Innovative Floodwater Management via Continuous GIS Monitoring

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Abstract. Flood management is essential for the sustainability of communities, particularly in mountainous regions where floodwaters can cause significant damage to infrastructure, agriculture, and settlements. This research explores a novel floodwater management system using continuous GIS monitoring to protect villages located in Turkmenistan's foothills, with a focus on Nohur village in the Baherden district. The proposed method emphasizes the construction of medium-height rock dams along flood streams, aimed at preventing flood-related destruction while providing a reliable water source for households, agricultural lands, and industrial enterprises throughout the year. Using Google Earth Pro for terrain analysis, this study evaluates floodwater flow patterns and presents a cost-effective solution to capture and utilize rainwater. The findings contribute to sustainable water resource management, supporting the broader objectives of environmental protection and local development. This innovative approach ensures both flood protection and water conservation, offering long-term benefits for the local population and infrastructure resilience.

1 Introduction

The conservation and protection of natural resources, particularly water, is a pressing global issue, exacerbated by industrial development, agricultural expansion, and population growth. Water management, including flood control and wastewater reuse, is crucial for sustainable development and environmental protection. Effective strategies must focus on studying the characteristics and formation of flood flows, classifying flood types, and developing methods for determining their computational and pressure impacts on infrastructure. Additionally, strategies should include protection of mountainous areas from flooding and regular utilization of wastewater for cleaning purposes.

Mountain areas are an important source of cultural, ecological, and life-sustaining resources, but are also subject to devastating natural hazards. Flood hazards in mountain areas are generated by a number of landscape processes (e.g., landsliding, glacial lake failures,

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local convective and orographic precipitation events) that do not occur in the valley floodplains, where most flood hazard planning and infrastructure has historically been developed [1]. Floodwaters damage highways, railways, bridges, irrigation canal systems, power lines, residential buildings, and industrial structures. They disrupt train and vehicular traffic, clog pipelines and bridges, derail them, and destroy and damage the foundation soil, bridge piers, and pilings. There is an increasing need to study the conditions of the hazardous occurrence of flood flows and their formation in seismically active regions. 30% of the territory of the Commonwealth of Independent States is the main flood prone area [2].

According to Tullos et al., flood risk management in mountainous regions requires an integrated approach that includes basin-scale hazard assessment, disaster response planning, and the development of early warning systems. The study also emphasizes the importance of involving local communities in flood risk reduction efforts [1]. These insights directly relate to the focus of this study on protecting mountainous villages in Turkmenistan, such as Nohur, from flood damage through the implementation of flood control measures like rock dams and the use of GIS technologies for continuous floodwater monitoring. By reviewing the practices highlighted in this study, such as multi-level governance and the need for robust data collection systems, this research aims to contribute to the broader discourse on sustainable flood risk management in vulnerable mountainous areas.

The main principle of protection against floods is the construction of special artificial structures, and it consists in ensuring the ability of highways and bridges to be protected from erosion and destruction, the safe movement of vehicles, and the protection of villages in mountainous regions from flooding.

Remotely sensed data are being increasingly used for flood extent mapping and damage assessment [3]. The problem considered in the work is to choose an artificial device that meets modern requirements and meets the climatic conditions of our country in order to prevent the damage of houses and streets due to heavy rains in the mountainous regions of our country or due to the formation of flood flows for other reasons.

Significance of the work: reservoirs for the collection of flood waters in the mountainous regions of the country play an important role. This provides an opportunity to prevent the formation of flood waters and their damage, and to use the collected water for the household needs of the population, agricultural lands, and irrigation. Supplying populated areas, industrial enterprises and agriculture with plenty of water is one of the main tasks of the era. Along with all the countries of the world, taking into account that the living conditions of the population of our country are growing day by day and the demand for water resources is increasing, and based on the analyzes conducted, the use of flood waters is one of the most important issues.

1.1 Objectives of research

- to study the basic characteristics of flood flows;
- to look groups of flood flows over;
- characterization of the movement of flood flows and study of their formation;
- to consider the methods of determining the computational characteristics of flood flows;
- methods of determining the pressure of flood flows on construction facilities ;
- to develop a method of protecting mountain areas from floods;
- regular use of wastewater for screen cleaning.

