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DEVELOPING FLOOD HAZARD ASSESSMENT SOFTWARE FOR ARMENIA

By 2050, a significant portion of the global population will reside downstream from thousands of large dams constructed during the 20th century. Many of these dams are currently operating at or beyond their intended lifespan, as indicated by an analysis conducted by the United Nations University. An illustrative case is the Sardoba reservoir in Uzbekistan, which ruptured at 05:55 on May 1, 2020. Although no fatalities were reported, but 56 persons were injured and hospitalized, and more than 70 thousand people were evacuated from around 22 villages to neighboring areas. The outflow water reached even to Kazakhstan, where around 30 thousand people were also evacuated. The outflow from the reservoir was stopped and the water was discharged to Arnasai lake on May 8. Given the existence of numerous similarly outdated reservoirs in Armenia, the Government of Armenia, in cooperation with UNDP, is actively considering mitigation measures for such reservoirs.

To carry out flood simulations, the authors have developed specialized training software, a modified version of the flood software developed earlier under the UN-Habitat project. Besides, it is suggested to create a database compiled from water reservoir data. Considering the water reservoir safety, comprehensive management including maintenance is necessary, but this paper mainly focuses on the development of simplified hazard maps.

Keywords: *simplified flood simulation, flood hazard map, mudflow, flood.*

The break of Sardoba reservoir in Uzbekistan occurred at 05:55 on 1st May 2020. There were no killed, but 56 persons were injured and hospitalized, and more than 70 thousand people were evacuated from around 22 villages to neighboring areas. Some residents of neighboring villages also provided shelter for the evacuees. The outflow from the reservoir was stopped and the water was discharged to Arnasai lake. However, the outflow water reached even to Kazakhstan, where around 30 thousand people were also evacuated.

By 2050, a significant portion of the global population will reside downstream of tens of thousands of large dams constructed during the 20th century, many of them currently operating at or beyond their intended lifespan, as indicated by an analysis conducted by the United Nations University [1]. According to that analysis, most of the 58,700 large dams worldwide are constructed between 1930 and 1970 with a design life of 50 to 100 years, adding that at 50 years a large concrete dam "would most probably begin to express signs of aging". The report also mentions that dams that are well-designed, constructed, and maintained can "easily" reach 100 years of service, but predicts an increase in "decommissioning" — a phenomenon gaining pace in the USA and Europe — as economic and practical limitations prevent ageing dams from being upgraded or if their original use is now obsolete. Namely, the necessity of maintenance of the dams is increased. As concluding Worldwide, the huge volume of water stored behind large dams is estimated at 7,000 to 8,300 cubic kilometers.

Armenia also faces this problem. However, there have been no major floods caused by heavy rains or dam failures in Armenia recently. Hence, there is not enough reference data (such as hydraulic information, etc.) on floods. In this situation, it is necessary to implement flood simulation using only very limited information. The results of the simulation can be used for proper planning of downstream maintenance and evacuation of people.

To achieve the above goal, the authors simplified the simulation software developed under the UN-Habitat project, making it suitable for use also in Armenia, where flood data is limited. The simplified software can be used to compose simple hazard maps to be considered in evacuation plans.

UN-Habitat project

In 2008, UN-habitat launched a project "Development of Simplified Risk Mapping Tools to Facilitate and Optimize Emergency Response to Major Floods". The goal of the UN-habitat was developing a simplified flood assessment tool for developing countries, which are prone to flood disasters. The probability of flood disasters is increased due to the effect of climate change. Compared to developed countries, it is difficult to build infrastructure, such as riverbanks, etc., in developing countries due to cost. Therefore, soft countermeasures, such as evacuation are applied. Thus, there was a necessity to develop a software to assess the flood flow. The purpose of the project was the development of a simplified flood risk assessment tool (FRAT) that can be used to produce a Shelter Response Plan and Strategy facilitating and maximizing emergency response and predictability [2].

A capacity development in Armenia is necessary, when considering mudflow/flood simulation due to water reservoir collapse. A modified FRAT software is proposed for this purpose.

Flood simulation by UN-Habitat

The FRAT simulation software developed by UN-Habitat is for educational purpose. It simulates flooding using only topography and hydrograph information. For the topography data a satellite digital elevation model (DEM) is used.

