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AUTOMATED WATER LEVEL MONITORING SYSTEM IN WATER BODIES

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Abstract. The article is devoted to the creation of an automated system for monitoring the water level in reservoirs to prevent the breakthrough of weirs and dams. The paper offers hardware and software for monitoring the reservoir occupancy with prompt notification of interested organizations (local administrations) and local emergency departments.

The article describes a developed automated system for monitoring the water level in a reservoir, which allows to get real-time information about the relative humidity and air temperature, the distance from the dam crest to the water surface in the reservoir. Based on the information received, the system allows to estimate the forecast time of increasing the volume of water level from the current to the critical level and inform the population about the state of the reservoir.

The general characteristic of the problem and the formulation of the research objectives are given. Based on microprocessor technology and sensor sensors, an autonomous microcomputer climate data transmission system has been developed.

Keywords: flood, dam, water level monitoring, microprocessor system, water level sensor, Raspberry microcomputer, Arduino UNO platform.

Introduction

It is necessary to analyze large volumes of heterogeneous information, inconsistency of goals of various state bodies to assess the environmental safety of the region. The solution of such tasks is impossible without the use of modern information systems for decision support.

Currently, there are 1665 hydraulic structures on the territory of the Republic, including reservoirs with volume greater than 1.0 m^3 – 319 units (including in the Republican ownership – 83, in municipal ownership – 200 in private ownership – 34 and ownerless – 60); dams – 443 units (including in the Republican ownership – 32, in municipal ownership – 346, private ownership – 45 and ownerless – 20); dams – 125 units and other hydraulic structures – 778 units.

As of May 1, 2017, a total of 1212 hydraulic structures were examined, 865 hydraulic structures of them are in satisfactory condition, and 347 hydraulic structures are in unsatisfactory condition and require repair.

The necessity of legal regulation of the safety issues of hydraulic structures is determined by the large-scaled social and economic consequences of their damage and destruction. At the same time, human losses and material damage are comparable to the consequences of devastating natural disasters.

In Kazakhstan the construction of many hydraulic structures was carried out in the 60-80s of the last century [1]. Their survey today shows that the actual depreciation is more than 60%, the reliability and safety of strategically important hydraulic structures are sharply reduced.

In accordance with the Water code, Presidential decree of the Republic of Kazakhstan dated November 1, 2004, no. 1466, a list of water facilities (hereinafter referred to as the List) of particular strategic importance was defined, which includes 57 reservoirs and 29 retaining hydraulic structures. In accordance with Article 25 of the Water Code, these water facilities cannot be leased, trust and cannot be privatized.

The long service life and reduction in the last 20 years of funding for operating expenses, current and capital repairs, as well as the influence of climatic and seismic factors gradually lead to moral and physical deterioration of the entire complex of hydraulic structures. There are also objects located close to hazardous industries.

A dam is a blocking river (or other watercourse) for raising the water level in front of it, concentrating the pressure at the location of the structure and creating a reservoir. The dam and reservoir significantly affect the river and adjacent territories: the regime of river flow, water temperature, and the duration of freezing change; migration of fish is difficult; the banks of the river in the upstream are flooded; the microclimate of coastal territories is changing.

The damage caused by natural disasters is, in particular, slightly worn, while the loss of life is slightly higher. To select a set of measures to minimize the damage, it is advisable to carry out a forecast of the main characteristics of floods affecting the magnitude of the damage. Their size influences the severity of the consequences of floods for population, economy, agriculture, etc.

At the present time, it is possible to have many times of flooding, flooding and erosion of the land caused by such an extraordinary accident, like breaking the plate.

Emergencies that arise as a result of the destruction of pressure front facilities and are characterized by a major damaging factor: a breakthrough wave and, accordingly, a catastrophic flooding of the area are often accompanied by secondary damaging factors:

- fires: due to breaks and short circuits of electric cables and wires;
- landslides, landslides: due to erosion of the soil;
- infectious diseases: due to contamination of drinking water, food, etc.

The causes of accidents, accompanied by a breakthrough of hydraulic structures of the pressure front and the formation of a breakthrough wave, can be different. Most often, such accidents occur due to the destruction of the foundation of the structure and the lack of spillways. The percentage ratio of their various causes is shown in table 1.