1.2 Research questions

- What are the main characteristics of flood flows in mountainous regions, and how do these characteristics affect the movement and formation of floodwaters?
- How can flood flows be classified based on their recurrence and impact on infrastructure in seismically active areas?
- What are the most effective methods for determining the computational and pressure impacts of flood flows on construction facilities, such as highways and bridges, in flood-prone regions?
- What role can reservoirs play in the regular collection and utilization of floodwaters in mountainous regions, and how can they support local water needs for household, agricultural, and industrial purposes?
- How can artificial structures, such as medium-height rock dams, be optimized to protect mountainous settlements from flood damage while ensuring water conservation and sustainable use?
- What are the potential benefits of integrating remotely sensed data and GIS technologies for flood mapping and damage assessment in mountainous regions?
- How can the regular use of wastewater for screen cleaning be incorporated into a comprehensive flood management strategy?
- What are the socio-economic and environmental impacts of implementing flood protection systems in foothill regions like Nohur village, and how can these systems be tailored to meet local needs and climatic conditions?

1.3 Scope of the Study

This study focuses on the development of an innovative and sustainable floodwater management system, specifically targeting mountainous regions such as Nohur village in Baherden district, Turkmenistan. The scope includes an in-depth analysis of flood flow characteristics, such as their speed, recurrence, and pressure on infrastructure, as well as classifying these flows based on their frequency and the damage they cause. It also involves evaluating the impact of floodwaters on critical infrastructure like highways, bridges, and residential areas, particularly in seismically active regions. The study proposes the construction of medium-height rock dams to manage floodwaters and create reservoirs for long-term water storage, aiming to support households, agriculture, and industrial activities. A key aspect of the research is the use of GIS tools, specifically Google Earth Pro, to map flood-prone areas and analyze floodwater flow paths, helping to optimize flood management strategies. Furthermore, the study explores the potential for wastewater and floodwater utilization, ensuring sustainable water management for both household and agricultural needs. The overall focus is on developing flood control strategies that not only mitigate flood damage but also support water conservation and environmental sustainability in mountainous regions.

1.4 Expected Contributions

The study is expected to offer several key contributions. First, it proposes an innovative, cost-effective floodwater management solution tailored to the needs of mountainous regions through the construction of medium-height rock dams. This approach will significantly reduce flood damage while providing a reliable water source for local use. The research also aims to enhance infrastructure resilience by improving the design of protective structures that safeguard highways, bridges, and other facilities in flood-prone areas. In terms of water management, the study will introduce a system for the regular collection and use of floodwaters, which addresses the growing demand for water in regions like Turkmenistan and supports sustainable agriculture and industry. Additionally, the integration of GIS technologies for flood monitoring and mapping will contribute to more effective, data-driven flood management strategies. By reducing flood-related costs and ensuring a stable water supply, the research will positively impact local economies, especially in agricultural and industrial sectors. The study also addresses the unique challenges of flood management in seismically active regions, offering insights that can be applied in similar geographic areas. Finally, the environmental and ecological benefits of the study include preventing soil erosion, protecting local vegetation, and minimizing the destructive effects of floodwaters, contributing to broader efforts in environmental conservation. The research also provides valuable policy recommendations, offering a framework for planners and engineers to implement effective flood protection systems in similar regions.

2 Materials and methods

70% of the Earth's surface is covered by water. Water is in the atmosphere and earth, and it forms oceans, rivers and lakes. Plants, animals and people cannot live without water. 29.2% of the Earth's total area of 510 million km^2 is covered by dry land. The rest of the planet is covered by seas and oceans. The reserve water of the world ocean is equal to 1370 million km^3 (93.96%). Fresh water of rivers and lakes is close to 230 thousand km^3 (3% of land area). Glaciers cover a volume of 24 million km^3 (11% of the continent's area). Glacier drift could raise the global sea level by 0.64 m and lead to 1% of land inundation. Groundwater (with a thickness of 5 km) is 60 million km^3, of which 4 million km^3 is located in the aquifer zone. 85 thousand km^3 of soil is stored in the upper layer. According to the US Geological Survey, the distribution of water reserves in the hydrosphere has been developed [4]. Water is always in motion – both its quantity and quality vary over time and space. Water resources are characterized by centuries of reserve water and renewable resources.

