

The system of modeling of transboundary pollution transfer for the Kazakhstan part of the Ili river

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Abstract: *The paper presents the results of modeling of the transport of pollution in the Ili River basin (the Republic of Kazakhstan, Central Asia). The expediency of forecasting the discharge and spread of pollutants into water bodies is justified. Simulation modeling is considered as an essential methodological supplement for obtaining information on the dynamics of distributed parameters of water objects. The base of the mathematical model HSPF (Hydrological Simulation Program - FORTRAN) developed a geographic information system for modeling scenarios of pollution transfer. The calculations include the modeling of the hydrology of the river basin and the calculation of the concentration of non-point sources of pollution. The comparison with the data of natural hydrological observation post.*

Keywords: *geoinformation system, HSPF, modelling and simulation, BASINS, watershed, pollution transport in river, BOD, nitrate, dissolved oxygen*

1. Introduction

The Ili River is one of the largest transboundary rivers connecting the Republic of Kazakhstan and China, and is also one of the most important sources of fresh water for the Republic of Kazakhstan. The object of study is the Kazakhstan section of the Ili River from the border with the People's Republic of China to the delta including the Kapchagai Reservoir. The Ili River takes its origin on the Tien Shan mountain system in China (Xinjiang Uyghur Autonomous Region) and flows into the western part of Lake Balkhash. The length of the river is 1,439 km, of which 815 km (56.6%) in the Almaty region of Kazakhstan. The area of the basin in the territory of the Republic of Kazakhstan is 82488.53 square kilometres. The Ili River provides about 80% of the entire water flow of Lake Balkhash, 70% of which is formed in China. With transboundary rivers passing through the territory of China, not only organic matter enters the lake, but also selenium and heavy metal ions, the main sources of which are sewage waters of China's tannery. The developed system allows predicting the distribution of pollution along the Ili River based on modelling the hydro-chemical and hydrological parameters of the transboundary runoff of the river the nature of their transformation in the territory of the Republic of Kazakhstan under the influence of natural and anthropogenic factors.

2. Methodology and implementation

2.1. Basin model creation

At the moment, 4 hydrological posts of the RSE "Kazgidromet" function on the river's territory, which monitor the run-off of water. The problem of transboundary transport of pollutants in water belongs to a class of complex problems and they are solved, basically, by methods of mathematical modelling. To implement

calculations multifunctional system of environmental analysis BASINS 4.1 was used [1]. This system was developed by the Environment Protection Agency for the purposes of setting standards of the maximum total daily load (TMDLs) for water-bodies with impaired water quality and to allow local and state agencies to conduct analysis of watersheds. As similar researches were already executed before [2] the worked out algorithm of realization of calculations was applied. As a result, the resulting vector layers of the Ili river basin boundary, the river network with tributaries, and the Ili river sub-basins were obtained. Figure 1.



Fig. 1: Sub-basins and Ili river network.

The model HSPF [3] river represented as a graph, where each "top" is defined parameters River portion: length, height and delta cross-sectional data, are filled in FTABLE table figure 2. Each row includes values corresponding to a predetermined height of water surface. The system receives an intermediate value by interpolation. The number of rows in the table depends on the size of the cross-section and the resolution required. When the model was launched, the number of sections of the river was 48, where plot No. 48 was a wellhead. During the simulation, some shallow areas were incorporated with larger areas taking into account all hydrological features, which reduced the number of river sites to 26, but retained the identification values for each of the sites. Figure 2 (table HYDR-PARAM2).

As you can see from a picture 2 data of tables going to the text file of project namely - User control input (uci). In the managing file ways are prescribed to the file of meteorology, input and output files, a simulation period is set, and also hydrological and hydro-chemical parameters are indicated. Hydrological processes change in time and depend on the change of the state of environment, and for the estimation of contamination of the dispersed sources the sequences of sentinel fallouts, evaporation, temperature and other meteorological data are required. Table 1 present all meteorological parameters used for calculation [2].

TABLE 1: The Arrangement of Channels.

Dataset	Parameter specification
PREC	precipitation
CLOU	cloud cover
ATEM	temperature
WIND	windspeed
SOLR	solar radiation
PEVT	potential evapotranspiration
DEWP	dewpoint temperature

