotexniki qurğunun tikilməsi, üçüncüsü isə selə qarşı torpaq bəndlərin salınmasından ibarətdir. İkinci üsul kateqoriyalarla tikilməsi və möhkəm müqaviməti ilə əvvəllər tətbiq edilən üsullardan fərqlənir. Belə ki, bu üsulda palçıqlı-daşlı və sulu-daşlı sellərdə mühafizə bəndlərinin gətirmə konusun əvvəlindən ortasına kimi dəmir-beton konstruksiyalı, ondan sonra isə torpaq bəndlərdən ibarət olması təklif edilir. Dəmir-beton bəndlərin gətirmə konusun orta məsafəsinə kimi uzadılmasında məqsəd, bu bəndlərin selin dinamik oxunun hidravliki zərbəsinə müqavimət göstərmə qabiliyyəti ilə izah edilir.

Açar sözlər: sel, palçıqlı sel, palçıqlı-daşlı sel, sulu-daşlı sel, gətirmə konusu, sel gətirmələri