2.1 Data Collection Procedures

The data collection for this research was conducted primarily using Google Earth Pro for terrain analysis. Satellite imagery provided by the program was used to monitor the geographical features of the Nohur village in Baherden district, Ahal velayat, focusing on floodwater flow paths and sedimentary areas along the flood streams. The real-time images collected through Google Earth Pro were instrumental in understanding the terrain changes and potential flood risk zones. In addition to satellite data, hydrological data such as rainfall intensity, floodwater speed, and sediment movement were collected. This data helped in determining the volume of water likely to be involved in flood events and how this water flows through the mountainous terrain.

2.2 Analytical Techniques

Several analytical techniques were employed to interpret the data collected. One of the key calculations was flood flow estimation, where a specific formula was used to determine the amount of floodwater. This formula, Q=q×FQ = q \times FQ=q×F, calculates the flow rate based on the water productivity qqq and the size of the flood catchment area FFF. To estimate the total volume of floodwater, the study employed the formula W=Q×tW = Q \times tW=Q×t, where ttt is the duration of rainfall. This gave a precise understanding of the volume of floodwater generated during flood events. Additionally, GIS mapping techniques were used to identify flood flow paths and locate areas at risk. This mapping was crucial for determining optimal sites for building medium-height rock dams to prevent future flood damage.

2.3 Site Selection Criteria

The Nohur village was chosen as the site of study due to its specific geographical and environmental features. The village, located in a mountainous region with significant elevation changes, experiences heavy rainfall, which leads to rapid surface runoff. The soil in this region has high permeability, meaning that water quickly runs off the surface without being absorbed, contributing to the risk of flooding. Additionally, the steep slopes of the village's terrain increase the velocity of floodwaters, making it a prime location for studying floodwater management strategies. Historical flood events in the area, which have caused significant damage to houses, roads, and agricultural lands, also played a critical role in the selection of this site. These factors combined make Nohur an ideal candidate for implementing and testing innovative flood control measures [8-12].

2.4 Validation Methods

To ensure the accuracy and reliability of the research findings, several validation methods were employed. The data used in the study was validated by long-term observations, with over 10 years of rainfall and flood flow records from the region. This historical data helped to verify the accuracy of the flood flow calculations and predictions made in the research. Additionally, a comparative analysis was conducted by referencing existing flood management models developed by other researchers, such as Yu.B. Vinogradov and T. Takahashi [5], to ensure that the proposed solutions align with established scientific principles. Lastly, feedback from the local community, which has firsthand experience with past floods, was incorporated to ensure that the proposed flood management strategies are practical and feasible for implementation in Nohur village. These validation methods provided a robust foundation for the proposed floodwater management approach [13-18].

2.5 Basic characteristics of flood flows

Clusters of flood flows.

On the basis of these, the geological structure of the flood basins or the morphological structure of the movement of the characteristics of the flood flows are shown.

According to morphology, flood basins can be divided into two main groups - channel and slope. Geologically, the structure of flood basins consists of the following groups:

- *To steal the original form;*
- *Disposing of marine debris;*

Displacement of soft-packed loose alluvial, deluvial, and other sediments by volume (which characterizes flood flow capacity)

Rivers are divided into 6 groups:

- Very small - <1 thousand m ^{3};
- Small - 1 - 10 thousand m ^{3};
- Middle - 10 -100 thousand m ^{3};
- Large - 1-10 mln. m ^{3};
- Very large - 1 -10 mln. m ^{3};
- Huge - >10mln. m ^{3} [6];

It divides flood basins into 3 groups according to flood recurrence (which characterizes the flow activity) or frequency of passage.

- High (recurrence of flows 1 time in 3-5 years and faster)

- Average (recurrence of flows 1 time in 6-15 years)
- Low (recurrence of currents 1 time in 16 years)

In 1978, S. M. Fleishman presented 4 groups of flood protection according to the effect of flood flows on the properties of constructions:

- Non-major excavation, partial hole sealing of drainage facilities;
- Strong excavation, full clogging;
- Collapse of bridge trusses, girders, bridge pillars and external structures;
- Destruction of populated points, parts of road beds and facilities, placement of facilities under pumps [6].