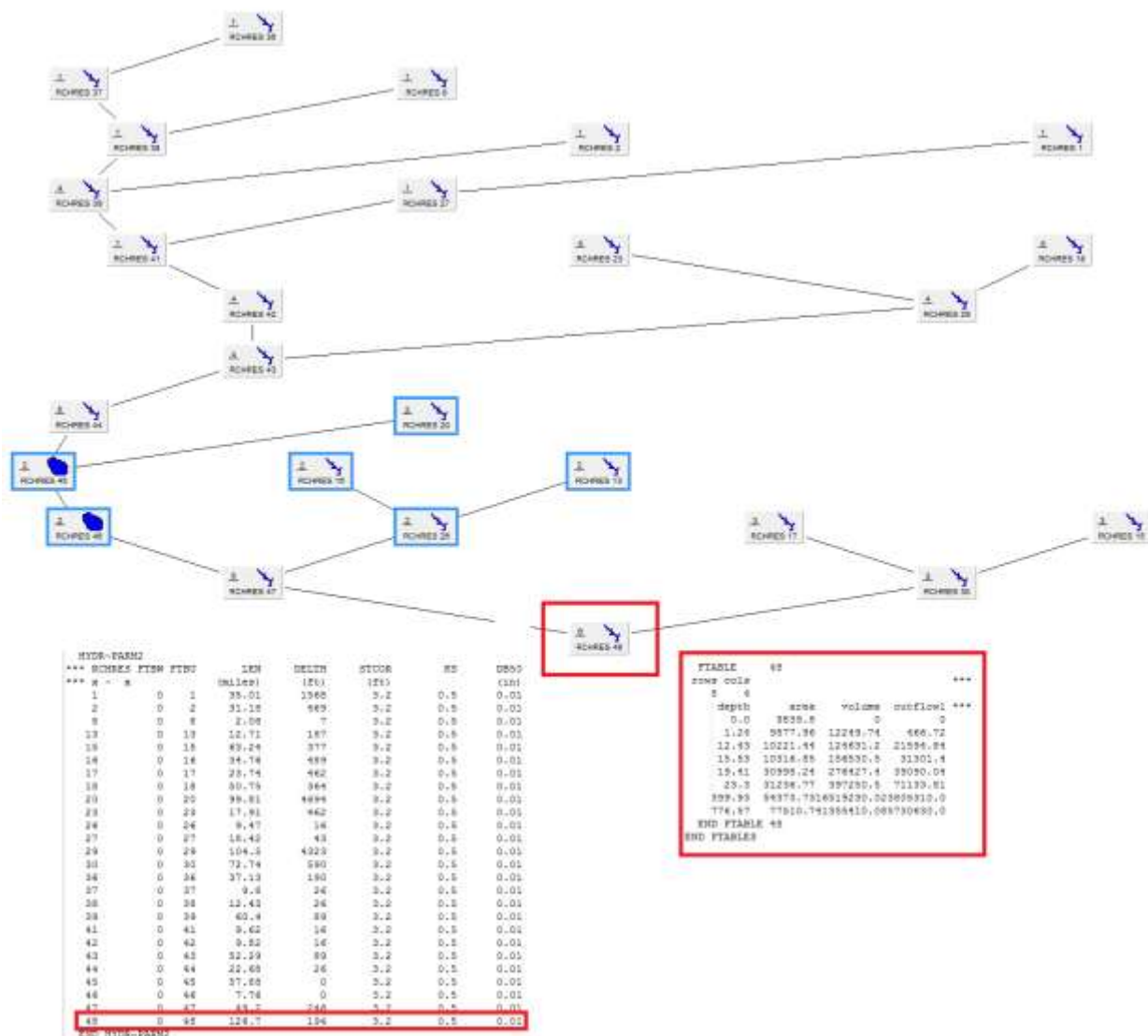


Fig. 2: Tables of hydrological parameters and data of cross-sectional for an area № 48.

2.2. Modeling system

For the simulation launch of calculations and view the results a system was developed which allows you to start calculations remotely from any computer connected to the Internet. For convenient and visual representation, the system is executed in the form of GIS (geographic information system). The architecture of the system is presented in Figure 3. The Web application is developed on the ASP.NET MVC platform, it provides the user with access to functions through the web interface. Access to the application is available using any device that has a modern Internet browser that supports HTML5, CSS3 and JavaScript. The Web application is developed on the ASP.NET MVC platform, it provides the access to the user to the functions through the web interface. For manipulating and working with maps and interacting co-operating with layers, the OpenLayers library is used. This library has high performance and good compatibility, supports a variety of standards for storage and display of geodata. GeoServer is used as a source of geodata - it is an open source software intended for publication of geodata. GeoServer stores data in the PostgreSQL database, and using the OpenLayers API they are inquired and represented on a map in the user's browser.

