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INTELLIGENT DAM BREACH THREAT MONITORING SYSTEM

Abstract: The article is devoted to the development of a river flow modeling technique. The paper considers possible approaches to modeling the flow of fluids, as well as an analysis of existing solution methods and the formulation of research problems. The task is analyzed and the main problems that may arise in the course of its solution are identified. A general description of the problem and the formulation of research objectives are given. The advantages and disadvantages of the described methods are highlighted. A comparative analysis of known methods for complex analysis, forecasting the consequences of natural and man-made emergencies using modern technologies of mathematical modeling and a computational experiment with displaying the results in a geographic information system and a study of a mathematical model of a dam breakthrough was carried out. A description of the flood and flood monitoring technology developed in Kazakhstan is given, the results of its practical use in certain regions are discussed, and directions for further development are outlined. Thus, based on the analysis of various existing methods, the goal and main objectives of research aimed at developing a methodology for predicting a hydrodynamic accident as an emergency were formulated. The continuous wave method or ultrasonic pulse echo method is used. Based on microprocessor technology and sensors, an autonomous microcomputer system for transmitting climate data has been developed. A program for monitoring the factors of breakthrough waves in real time has been developed. An autonomous microcomputer system

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for transmitting climate data has been developed. The autonomous power supply subsystem for satellite data transmission systems includes a set of equipment, the functions of which are to generate and store energy for its subsequent use in order to provide power supply to the equipment. Water level measurement equipment can be different. To ensure the functioning of the system, the measuring equipment will be interfaced with the data transmission subsystem and the power supply subsystem. The pairing of these systems will make it possible to monitor the water level in moraine lakes, the location of which is extremely inaccessible. Technical means measuring the water level must be able to receive data from sensors with different periodicity. The accumulated data is used to predict possible floods and floods, calculate water consumption, and for other purposes. The characteristics of dams and the capabilities of modern control systems based on the use of microprocessor technology are analyzed.

Keywords: flood, flood and breakthrough waves, water level, dam, computer simulation.

Introduction: Currently, there are many examples of emergency situations (ES) associated with flooding caused by the spread of flood and breakthrough waves. At present, in our country, the task is to protect agricultural lands and settlements from flooding. Flooding of agricultural lands occurs both when large-scale floods pass, and natural, man-made factors.

The flood problem is getting worse. The situation when settlements in different regions of the country literally go under water has already become the norm. At the same time, budget funds are still used to eliminate the consequences of floods, instead of preventing them. Flood – a phase of the water regime, which is characterized by an intense, usually short-term increase in water flow and levels and is caused by rain or snowmelt during thaws. The spring flood is a seasonal phenomenon, and, in fact, this phenomenon cannot be avoided to one degree or another in recent times.

Research methods: Attempts to resolve the conflict between the need to use floodplain and coastal lands and losses from possible floods have been made repeatedly by many specialists. But so far this conflict has not been resolved. To solve the problem of the possibility of using coastal lands, it is necessary to analyze the possible damage during floods.

Main part: In the event of a flood or breakthrough wave, the quality of the land deteriorates significantly. Even a short-term rise in water in a river during a flood can cause flooding of coastal lands, which will invariably entail significant losses associated with both possible loss of crops and deterioration in land quality Even a short-term rise in water in a river during a flood can cause flooding of coastal lands, which will invariably entail significant losses associated with both the possible loss of crops and the deterioration of land quality.

As measures to prevent damage caused by a possible flood, it is necessary to carry out such engineering and technical measures as:

– monitoring and regulation of river flood flow using various engineering structures: dams, dams, strengthening of river banks, straightening of channels, etc.;

– design and rational placement of infrastructure elements and residential buildings in accordance with potentially dangerous zones of possible flooding; in areas with frequent floods, it is possible to build houses on piles, or transfer the first floors of buildings to a non-residential fund;

– ensuring the stability of work, taking into account the possible occurrence of emergencies, important infrastructure elements: bridges, communication lines, etc.