2.6 Characterization of the movement of flood flows and their formation

An important characteristic of movement is speed. The speed of the flood flow is determined by the pattern of movement, the composition of the mixture of the flood flows, as well as the morphometric properties of the flow. For example, in high mountain regions, flood flows sometimes form a height of 2500-3000 m above sea level and from there they fall into valleys with an elevation of 500-700 m above sea level. By crossing this path, the current acquires a large kinetic energy. At the stroke, the pressure of the tidal flow at the barrier is 1.5-3 kgs/cm ^{2} or (1.5-3) x $10^{5\ \mathrm{Pa}}$ [7].

The drift or erosion of the bottom depends mainly on the flow velocity and the profile of the hole. A deep saturation shear current flows under the conditions shown in Figure 1 a. As the cell expands, the average velocity of the water decreases and the water is no longer able to move all the shear from point A; As a result, a larger accumulation of current begins. (Figure 1.b) [7].

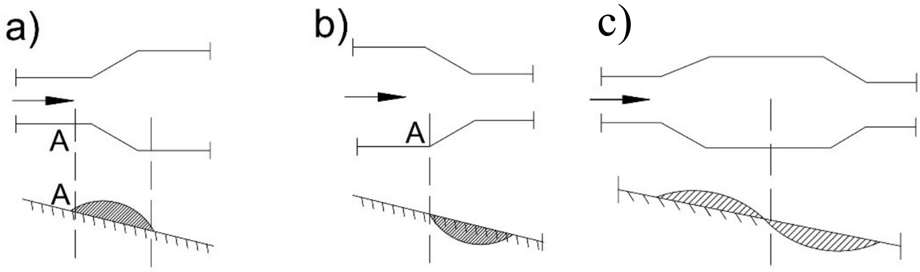


Fig. 1. The accumulation of the barrage and erosion according to the profile of the scour in the plan: (a) scour expansion; (b) scour contraction; (c) scour periodic schedule [2].

Flood flows can be turbulent and laminar in nature. A distinctive feature of the migration of siltstone flood flows during the final phase of their composition is the uniform location of the flood flow in parts. The reason for this arrangement is the turbulent flow of the mixture.

A characteristic feature of laminar flow is the parallelism of the fluid layers in the flow, in addition, the flow velocity is not uniform throughout the flow: In the flow, the zero point is at its peak near the top.

Disjoint flows behave only turbulently and obey the laws of hydraulics, while connected ones can behave both turbulently and laminarly and do not obey the laws of hydraulics, and the flow is in a plastic medium, also leak, eg like a concrete curve.

The associated (structural) silt flow contains 80-90% of the seeds of mountain fragments, of which the average density (pc)is 2000 to 2300 kg/m ^{3}. Unbound silt flows contain 15-60% solids, with an average density of 1100-1600 kg/m ^{3} (Figure 1.) [2].

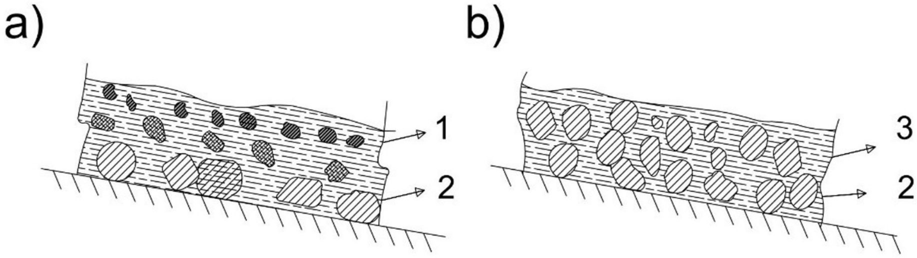


Fig. 2. Rheological-structural aspects of flow.
a) unrelated (rocky water, water slide); (b) related (dirty stones) [2];
1 - water or mixture; 2– material formed from small fragments; 3 – weight in dirty state;

Stagnant flow does not release water and solidifies the material without first sorting it, while turbulent flow tends to drag and dislodge size-sorted material along the spillway.

In 1980, Yu.B. Vinogradov proposed to classify flood flows based on their composition and flood weight density: [4]
Water repellency ($\rho_c = 1100 - 1600$kg/m ^{3}),
Pollution ($\rho_c = 1400 - 2000$ kg/m ^{3})
kg/m ^{3} of gravel($\rho_c = 1800 - 2500$ [5].