In fact, in detailed flood simulation, the target are needs to be divided into grids and information on each grid, such as roughness coefficient, water level, etc. needs to be entered. Besides, it is also important to get hydrograph data by means of observation. Therefore, the software should be used only for educational purpose.

However, the problem is not the calculation itself, but the initial conditions provided. Thus, the program is useful for developing evacuation plans in a situation where limited information is available.

Taisho mudflow

In Japan, volcanic mud generated as a result of eruption of Mount Tokachi on May 24, 1926, caused a disaster (called Taisho mudflow) that killed 144 people. This volcanic mudflow is one of the famous mudflows in Japan. Since, the source of the mudflow is known and there is no noise in the 50m scale DEM data of Japan with 50 meters spacing, we attempted to simulate the Taisho mudflow using the FRAT software.

Fig. 1 shows the actual situation of Taisho mudflow [3] and Fig. 2 shows the result of the simulation of the same mudflow by the use of FRAT software. The results of the simulation reproduce the reality with high accuracy.

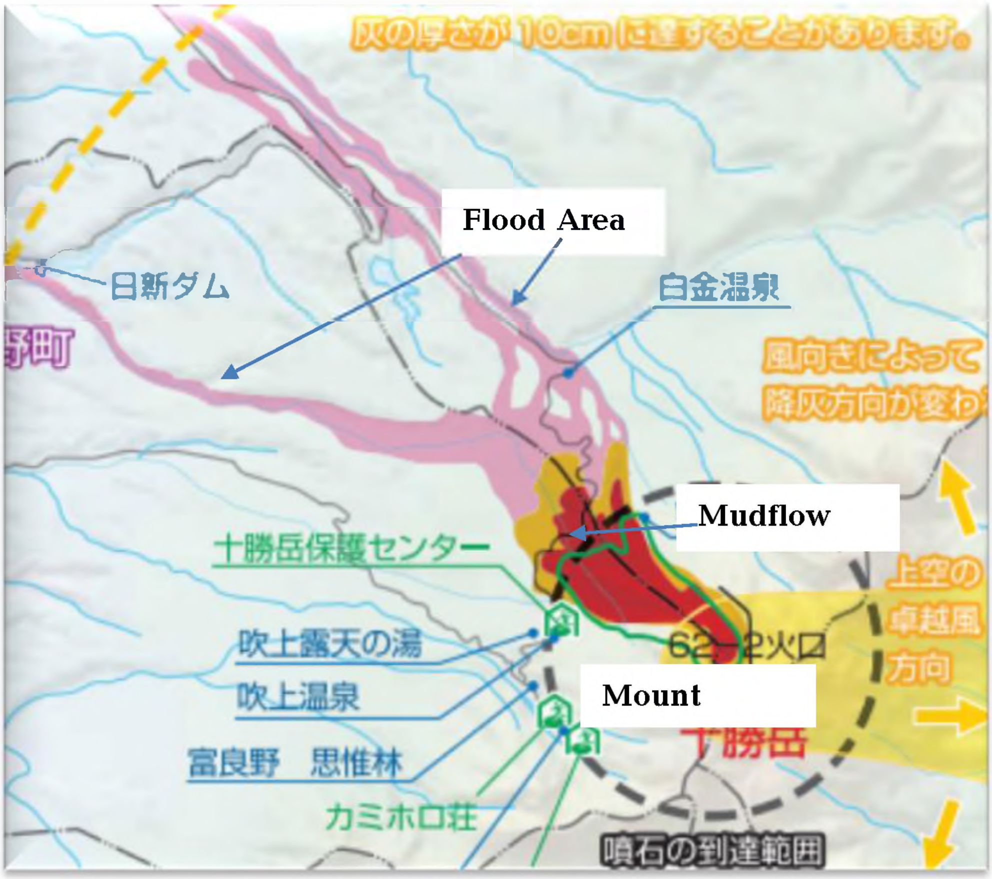

Fig. 1. Actual situation of Taisho mudflow

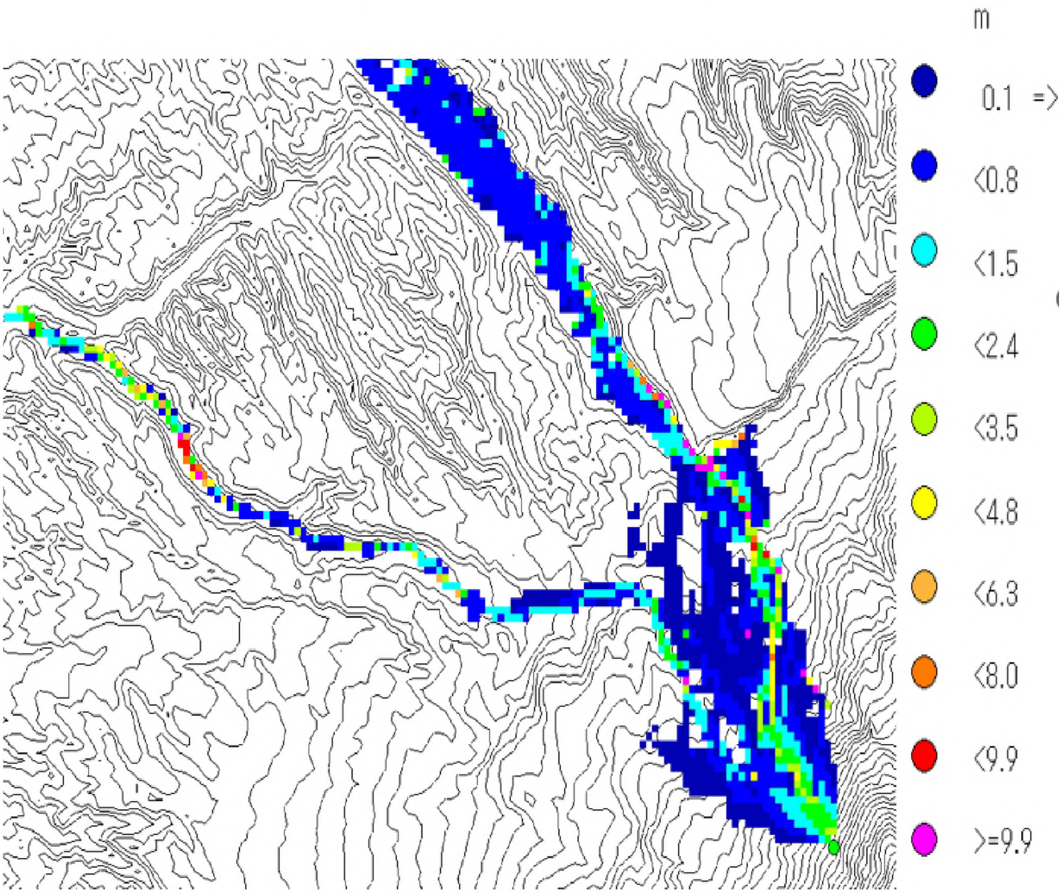

Fig. 2. The results of simulation of Taisho Mudflow by the use of FRAT software

Filtering using Double Fourier

As we know, topography data is necessary to implement simulation of floods. However, some noises due to high buildings, trees, dams, etc. are present in the satellite DEM data. These noises add elevated points on the river section, which blocks the flow of water during the simulation. In the original version of the software there was only the possibility to change the scale of the grids. However, in the modified version we added double Fourier filter to eliminate the noise.

Water reservoir

The target water reservoir is Geghi reservoir. This water reservoir was built during the Soviet Union era. Armenian experts point to the possibility of collapse due to problems related to the fact that it was built long ago (old age) and was constructed under old design standards (level of seismic evaluation). Comparison of some of the parameter of the discussed reservoirs is given in the table below.

Comparison of several water reservoirs

Water reservoir name	*Location*	*Dam height (m)*	*Maximum capacity (m^3)*
Geghi reservoir	Armenia	70	12,000,000
Sardoba reservoir	Uzbekistan	29	922,000,000
Kurobe reservoir	Japan	186	199,285,000

Speed of the flood

Some limitation is necessary to perform simulations. Otherwise, the accuracy of the results of the simulation will be low. In the case of Geghi reservoir, we limited the flood speed.