Discussion: The paper proposes the following system for monitoring the threat of a breakthrough of hydroelectric facilities, consisting of three blocks: 1) block for receiving and transmitting current information about the water level, humidity and temperature on the crest of the dam; 2) block for processing permanent and operational information about the threat of a dam break (server); 3) block for predicting the consequences of a dam break.

The main information for monitoring the risk of a dam break is the data coming from the water level sensor. Additional information is provided by data from temperature and precipitation sensors.

The unit for receiving and transmitting current information is implemented in the form of sensors about the water level, humidity and temperature and is located on the crest of the dam. The sensors are connected to the Arduino microprocessor [1-4], which provides preliminary processing of the data coming from the sensors and transfers them for further processing.

To create an autonomous microprocessor system for transmitting climate data, we used a single-board microcomputer RaspberryPi 3 B+ [2, 5].

Arduino is a device based on the ATmega 328 microcontroller [6-8]. It includes everything that is needed for convenient work with the microcontroller. To start working with the device, simply supply power from an AC / DC adapter or battery or connect it to a computer using a Universal Serial Bus (USB) cable.

The RaspberryPi is a single board computer the size of a bank card, meaning the various parts of the computer that would normally reside on separate boards are shown here on one. The Raspberry Pi runs primarily on Linux and Windows operating systems.

An ultrasonic sensor is a sensor that uses sound waves to measure or determine the distance to an object, in this case, sea water. Ultrasonic sensors can also be called SONAR (Sound Navigation and Ranging) sensors, an ultrasonic sensor works by sending out sound waves at a specific frequency (40 kHz). Note that sound waves travel in air at about 344 meters per second or 1129 feet per second, then to calculate the total distance of sound waves emitted by the ultrasonic transducer to and from the object field, i.e. sea water, received by the ultrasonic transducer. The delivery distance is multiplied by 2, so to measure the distance from the ultrasonic sensor, the reading of the object plane for 1 trip is the distance = speed of sound x the time taken is divided by 2 or S = 344 xt / 2, the distance explanation can be seen in figure 2. The ultrasonic sensor used uses the HC-SR04 (Ultrasonic sensor) type, which has the following characteristics, the detection range is 2cm – 500cm, the best detection angle is 15 degrees, the voltage is DC 5V, the frequency is 40KHz, it has 4 feet per pin, namely Vcc, Signal (Trigger & Echo), and ground. The size of the ultrasonic sensor HC-SR04 can be seen in Figure 1.

Figure 1. Ultrasonic sensor size

Water level measurements using ultrasonic sensors have been successfully tested, whereby a change in water level can be detected by ultrasonic sensors at a distance of about 500 m from the object, i.e. from the water surface. Based on figure 1 shows the size of ultrasonic or ping probe, for ultrasonic probe sizes use the following size, for probe length 1.8” (45.7mm), for

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width 0.84” (21.3mm) on Ping probe or the ultrasonic transducer has 2 versions of ultrasonic using 3ft data inlet and output and it is ultrasonic with 4ft in/out. Difference enabled for Pin signal split into 2 outputs i.e. trigger and echo. The trigger is used as a generator. Ultrasonic and echo signals are pins used for indicators. Ultrasonic type HC-SR04, the other 2 pins are pin ground and Voltage Collector Collector (VCC), ground is O Volt power supply, and VCC is 5 Volt voltage [9].