Fluid flows have high viscosity (the resistance of the inner layer of the fluid in motion is different). The high density and high flowability of the flood flows retain large boulders. Yu.B.Vinogradov's and T.Takahashi's models gained the most popularity in improving the models of flood flows [8].

In the work of T. Takahashi, he considered two cases of improvement of mixtures of flood flows:

1. They form a mass near the corner of the natural slope on the basis of soft soil formed by small fragments, not having connections, not destroyed in slopes;
2. The upper layer forms a mass with a smaller slope than the others with a soft character (so that it does not have traction) formed by small fragments;

In the first case (Fig. 3, a) the movement of soft rocks formed by small fragments forms a completely or partially cellular aqueous space;

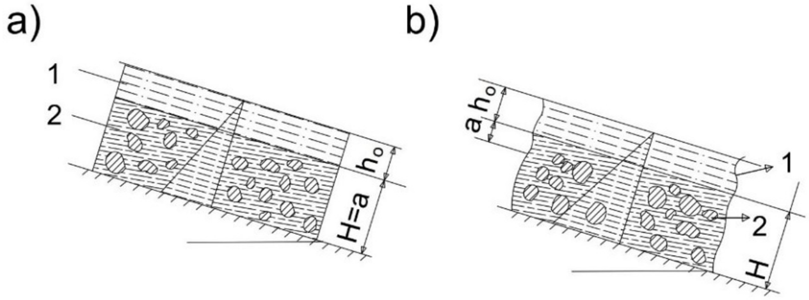


Fig. 3. Interrelation of shear and retention stresses in slopes.
a- increasing of critical importance; b- Not increasing critical importance;
1 – Aqueous stream; 2 - Soft sex made up of small pieces [2].

In the second case (Figure 3,b) the movement of soft rocks formed by small fragments can also be observed on slopes. Equation (1) should be used if the magnitude representing the resulting force acting on the surface flux is significant. The importance of the angle of displacement of soft rocks formed by small fragments in a layer of α thickness is calculated by the following equation:

$$\boldsymbol{tg\alpha} \geq \frac{\boldsymbol{C_*(p-p_0)}}{\boldsymbol{C_*(p-p_0)+p_0(1-h_0/\alpha)}}\boldsymbol{tg\varphi} \ (1)$$

Where h_0 is the bottom of the watershed;

α- thickness of sliding layer;

$\rho\ we\ \rho_0$- density according to water and rock types;

φ- angle of internal friction of soft rocks formed by small fragments;

$C\ *$- accumulation of sediments in the thickness of water-saturated soil.

2.7 Calculations of the flood protection system

The flood flow leads to changes in the biodiversity of our nature, protecting the mountains, destroying the vegetation layer, destroying the houses of the people living in the foothills, and damaging the roads.

The village of Nohur, Baherden Etrap, Ahal Velayat, which is one of the mountain foothills with high rainfall, was chosen. The relief of the place where the village is located is high and low. Earth's total permeability is high. Due to the high slope of the soil, the rainwater does not soak into the ground, it moves towards the low ground and creates a water flow. Downstream, the velocity of the flow, and therefore its kinetic energy, increases, and a tidal flow is formed. A silt is a rocky stream with a high kinetic capacity. In mountainous areas, the speed of the flood flow is high because there are no thick trees or bushes to resist the movement of the flow. As a result, the flood flow carries soil particles, small and large pebbles and moves towards the village at high speed. The flood water formed during heavy rains creates a natural phenomenon within the village, that is, it leads to the collapse of houses and the burying of streets with stone rubble.

To protect populated areas from floods, it is considered to be the most convenient and economical solution to construct four medium-height rock dams along the flood stream. Dams equipped with regulating layers will not only prevent flooding, but also provide an opportunity to provide water to villages and farmlands throughout the year by managing floods. This will help to a certain extent in the implementation of the work of providing abundant water to settlements, industrial enterprises and agriculture .

Innovation of the scientific work: For the first time, a method was developed to protect settlements located in the foothills from flooding. For the first time, it was developed for the village site to build a dam along the riverbed and create a reservoir. The data was processed using Google Earth Pro software. It is also proposed for the first time that the material of the dam will be constructed from the stones of the village.