Table 1 – Frequency of various causes of accidents in hydraulic structures, accompanied by the formation of a breakthrough wave.

Reason for destruction	**Frequency %**
Destruction of the foundation	40
Spillway Insufficiency	23
Design flaws	12
Uneven draft	10
High threshold (capillary) pressure in the washed dam	5
Military actions	3
Creep slopes	2
Material defects	2
Earthquakes	1
Improper operation	2
TOTAL:	100

One of the main reasons leading to accidents at hydrotherapy consoles is as natural, and so are the factors:

– if you are in extreme use, it may be possible to overfill the water and to avoid regular waste of work, which will result in a loss of water;

– due to the long service life, it is possible to wear out the main weir and hydraulic equipment, which may result in loss of life;

– due to a malfunction of the personnel associated with the lack of monitoring of dangerous situations and the inadequacy of the information provided on the product;

– consequence of the possible terrorist act leading to the destruction of the dam.

Today, such large reservoirs are operated as the Astana reservoir built in 1970 with a capacity of 410.9 million cubic meters, the Seletinsky reservoir – 1965 (230 million cubic meters), the

Kargalinsky reservoir – 1975 (280 million cubic meters), the Bartogaysky reservoir – 1982 (320 million cubic meters), the Kapshagai reservoir – 1970 (18560 million cubic meters), the Ters–Ashibulak reservoir – 1963 (158,6 million cubic meters), the Tasotkelsky reservoir – 1974 (620 million cubic meters), the Samarkandsky – 1939 (253,7 million cubic meters), the Upper Tobol – 1972 (816,6 million cubic meters), the Karatomarskoy – 1965 (586 Bugunskoybuilt in 1967 (370 million cubic meters) and others.

Monitoring systems should ensure constant monitoring of phenomena and processes occurring in nature and the technosphere, in order to anticipate increasing threats to humans and their environment. The main purpose of monitoring is to provide data for an accurate and reliable forecast of emergencies based on the combination of intellectual, informational and technological capabilities of various departments and organizations involved in monitoring certain types of hazards. Monitoring information serves as the basis for forecasting.

Microprocessor technology has now actively entered our lives. Versatility, flexibility, simplicity of hardware design, almost unlimited possibilities for complicating information processing algorithms – all this promises a great future for microprocessor technology. Microprocessors are used both in household appliances for the simplest signal processing and command generation, as well as in the most complex measuring systems for digital signal processing.

Modern opportunities for the development of various sensors [2, 3] and the cheapening of microprocessors have also opened up a wide opportunity to implement hardware-software tools for monitoring climate parameters.

In particular, the relatively cheap Arduino controller, which has a large database of developed sensors and their means of communication with a computer, has found wide application in applied problems [4, 5].

In this regard, the research in this work on the development and research of a mathematical model of a dam breakthrough and information security tools is relevant.

Implementation

The following system is proposed for monitoring the threat of a breakthrough of hydroelectric facilities, consisting of two blocks:

1) block for receiving and transmitting current information about water level, humidity and temperature on the dam crest;

2) block for processing constant and operational information about the threat of a dam break (server).

There are two options for connecting blocks.

In the first case, the Arduino microprocessor is directly connected to the server. This option requires a permanent power supply system and the presence of processing personnel at the waterworks.

In the second case, the Arduino microprocessor is connected to the Raspberry Pi microcomputer, which transmits current information to the server via satellite communication. This option does not require the constant presence of processing personnel at the waterworks. And due to its small size and low power consumption, it can be provided with small-sized solar energy.

Block for receiving and transmitting current information

The block for receiving and transmitting current information is implemented in the form of the water level sensors, humidity and temperature and is located on the crest of the dam. The sensors are connected to an Arduino microprocessor, which provides pre-processing of data received from the sensors and transmits them for further processing.

To create an autonomous microprocessor system of transmitting climate data, we used a single-board Raspberry Pi 3 B+ microcomputer [6, 7]. Power is provided by a solar panel.