There is a statistical relationship between slope gradient and velocity of flow, as shown in Fig. 3. Based on this relationship, we can conclude that the velocity of flow in the case of Geghi reservoir (with 1/40 gradient) will be around 7.6km/h. That means that the flood will reach Kapan city in about 2 hours.

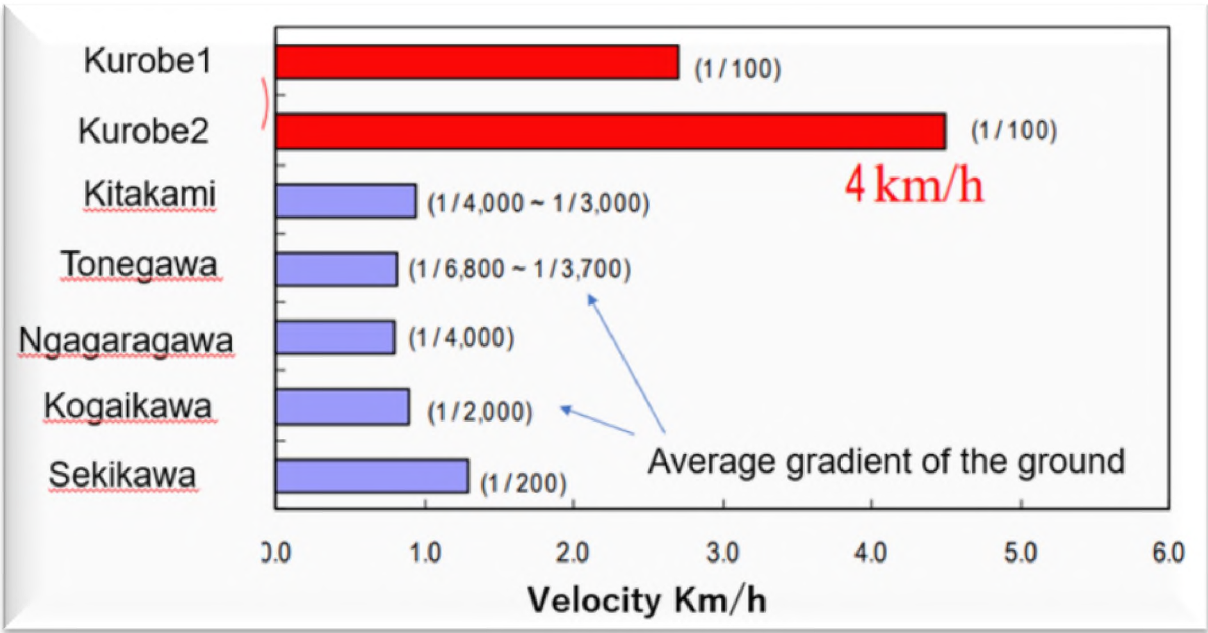

Fig. 3. Relationship of slope gradient and flow speed

Hydrographs show the change of water flow over time. Its vertical axis is the water flow rate and the horizontal axis is the time. The water flow is one of the most important parameters to analyze the floods. Actually, hydrographs are composed by the use of the data of past floods. However, no major floods have been observed in Armenia due to heavy rains. Therefore, it is necessary to carry out hydraulic measurements in Armenia.

In such a situation, where there is not enough data, we need to somehow estimate the hydraulic performance. Thus, we have assumed that 10 times the amount of reserved water will be discharged during the first 30 minutes. The reason why we estimated 10 times the amount of water is that in case of such simulations it is necessary to consider the worst-case scenario. Thus, we assumed that the level of water exceeded the maximum capacity of the reservoir and additional upstream water continues to flow into the reservoir. The corresponding hydrograph is shown in Fig. 4.