2.8 Productivity Benefits

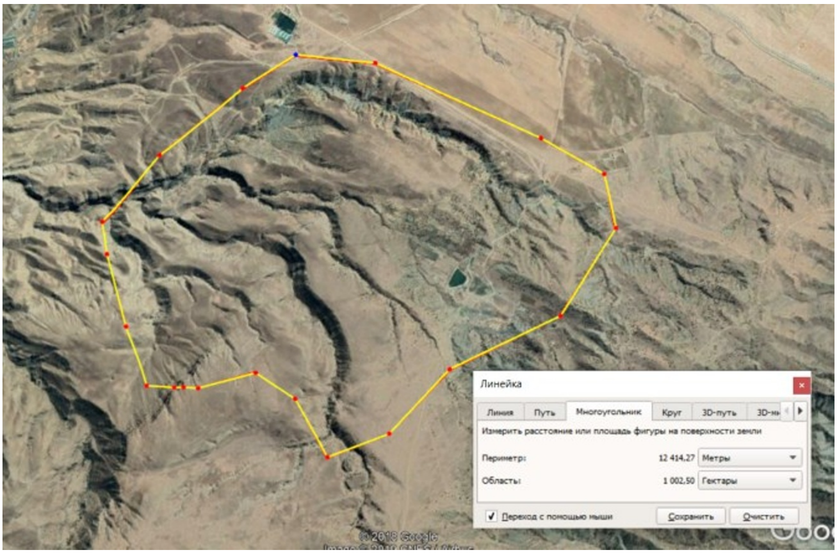
1. It is considered the most convenient and economical solution to build four medium-height rock dams along the flood flow to protect populated areas from floods.

2. Dams equipped with regulating layers will not only prevent flooding, but will provide an opportunity to provide water to the village and farmlands throughout the year by managing flood waters. This will contribute to the implementation of the paternal concern of the President to provide abundant water to the settlements, industrial enterprises and agriculture.

3. The streets, crops and houses of the village are destructed because of the annual floodwaters. This requires the implementation of landscaping works. As a result, financial costs are constantly incurred. If the proposed scientific work is implemented in the village, it will completely prevent flooding in the village and save water for the village.

3 Results and Discussion

Google Earth pro internet application was used to study the amount of flood water coming to the village and the rainwater catchment areas as well as the flow paths. Based on the data obtained from the Google Earth Pro program, it was found that there are 1000 hectares of sedimentary areas for collecting rainwater along the flood stream coming to the village of Nohur, and the water comes along 3 branches and forms a common channel. As can be seen from the previous calculations, the proposed flood protection facilities will provide an opportunity to completely protect the village of Nohur from flooding, as well as to increase the area of irrigated agricultural lands due to flood waters.



Измерить расстояние или площадь фигуры на поверхности земли

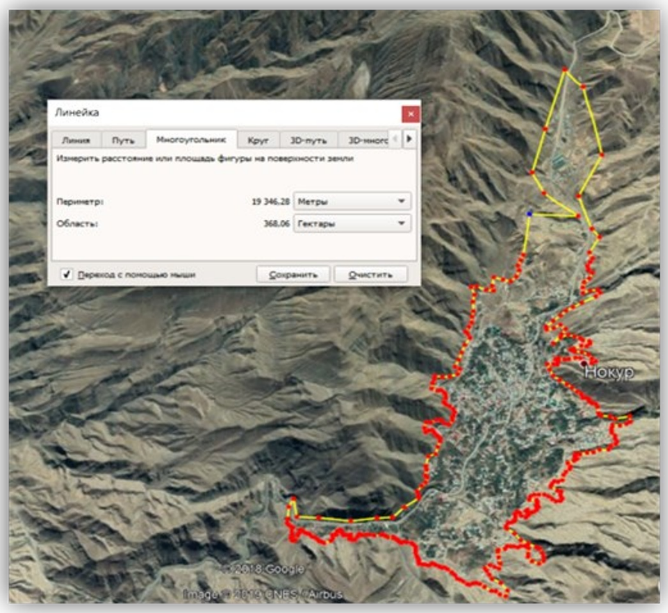
Периметр: 12 414,27 Метры

Области: 1 002,50 Гектары

☑ Переход с помощью мыши

Fig. 4. Rainwater catchment area. (*Google Earth Pro)*

As can be seen from the picture, the amount of flood water coming to the village is equal to the sum of the water collected in the four branches.