The system includes a set of necessary sensors and software. онThe measurement modules are connected to the computer via a USB adapter.онThe software presents the results of measurements in tabular and graphical form, and also allows to view and print the archive of measurements accumulated in the database for any period of time. онIt is possible to view data from sensors both on other computers of the local network and via the Internet.

The Arduino is a device based on the ATmega microcontroller 328 [8-10]. It includes everything necessary 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 USB cable.

The Raspberry Pi is a single-board computer with the size of a bank card, that is, the various parts of the computer that are usually located on separate boards are presented here on one. Raspberry Pi runs mainly on Linux and Windows operating systems.

The PC-oriented experiment is configured using ISES relay modules (1) for the control pump and sensors (2) for measuring the water level (Figure 1). Modules work using the ISES panel (3) and the server. Based on the above blocks, an autonomous microprocessor data transmission system is implemented (Figure 2).

Figure 1 – Location of the control remote experiment controlling the water level Relays (1), Sensors (2) and ISES Panel (3)

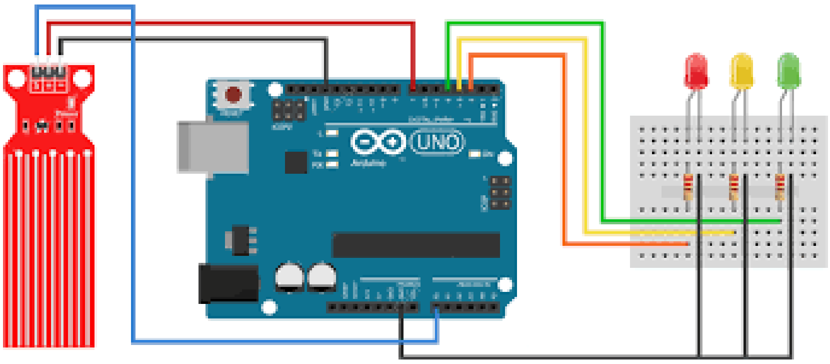

Figure 2 – Water level sensor and its interaction with Arduino

The processing block of constant and operational information

The 2nd block contains constant information about the characteristics of the reservoir and dam, and also quickly receives current information. Based on the processing by which it calculates the level of safety, anxiety or disaster of the hydraulic unit. In the latter case, it automatically informs state authorities (emergencies, akimats, etc.) about the possible threat of a dam break.

Due to the specifics of the studied hydrological processes [11-13], fuzzy and interval mathematics are used in the work [14-16].

To assess the threat of a breakthrough, the mathematical model is proposed with the following interval linguistic variables:

1) low level;
2) safe level,
3) alarming level, and
4) catastrophic level of reservoir occupancy [17-18].

The values of the entered linguistic variables are predefined in the following percentages of the dam height:

1) low level – 40%;
2) safe level – 30%,
3) alarming level – 20%;
4) catastrophic level – 10%.

For underground dams, the catastrophic level decreases by 3%. In the presence of precipitation for underground hydraulic structures, the catastrophic rate from the reference book "Name of dams or weirs” is reduced by another 2%, to take into account the possibility of dam weakening due to external precipitation.

On the night of March 10, the water level reached 30 million cubic meters. The next day, in the afternoon or in the evening, exact time unknown, the water level exceeded 40 million cubic meters. In other words, 15-16 million cubic meters of water was added to the Kyzylagash reservoir in 15-16 hours. The dam broke on March 11 at 10.30 p.m. Two hours later, the water gushed towards the village of Kyzylagash. The wave width of the mudflow was 1.6 kilometers, and the height was about 3-4 meters. According to official data, most of the village was severely damaged. 70% of the village of Kyzylagash was destroyed. The tragedy in Kyzylagash claimed the lives of 44 people.

Conclusion

This article analyzes the characteristics of dams, the capabilities of modern control systems based on the use of microprocessor technology.

The tragic occurrences of spring 2010 in the Almaty region and 2014 in the Karaganda region with human casualties and destruction, as well as floods in other regions of Kazakhstan, served as a serious lesson to prevent similar situations in the future. It is necessary to develop recommendations for equipping hydraulic structures with modern control and measuring devices, equipment and means to improve operational safety.

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