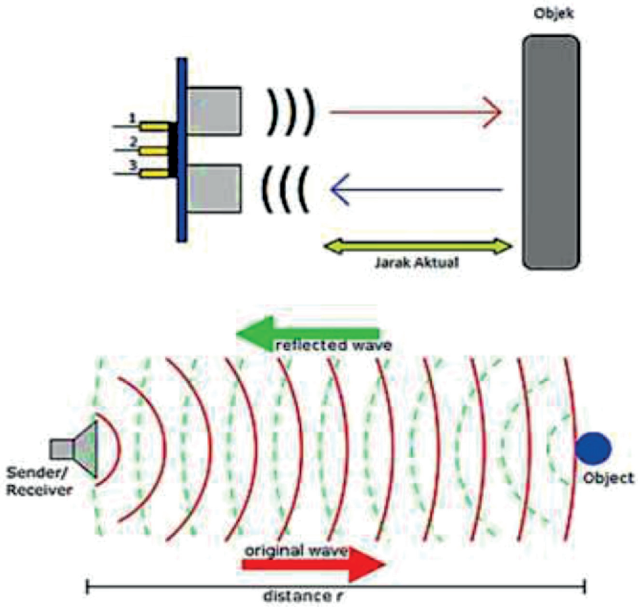

Figure 2. Actual ultrasonic sensor distance

The block for processing permanent and operational information about the threat of a dam break contains permanent information about the characteristics of the reservoir and the dam, and also promptly receives current information. Based on processing, during which the block calculates the level of safety, anxiety or catastrophicity of the hydroelectric complex. In the latter case, it automatically notifies state authorities (emergency situations, akimats, etc.) about a possible threat of a dam breakthrough.

The block for predicting the consequences of a dam breakthrough, based on the mathematical model developed in the dissertation, the characteristics of the reservoir (volume, height and width of the dam, etc.), calculates the possible height of the breakthrough wave at various distances from the dam base and, thereby, allows predicting the consequences of a hydrodynamic accident [10, 11].

One of the most effective areas of application of Earth remote sensing (ERS) data is monitoring of emergency situations (ES) [12]. Within the framework of the State Program, it was envisaged to develop a number of integrated Geographic Information System (GIS) technologies for monitoring emergency situations, providing the solution of the following tasks:

– flood monitoring and risk assessment of flooding in the regions of Kazakhstan;
– monitoring of forest and steppe fires and fire risk assessment;
– early warning and remote monitoring of natural disasters of a meteorological nature;
– monitoring of transboundary emergencies;
– remote control of the temperature regime of seismic activity sources.

Work on the creation of technologies for space monitoring of floods and inundations has been carried out in Kazakhstan since 2002 [13-15]. As part of the complex, several technological blocks have been implemented, allowing:

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– quickly detect areas of flooding;
– map and determine the areas of flood zones with a cumulative total;
– forecast the development of floods and assess their potential hazard to settlements and especially important facilities;
– asses and analyze flood risks for different regions.

To solve the problem of obtaining flood zones as a result of a flood, the following methods of obtaining results are possible:

1. Physical Models;
2. Carrying out analytical calculations;
3. Numerical simulation.

To date, it has been shown that it is possible to determine the propagation parameters of flood and breakthrough waves only with the use of numerical computer simulation. Fluid flows are divided into two very different types from each other: laminar (smoothly changing, regular) and turbulent (disordered). In cases of propagation of flood and breakthrough waves, the fluid flow will be turbulent [16].

All existing software systems can be divided into one-dimensional, two-dimensional and three-dimensional. Numerical modeling in one-dimensional and two-dimensional cases greatly simplifies the model under study and does not give a complete picture of the processes occurring during the propagation of a breakthrough wave or a flood wave, which will be shown below. Thus, the most accurate will be the use of three-dimensional numerical modeling for the calculation of flood and breakthrough waves.

In most cases, the basic system for hydrodynamic modeling is the three-dimensional system of evolutionary Navier-Stokes equations.

Let's analyze the necessary initial data for various modeling methods.

