Algorithm for predicting of the transition of a key point of geodynamic control to the risk zone

N V Dorofeev, R V Romanov, A V Grecheneva and E S Pankina
Vladimir State University, Faculty of Radio-electronics and Computer Systems, 23 Orlovskaya str., Murom, Vladimir Region, 602264, Russia

E-mail dorofeevnv@yandex.ru

Abstract. The article discusses the algorithm for assessing changes in the level of risk of karst hazard of the territory based on the forecasting of the number of holes depending on the water level. Based on the results of the analysis, the values of bifurcation parameters are determined, the transition through which sharply increases the formation of new holes. The article provides the developed block diagram of the neural network for assessing the dynamics of the occurrence of holes, as well as an algorithm for generating a predictive estimate of the number of holes. An analysis of the occurrence of the number of holes is carried out on the basis of water level data in the Oka River. The results of spline interpolation of the data are presented in the dependence on the number of holes on the dynamics of the water level in the river for the current and previous year. Practical verification of the developed algorithm was carried out on the basis of the new set of data on the water level in the river and the number of holes. The developed algorithm can be used in predicting the spread (leaching from the soil) of pollutants.

1. Introduction
Groundwater regime depends on climatic and geological parameters [1, 2]. When analyzing the landscape at the stage of planning, construction and operation of national economic objects, an important task is the assessment of hydrogeological processes, including the assessment of the groundwater regime and the development of suffusion processes [3, 4].

One of the indicators of the development of karst-suffusion processes is the level of river runoff and water mineralization [5-7]. The results of the analysis of these data can improve the efficiency of geoeological monitoring systems and increase the accuracy of forecast estimates of the development of destructive karst-suffusion processes [8, 9].

The aim of the work is to increase the efficiency of systems of modeling and forecasting geodynamics by developing an algorithm for assessing changes in the risk of development of suffusion processes based on an analysis of the dynamics of the level of ground and surface waters.

2. The methods and approaches
Before describing the proposed approaches, we describe the data of the analysis. Figure 1 shows the graph of changes in water level in the Oka River and the number of new holes in the area of Dzerzhinsk town. The appearance of new holes correlates well with the dynamics of changes in the water level in the river (figure 2). Peaks of the sharp decrease of river water levels coincide with an increase in the number of holes in the next year (figure 3), while an increase of river water levels reduces the appearance...
of new holes in the next year. Figure 4 shows the result of interpolation using the thin-plate spline of the dependence of the number of new holes on the dynamics of the appearance of holes for the past year and the dynamics of changes in the water level in the river for the current year.

![Graphs of the water level in the Oka River and the number of new holes.](image1)

**Figure 1.** Graphs of the water level in the Oka River and the number of new holes.

![Graphs of changes of water level in the Oka River and the number of new holes.](image2)

**Figure 2.** Graphs of changes of water level in the Oka River and the number of new holes.

As can be seen from figure 4, before the holes occur, the sharp decrease in the water level in the river occurs. At the same time, a further decrease in the level in the river is a decrease in the number of new holes. In this case the bifurcation point is the transition of the dynamics of the water level in the river and the dynamics of the appearance of holes for the previous year through the zero mark. The graph shows that a large number of holes is possible with a sharp change in the dynamics of water from positive to negative, and the number of new holes is proportional to the rate of increase in water in the previous year and the rate of decrease in water in the current year.

Based on the analysis, the neural network was built to predict the occurrence of new holes based on the data of the water level in the river (figure 5). Neural network training was based on Bayesian Regularization. The whole sample was divided into 3 parts: 70% of the sample was allocated for training, 15% for correction, and 15% for testing.

The algorithm for estimating the number of holes is shown in figure 6.
Figure 3. Graphs of changes of the water level in the Oka River for the previous year and the number of new holes in the current year.

Figure 4. Interpolation Results.

Figure 5. The structure of the neural network assessment of the dynamics of failures.

D1 – The dynamics of changes in water level in the Oka River, meters / current year
D2 – The dynamics of changes in water level in the Oka River, meters / previous year
Np – The dynamics of changes in the number of failures for the previous year
Nc – The dynamics of changes in the number of failures for the current year
Figure 6. Algorithm for estimating the number of failures.

3. Results
The practical validation of the developed algorithm was carried out on the basis of changes in the level of the Oka River and the appearance of new holes from 2012 to 2019 (figure 7).

As can be seen from figure 7, the developed algorithm allows us to identify the dynamics of the formation of holes. The modeling accuracy in comparison with the available data is at least 83.7%.
4. Conclusion
It should be noted that, due to the small set of training sample, the accuracy of the developed algorithm can significantly differ from that indicated above when analyzing a new data set, as well as data from other territories. This drawback can be partially eliminated by retraining the neural network on an expanded data set, or by adapting the structure of the neural network to the individual characteristics of the territory by introducing additional parameters (geological, hydrological, climatic) into the processing. The developed algorithm can supplement the methodological base of systems for predicting the spread (leaching from the soil, accumulation, transfer) of pollutants and changes in the level of mineralization of ground and surface waters used in national economic activity.

Acknowledgment
This paper is an output of the science project executed with the support of the grant of the President of the Russian Federation No. MD-1800.2020.8.

References
[1] Bochever F, Garmonov V, Lebedev A and Shestakov V 1965 Fundamentals of hydrogeological calculations (Moscow: Nedra)
[2] Shestakov V, Nevechera I and Avilina I 2009 Methods of assessing groundwater resources in areas of coastal water intakes (Moscow: KDU) p 192
[3] Romanov R V, Kuzichkin O R, Dorofeev N V and Grecheneva A V 2020 The assessment of the influence of the hydrogeological regime of rivers on the conditions of the decentralized water supply in karst areas. IOP Conference Series: Earth and Environmental Science
[4] Kuzichkin O R, Romanov R V., Dorofeev N V and Grecheneva A V 2020 IIOAB Journal 11(1) 20-6
[5] Pecherkin A 1986 Geodynamics of sulphate karst (Irkutsk: University Press)
[6] Grecheneva A V, Kuzichkin O R, Romanov R V and Bykov A A 2017 Jour. of Eng. and Appl. Science 12(24) 6852-7
[7] Dublyansky V and Kiknadze T 1984 Hydrogeology of the Karst of the Alpine folded region of the USSR (Moscow: Science, Russia) p 128
[8] Tokarev S 2018 Mountain Crimea geography Questions 147 143–60
[9] Klimchuk A and Tokarev S 2014 Speleology and karstology 12 5–16