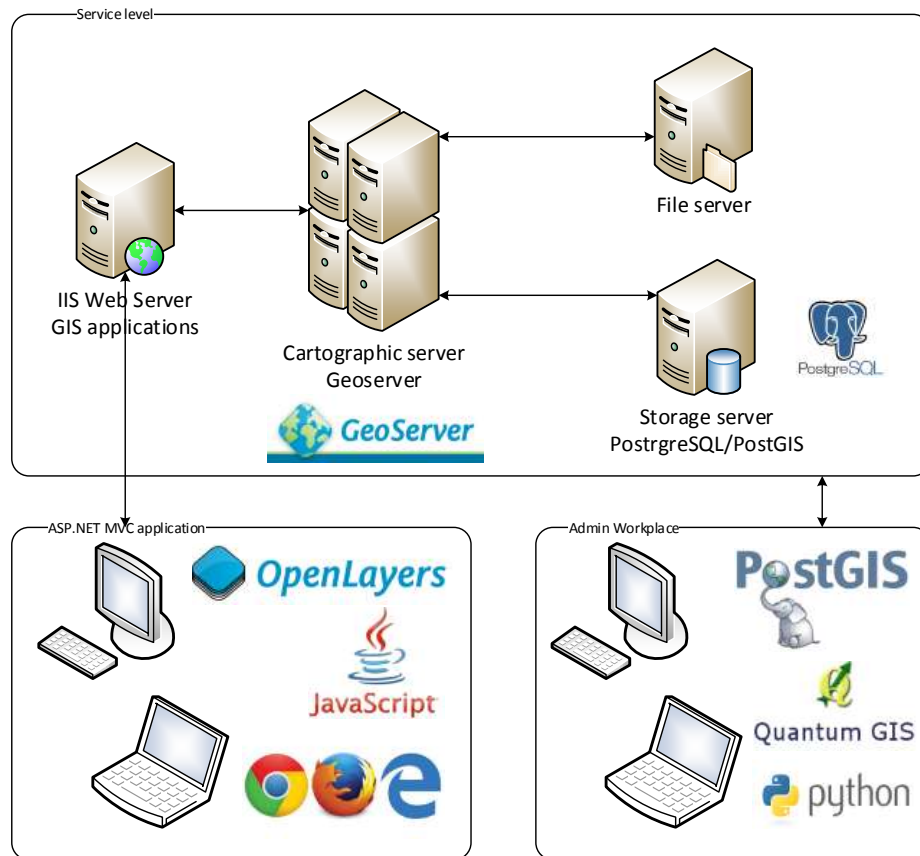


Fig. 3: Architecture of the system.

Via the web interface, the user enters the simulation data and starts the calculations. The Web application prepares input data and starts calculations using WinHSPF modelling program. When the calculations are complete, the data is displayed on the map. User interaction with the system is presented in Figure 4.

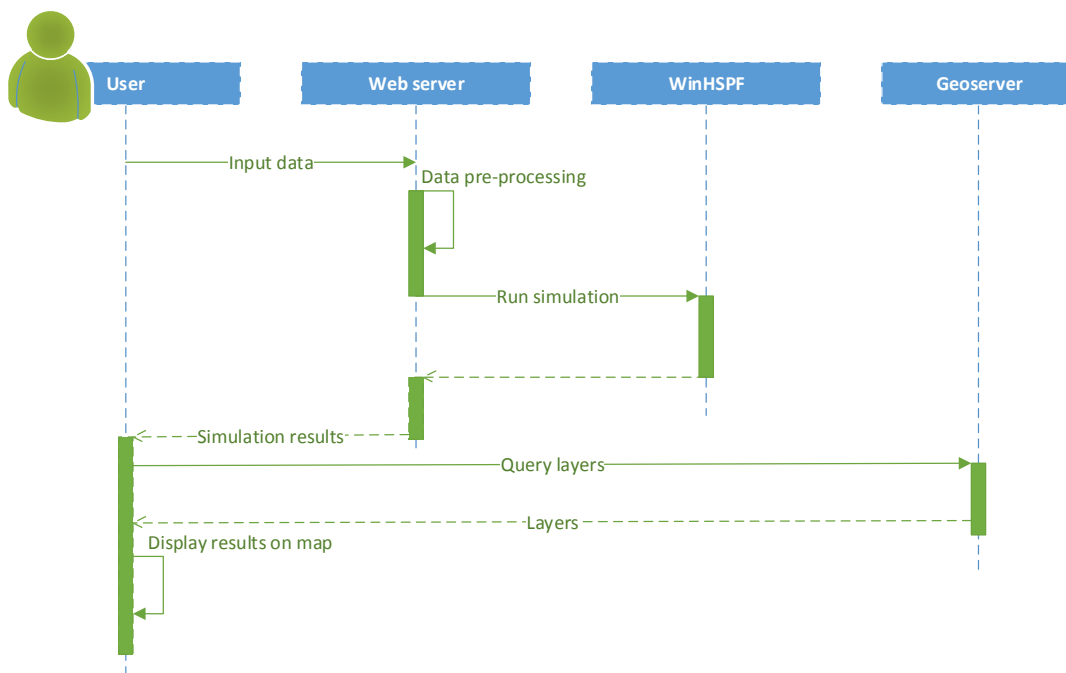


Fig. 4: Sequence diagram.