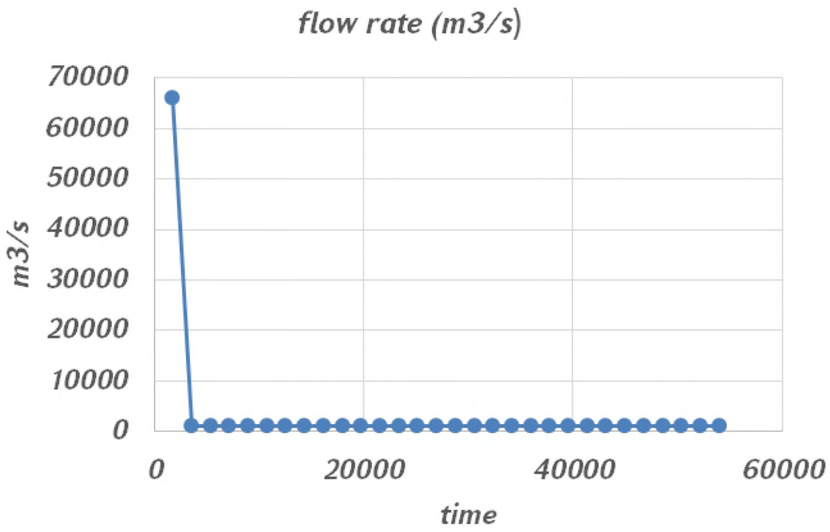

Fig. 4. Example of hydrograph (66000m^3/sec x 1800 sec = 11,800,000 m^3)

Results of the simulation

Fig. 5 and Fig. 6 below show the flood situation 1 and 2 hours after the dam collapse, respectively. The color of each cell in the Figure reflects the depth of inundation. Our assessment shows that the flood will reach Hamletavan village within an hour and Kapan city within two.