Линейка

Измерить расстояние или площадь фигуры на поверхности земли

Периметр: 19 346.28 Метры

Области: 368.06 Гектары

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Fig. 5. Geographical location of Nohur village obtained using Google Earth Pro. (*Google Earth Pro)*

3.1 Workflow

To determine the amount of flood water coming to the village, the method used in the design of the sewerage system in settlements was chosen [4]. According to it, the amount of flood water is determined by the following formula:

$$\mathbf{Q_{\acute{y}} = \mathit{q} \cdot F}, \qquad \mathbf{l/sec}$$

here

q-oil productivity during t-time, l/sec ·;

F – flood catchment area, ha.

Fig. 6. A view of the river flowing into the village of Nohur.

For the village of Nohur, according to the results of the observations made during 10 years, it was revealed that during heavy rains, about 60 liters of rainwater is collected per hectare of land per second.

According the data, assuming that q= 0.06 m3/ha·sec , rain water collection area F= 1000 ha, rain duration t=20 minutes (t=1200 seconds).

We calculate the amount of flood flow by taking the catchment area as F = 1000 hectares as mentioned above :

$$\boldsymbol{Q_{\acute{y}} = 0,06 \cdot 1000 = 60\frac{m^3}{sek}}$$

$\mathbf{Q}_{\acute{y}}$- flow rate of rainwater, $\mathbf{\frac{m^3}{sek}}$;

The amount of flood water is determined by the following formula:

$$\mathbf{W} = \boldsymbol{Q_{\acute{y}} \cdot t}$$

$$\mathbf{W} = \boldsymbol{Q_{\acute{y}} \cdot t} = \mathbf{60}\ \boldsymbol{\frac{m^3}{sek}} \cdot \mathbf{1200}\ \text{sek} = \mathbf{72\ 000}\ \boldsymbol{m^3}$$

Considering that this happens twice a year

$\boldsymbol{W_2} = \mathbf{2 \cdot W = 2 \cdot 72000 = 144000}\ \boldsymbol{m^3}$– flood water will be collected

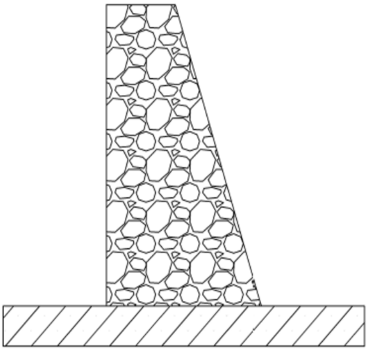

Fig. 7. Internal structure of proposed dams [2]

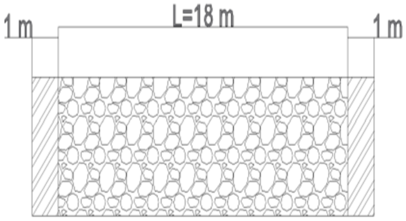

Fig. 8. Facade view of the proposed dams [2]

The height of the dam $\boldsymbol{h_1 = 3\ m}$, $\boldsymbol{h_2 = 2,5\ m}$ $\boldsymbol{h_3 = 2\ m}$, $\boldsymbol{h_4 = 1,70\ m}$

Then:

Dam sizes and thicknesses:

1. $\mathbf{V_1 = 135\ m^3}$; $\mathbf{l_1 = 0.7\text{-}1.30\ m}$
2. $\mathbf{V_2 = 118\ m^3}$ $\mathbf{l_2 = 0.6\text{-}0.9\ m}$
3. $\mathbf{V_3 = 85\ m^3}$ $\mathbf{l_3 = 0.5\text{-}0.8\ m}$

4. $V_4 = 55\ m^3$ $l_4 = 0.4$-0.7 m

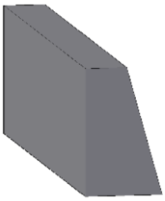

Fig. 9. 3D rendering of the proposed dam [2]