The system of Saint-Venant differential equations for unsteady fluid motion, under the condition of flow in a channel with a sufficiently large bottom slope, can be reduced to the form:

$$\frac{\partial h}{\partial t} + \frac{1}{b}\frac{\partial Q}{\partial x} = 0, \tag{1}$$

$$\frac{\partial Q}{\partial t} + \left(\frac{Q}{bK}\frac{dK}{dh}\right)\frac{\partial Q}{\partial x} - \frac{K^2}{2bQ}\frac{\partial^2 Q}{\partial x^2} = 0, \tag{2}$$

where: t – time, $0 \le t \le T = const$, c; x – spatial coordinate in the direction of travel, where $0 \le x \le l$, m; J – bottom slope, m/m; b – channel width σ, m; h(x,t) – channel depth, m; K(h) – flow characteristic of the channel ($K(h) = \frac{bh^{\frac{5}{3}}}{n}$ where n –roughness factor); v(x,t) – average flow velocity in the channel section, m/s; Q(x,t) – flow rate in the selected section, $\frac{\mathrm{m}^3}{\mathrm{s}}$

To calculate according to these equations, which describe the unsteady uneven movement of water masses, it is necessary to set the initial and boundary conditions on the river section. The initial conditions require you to set the state of the flow, its speed or flow rate at all points of the channel at the moment of time t=0. Boundary conditions determine the water level, its speed or discharge in the upper and lower sections of the river section at any time.

The initial conditions will look like:

$$Q(x,0) = \sigma_0(x),\ b(x,0) = \gamma_0(x), \tag{3}$$

Border conditions:

$$Q(0,t) = \sigma_1(t),\ h(0,t) = \gamma_1(t), \tag{4}$$

$$Q(l,t) = \sigma_2(t),\ h(l,t) = \gamma_2(t), \tag{5}$$

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The problem can be solved by dividing the interval [0, T] into segments and calculating all the characteristics of the flow on them, since for real river channels under conditions of uneven movement, the cross-sectional area varies depending on x, and since the movement is unsteady, then the area depends on and from time. Thus, it is necessary to divide the section into segments with unchanged hydraulic characteristics, then solve the systems of Saint-Venant equations for the segments, where for the first section the input hydrograph is taken from the initial data, then the runoff parameters in this section and the output hydrograph are calculated, which serves as the output hydrograph for second section, and so on.

Due to the fact that the parameters of the model (1)-(5) cannot be set with absolute accuracy, the article uses the author's interval analysis [17]. For the numerical study of the model (1)-(5), a program was developed based on the library of interval functions [18]. Experimental studies on numerical data showed good convergence of the program.

The task of river flow modeling is an important problem. Currently, there is no single solution for river runoff forecasting. The constant desire to simplify methods leads to a loss of quality in research results. But for more complex models, it is required to specify numerous observational data, which are often not available, so one has to resort to simplifying the models. One-dimensional river runoff models can only be used for preliminary calculations. For a more accurate study, higher-level models should be used [19].

Conclusion

The paper shows that it is possible to determine the propagation parameters of flood and breakthrough waves only with the use of numerical computer simulation. All the considered methods do not allow to quickly obtain initial data to justify flood control measures and require significant material and time resources. Thus, it is obvious that there is a need to create a simplified technology for engineering justifications of flood control measures, comparable in terms of the reliability of obtaining results with existing ones, but at the same time having an advantage in the speed of modeling and ease of implementation. The technology should, with a minimum set of initial data, allow modeling the propagation of a flood wave or a breakthrough wave, as a result of which to obtain a two-dimensional map of the study area with flood zones ranked by depth, as well as other parameters characterizing the propagation of waves.

The novelty of the article is the application of its own interval mathematics to the study of the model (1)-(5). This approach made it possible to take into account inaccurately specified model parameters.

The paper solves the problem of developing a unified integrated approach to ensure the safe operation of hydraulic structures, based on monitoring and alerting stakeholders in real time. An autonomous microcomputer system for transmitting climate data has been developed, the nomnistem provides a general description and formulation of the problem of predicting the factors of breakthrough waves in real time [20].

In the future, it is planned to develop an experimental sample and conduct trial operation on several reservoirs in the Almaty and Zhetysu regions of the Republic of Kazakhstan. Based on the results of the tests, the possibilities of commercializing the project as a whole will be considered [21].

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