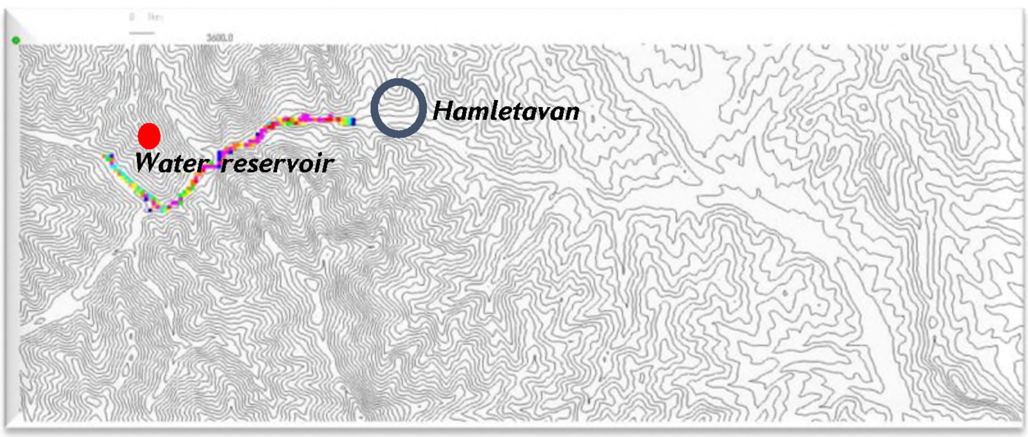

Fig. 5. Analysis of the flood for the first one hour

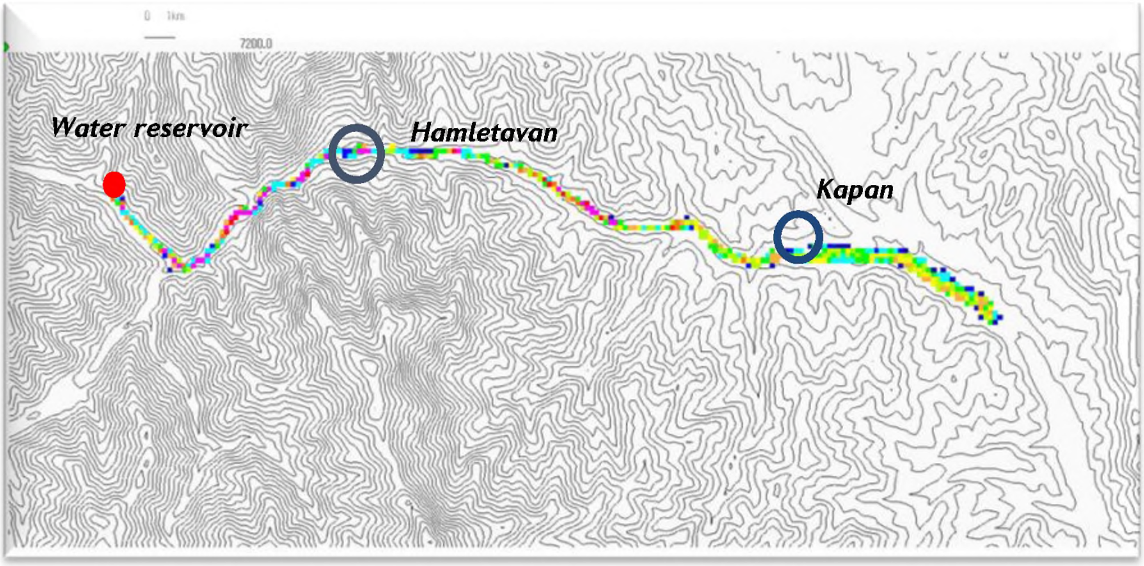

Fig. 6. Analysis of the flood for the first two hours

Discussion

Fig. 7. shows the estimated inundation data. Yellow to orange parts show that the deepest point is around 5m-6m. In case of Kapan city, there will be no much accumulation of water and it will flow downstream. The inundation depth will not be significant. However, two hours is very short to properly evacuate residents. Therefore, the decision to evacuate should be made by the resident themselves based on the data from the early warning system.

Regarding the critical water level, according to the questionnaire completed by the evacuees of Isewan typhoon [4], the evacuation becomes difficult if the water level exceeds 0.7m in case of males and 0.5m in case of females. Thus, it is assumed that floods can cause damages to buildings and people if the water level exceeds 0.5m. In this regard, appropriate officials should think ahead of time about how they will assist residents to evacuate effectively.

Fig. 7. Inundation data depicted on google map (Kapan city)

Conclusion

In this paper, we developed software for a simple assessment of hazards caused by break of dams of water reservoirs in Armenia by modifying the FRAT software developed under the UN-Habitat project. Topographical data available in Armenia were used for the assessment.

There are concerns all over the world about the existence of reservoirs with high probability of collapse due to lack of maintenance, including in Armenia there are many dilapidated dams that have not undergone proper maintenance and the possibility of their collapse is pointed out.

There have been no major floods caused by heavy rains or dam failures in Armenia recently. Hence, there is not enough hydraulic information on floods. Therefore, it is too early to talk about developing evacuation plans based on actual hydraulic data. However, even in the absence of hydraulic data, it is necessary to be prepare for dam failure.

To solve the above issue, in this paper we suggest the use of the modified FRAT software for the development of disaster management plans considering possible dam failures.

In the future, when sufficient hydraulic data is available, more accurate assessments can be made. It is strongly recommended that early warning systems be installed downstream of dams with a medium to high probability of failure.

We will be happy if our efforts are helpful in saving human lives and property in the event of disasters.

Acknowledgement

The project was carried out in cooperation with the Ministry of Emergency Situations of Armenia and UNDP. The authors would like to thank the experts of those organizations for fruitful workshops and discussions, which contributed to the development of more user-friendly software. In addition, the authors express their gratitude to the Embassy of Japan in Armenia and JICA for financial support for the implementation of the climate change project in Armenia.

Reference

1. **Duminda Perera,** Vladimir Smakhtin, Spencer Williams, Taylor North, Allen Curry, *"Ageing Water* Storage Infrastructure: An Emerging Global Risk", UNU-INWEH Report Series, Issue 11, 2021.
2. **UN-habitat,** Development of Simplified Risk Mapping Tools to Facilitate and Optimize Emergency Response to Major Floods (FRAT), 2008.
3. **Kamifurano-cho,** Tokachidake volcano disaster prevention map - melting snow lahar impact area map (1/25,000), 2016.
4. https://www.river.go.jp/kawabou/glossary/kwb_apend/html/reference.html.