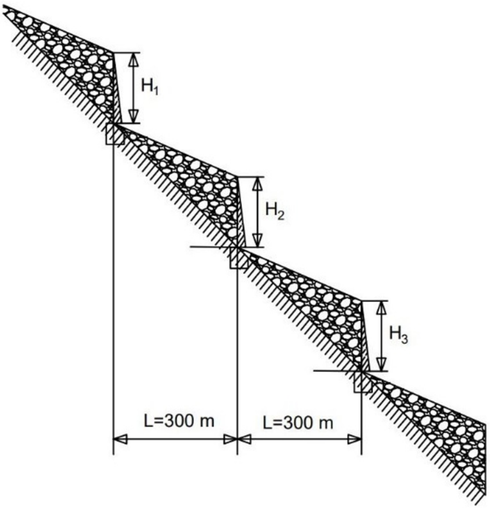

Fig. 10. Map of the location of the proposed dams on the mountain [2]

4 Conclusion

1. Based on the calculations, it is a convenient way to build 4 rock dams at intervals of 300 m in Degirmen Dere, which has an area of 16 hectares, to protect the settlements in the foothills from flooding.
2. In the body of each of the bunds, there are pipes equipped with a screen to protect them from dirt. Pipe diameter: d1=700 mm, d2=600 mm, d3=600 mm, d4=800 mm.
3. A 10-hectare reservoir with a depth of 4.5 m will be built at a distance of 300 m from the dam IV to collect flood waters in the village.

4.1 Suggestions

1. To prevent flooding in the villages located in the foothills of the country, to improve the village's water supply by regular use of flood waters, and to use rainwater for agricultural purposes.
2. Based on the measurements, it is proposed to build four dams with an interval of 300 m to protect the village of Nohur from flooding and to use the flood waters in agricultural areas. For the regular use of flood waters, it is planned to lay a pipe equipped with a zadvizhka

(adjusting-waiting device) in the body of the fourth dam. It is intended to irrigate agricultural lands through pipelines.

References

1. D. Tullos, E. Byron, G. Galloway, J. Obeysekera, O. Prakash, Y. Sun*, Review of challenges of and practices for sustainable management of mountain flood hazards*. Springer Science+Business Media Dordrecht **83**, 1763–1797 (2016)
2. J.B. Baynatov, *Artificial protective structures on mountain roads.* M., - (Itogi nauki i tekhniki. Ser. Automob. dorogi / VINITI; 10 (1992)
3. E. Psomiadis, K.X. Soulis, M. Zoka, N. Dercas, *Synergistic Approach of Remote Sensing and GIS Techniques for Flash-Flood Monitoring and Damage Assessment in Thessaly Plain Area, Greece*. Water.; 11(3):448 (2019)
4. A. Geldiyev, *Efficient use of water resources.* Textbook for higher education schools, Ashgabat (2010)
5. Y.B. Vinogradov, *Study of flood streams. - L.: Hydrometeoizdat,* 144 (1980)
6. S.M. Fleishman, *Hydrometeoizdat*, (1978)
7. I.S. Dornbaum, *Protection of populated areas from flood (mud) streams.* - M., 175 (1949)
8. B.S. Stepanov, T.S. Stepanova, *Mudflow mechanics*. *Hydrometeoizdat,* 379 (1991)
9. M. Bakiev and K. Khasanov, International Journal of Geoinformatics **17**, 37 (2021)
10. K. Khasanov, IOP Conf Ser Mater Sci Eng **883**, (2020)
11. Bakiev, M. Khasanov, K. and Primbetov, I., International Journal of Geoinformatics 53 (2022)
12. M. Bakiev, S. Djabbarova, and K. Khasanov, in *E3S Web of Conferences* (2023)
13. B. Masharif, D. Shakhnoza, and K. Khojiakbar, E3S Web of Conferences **263**, 02050 (2021)
14. M. Bakiev, S. Djabbarova, and K. Khasanov, in *E3S Web of Conferences* (2023)
15. A. A. Yangiev, M. R. Bakiev, O. A. Muratov, J. M. Choriev, and S. Djabbarova, in *J Phys Conf Ser* (2020)
16. K. Khasanov, IOP Conf Ser Mater Sci Eng **883**, (2020)
17. M. Bakiev and K. Khasanov, International Journal of Geoinformatics **17**, 37 (2021)
18. K. Khasanov and A. Ahmedov, in *E3S Web of Conferences* (2021)