The geodata of the layers displayed on the map are stored in the PostgreSQL relational database using the PostGIS [4] extension, this expansion adds support of storage of geographical objects and creation on them queries. The results of simulation calculations are stored in files in the format wdm - Watershed Data Management file system [1], this format is specially designed for storing and retrieving data necessary for manipulating hydrological, hydraulic models, and water quality models. These files are stored in a dedicated file system, and organized using directories.

2.3. Simulation result

The result of the scientific work was the geoinformation system, which allows modelling the transfer of pollutants taking into account the nature of their transformation. The figure 5 shows the results of the simulation outflow of the river (cubic meter per second).



Fig. 5: River outflow simulation result.

The results of modelling the concentration of pollutants from non-point sources of pollution are show in Figure 6-9.

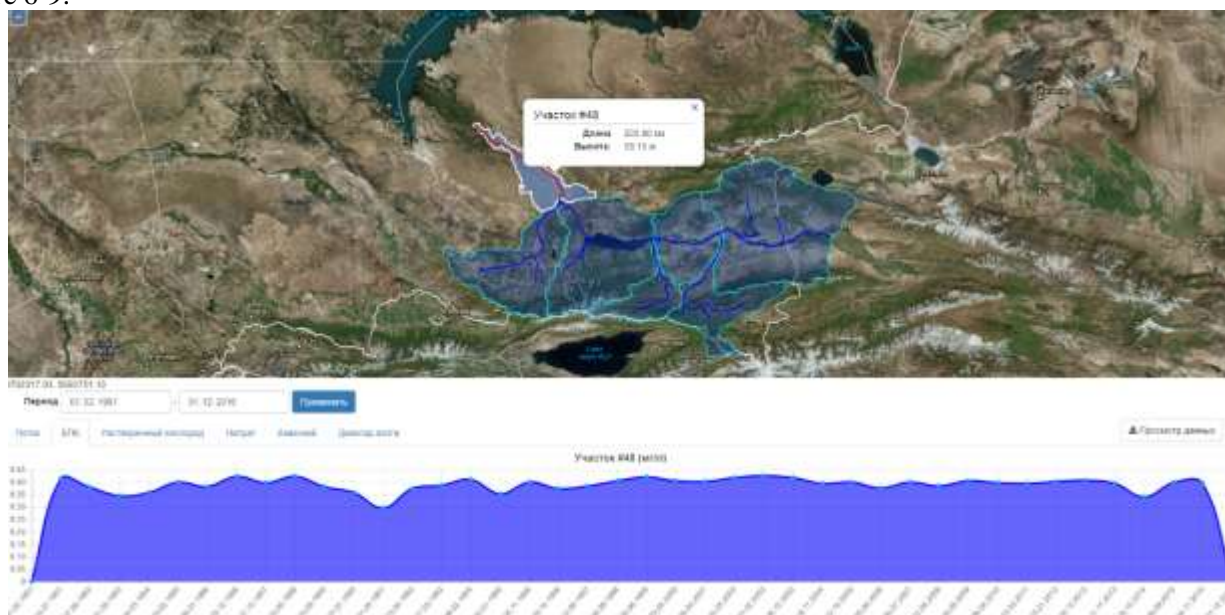


Fig. 6: The result of modelling the concentration of BOD (biological oxygen demand) (mg / l) is a water quality index characterizing the total content of organic substances in water.



Fig. 7: The result of modelling the concentration of dissolved oxygen (mg / l) in the estuary (area No. 48)



Fig. 8: The result of modelling the concentration of dissolved nitrates (NO₃) (mg / l).



Fig. 8: The result of modeling the concentration of dissolved ammonium (NH₄) (mg / l)

2.4. Conclusion

Water quality assessment is carried out by the criterion of exceeding the MPC (maximum permissible concentration). For each river section (Figure 2), for each time interval, the water flow, the total volume of the pollutant, the concentration of pollutants were calculated. The amount of pollution in each of the sections depends on the difference between the flow of contaminants to the site (from the upper section or sources of pollution in this area) and the transport of contaminants to the next downstream section. Figure 8 shows the results of the simulation of water discharge for plot No. 48. As can be seen from the figure, the average annual water discharge in the river is 566 cubic meters per second (m^3 / s) [5,6]. According to the Institute of Geography, the average annual water discharge in the river was 520 cubic meters per second. Thus, the deviation was ~ 8%. The result of pollutant comparison is shown in Table 2.

TABLE 2: The Arrangement of Channels.

Name of pollutant	MPC mg/l	Obtained max value mg/l	Obtained min value mg/l	Avg. Calculated value mg/l	Avg. Data from observation station mg/l
BOD	3	0,45	0,30	0,37	0,405833
DO	6	13	9	10	9,6
NO3	9,1	1,2	0,6	0,82	1,069167
NH4	0,39	0,06	0,03	0,032	0,03825

3. Acknowledgements

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