Ջ. Մացուո, Գ.Ս. Գևորգյան, Ք. Շիվակու, Ա.Ս. Չիլինգարյան

ՀԱՅԱՍՏԱՆԻ ՀԱՄԱՐ ՀԵՂԵՂՈՒՄՆԵՐԻ ՎՏԱՆԳԻ ԳՆԱՀԱՏՄԱՆ ԾՐԱԳՐԻ ՄՇԱԿՈՒՄ

Մինչև 2050 թվականը աշխարհի բնակչության զգալի մասը կբնակվի 20-րդ դարում կառուցված հազարավոր մեծ ջրամբարներից ներքև: Ինչպես ցույց է տալիս ՄԱԿ-ի համալսարանի կողմից իրականացված վերլուծությունը, այս ջրամբարներից շատերը ներկայումս գործում են իրենց նախատեսված շահագործման ժամկետից դուրս: Որպես օրինակ կարելի է նշել Ուզբեկստանի Սարդոբա ջրամբարը, որի պատվարի փլուզումը տեղի է ունեցել 2020թ. մայիսի 1-ին ժամը 05:55-ին: Թեև զոհեր չեն գրանցվել, սակայն 56 մարդ վիրավորվել և հոսպիտալացվել է, իսկ շրջակա 22 գյուղի ավելի քան 70 հազար բնակիչ տարհանվել է հարևան շրջաններ: Արտահոսքը հասել է նույնիսկ Ղազախստան, որտեղ նույնպես տարհանվել է մոտ 30 հազար մարդ: Ջրամբարից արտահոսքը դադարեցվել է մայիսի 8-ին, և ջուրը բաց է թողնվել Արնասաի լիճ: Հաշվի առնելով Հայաստանում նմանատիպ բազմաթիվ հնացած ջրամբարների առկայությունը, Հայաստանի կառավարությունը, ՄԱԿ-ի Զարգացման Ծրագրի հետ համագործակցությամբ, ակտիվորեն դիտարկում է նման ջրամբարների վտանգի մեղմացման միջոցառումներ:

Հեղեղումների մոդելավորում իրականացնելու համար հեղինակները մշակել են մասնագիտացված ուսուցողական ծրագիր, որն ավելի վաղ ՄԱԿ-ի Հաբիթաթ ծրագրի շրջանակներում մշակված ծրագրի փոփոխված տարբերակն է: Բացի այդ, առաջարկվում է ստեղծել ջրամբարների տվյալների բազա: Հաշվի առնելով ջրամբարների անվտանգությունը՝ անհրաժեշտ է համապարփակ կառավարում, ներառյալ սպասարկումը, սակայն սույն աշխատանքը հիմնականում կենտրոնանում է վտանգի պարզեցված քարտեզների մշակման վրա:

Առանցքային բառեր. *սելավ, հեղեղում, հեղեղումների պարզեցված մոդելավորում, հեղեղումների վտանգի քարտեզ:*

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РАЗРАБОТКА ПРОГРАММНОГО ОБЕСПЕЧЕНИЯ ДЛЯ ОЦЕНКИ ОПАСНОСТИ НАВОДНЕНИЙ В АРМЕНИИ

К 2050 году значительная часть населения планеты будет проживать ниже по течению от тысяч крупных плотин, построенных в XX веке. Многие из этих плотин, как показал анализ, проведенный Университетом ООН, в настоящее время работают на пределе или за пределами запланированного срока службы. В качестве примера можно привести Сардобское водохранилище в Узбекистане, прорыв которого произошел в 05:55 1 мая 2020 года. Хотя погибших не было, но 56 человек получили ранения и были госпитализированы, а более 70 тыс. человек были эвакуированы из около 22 поселков в соседние районы. Поток дошел даже до Казахстана, где также было эвакуировано около 30 тыс. человек. 8 мая отток воды из водохранилища был прекращен, и вода была сброшена в озеро Арнасай. Учитывая наличие в Армении множества аналогичных устаревших водохранилищ, правительство Армении в сотрудничестве с Программой Развития ООН активно рассматривает возможность принятия мер по снижению воздействия подобных водохранилищ.

Для проведения моделирования наводнений авторами было разработано специализированное учебное программное обеспечение, представляющее собой модифицированную версию программы для моделирования наводнений, разработанной ранее в рамках проекта ООН-Хабитат. Кроме того, предлагается создать базу данных, составленную на основе данных о водохранилищах. Для обеспечения безопасности водохранилищ необходимо комплексное управление, включая техническое обслуживание, однако в данной работе основное внимание уделяется разработке упрощенных карт опасности.

Ключевые слова: *наводнение, сель, упрощенное моделирование наводнения, карта опасности наводнения.*

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