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MATHEMATICAL SIMULATION AND FORECAST OF WATERCOURSE DEFORMATIONS OF TOM RIVER WITHIN THE LIMITS OF TOMSK CITY (WESTERN SIBERIA)

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The mathematical model of watercourse deformations of Tom river within the limits of Tomsk city on river stretch 74,8...58,3 km from a mouth is developed and evaluated. Distribution of the intensity of vertical bottom deformations along the river, tractional and suspended discharge of the load is determined for periods of high, average and low water content. It is shown, that conserving natural and anthropogenic conditions of formation of sediment runoff of the river Tom within the limits of Tomsk city, formed in 2003-2006, definite river-bed level lowering is probable in the next decade and further forming of the island in the south part of a city. Effectiveness evaluation of channel dredging on the river Tom is carried out, and the forecast of watercourse deformations is given under different variants of anthropogenic impact on the stream.

Introduction

Tom river is one of the largest inflows of Ob river, more than 2 million people live in the basin of Tom river, mainly in the metropolises, located at the bank of the river (Mezdyrechensk, Novokuznetsk, Kemerovo, Yurga, Tomsk, Seversk). Such a distribution of settlements, which is conditioned by the history of economic opening of Siberia, on the one hand, allows using water resources more actively and minimizing water supply and drainage system costs. On the other hand, more attention has to be paid to such problems as prevention of water negative influence, including river bank and hydraulic facilities' erosion. This is a burning issue for Tomsk as within its bounds intensive naturally-anthropogenic watercourse deformations of the river Tom is observed.

Analysis of research results, performed earlier by «Tomskgeomontoring», Tomsk polytechnic university (TPU) and Tomsk state university (TSU), with author's direct participation, shows that since 50^{th} till mid 80^{th}, because of watercourse quarrying of sand-gravel materials (SGM), river-bed level and, subsequently, water level lowering on 2,0...2,5 m happened. Then shore line contour and watercourse formations changed, many islands either disappear, or decreased. In the middle of the 1980^{th} quarrying of SGM near Tomsk were stopped. In the end of the 1990^{th} on the 73...70 km from river Tom mouth, widening of existing midstream sandbanks, and their turning to islands were marked. Thereupon, strengthening of the channel erosion and increase of maximum water-level happened, this was not observed over 40 years [1, 2].

The channeling (dredging) works were held to stop watercourse deformation on Tom river in 2005–2006 years. Particularly, in 2005, SGM extraction was fulfilled from two sand-pits in the middle and left-bank parts of the channel and near TSU building № 6 (approximately 72,5...71,0 km from the river the mouth), the total work area – $1{,}61\cdot10^6$ m^2. Total bottom sediments' volume was evaluated at 210900 m^3. SGM's quarrying came to 60 % of extracted from 2 sand-pits, and 40 % from this volume were redistributed in the channel, downstream from sand-pits. It leaded to new channel forming between sand-pits and oseredoks growth downstream from them. In 2006 channel improvement wee fulfilled in 70,7...70,5 km and in 68,6...68,3 km from Tom river mouth. Excavation square at the first section came to 31000 m^2, decreasing of SGE value – 28500 m^2, excavation square at the second section came to 29500 m^2, decreasing of SGM value – 3500 m^2.

Comparison of channel survey materials, fulfilled before and after implementation of the mentioned works, allows concluding the following. Firstly, during dredging work in any downstream section, alluvion accumulation is probable, this can reduce effect, expecting from fulfillment of mentioned work. Secondly, it is impossible to increase effectiveness from dredging work and shore protection without mathematical simulation and forecast of watercourse deformation, taking into consideration different variants of hydrological conditions' changing and engineering operations fulfillment. All these determined aim of concerned research, during which, the author developed and approved simulator of watercourse deformations of the river Tom, Tomsk. The scheme of the analysis area is presented on the Fig. 1.

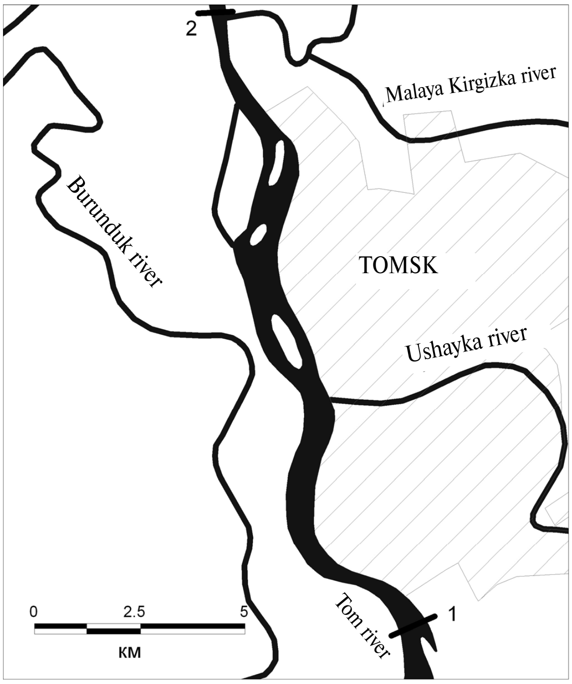

Fig. 1. *The scheme of the analysis area of the river Tom; station of the river mouth: 1) in 74,8 km (hydrostation); 2) in 58,3 km*

Source information is the data of channel survey, fulfilled by «Tomskgeomontoring», «Tomsk waterway and navigation region», data of hydrological observations from Tomsk center of hydrometeorology and environment monitoring (TCHEM), TSU, TPU for 2003–2006.

Structure of the mathematical model

The concerned simulator is based on numerical solution of the equation of watercourse deformation, having the following form:

$$\partial G_{al}/\partial x - q_{susp} + m_0 B \partial z/\partial t = 0, \qquad (1)$$

G_{al} is the alluvion flow in the volume uncavitated rocks; q_{susp} is suspended sediments flow, settling at the bottom or ascending upwards; m_0 is relative density of soil and alluvion; B is river width, m; x is axis of coplanar motion; z is the bottom level; t is the time base. The value q_{susp} is calculated according to A.V. Karayshev's method, alluvion flow according to G.I. Shamov's method [3].

Solution of equation (1) is founded for every local stream, having a flow equal to $q=Q/10$, where Q is the total water flow in the selected section. Boundaries of the local stream are determined by interpolation along the curve $q=q(b)$ for each range, where b is the distance between dam crest of the right shore. Water-level is determined according to Bernulli equation, through optimization of golden section method. Fig. 1 presents a general model structure, realized by the author with MS Excel help, as bundled software HYM. Results of model verification of data on the Tom river channel survey in Tomsk in May 2001 and 2003 presented in [4].

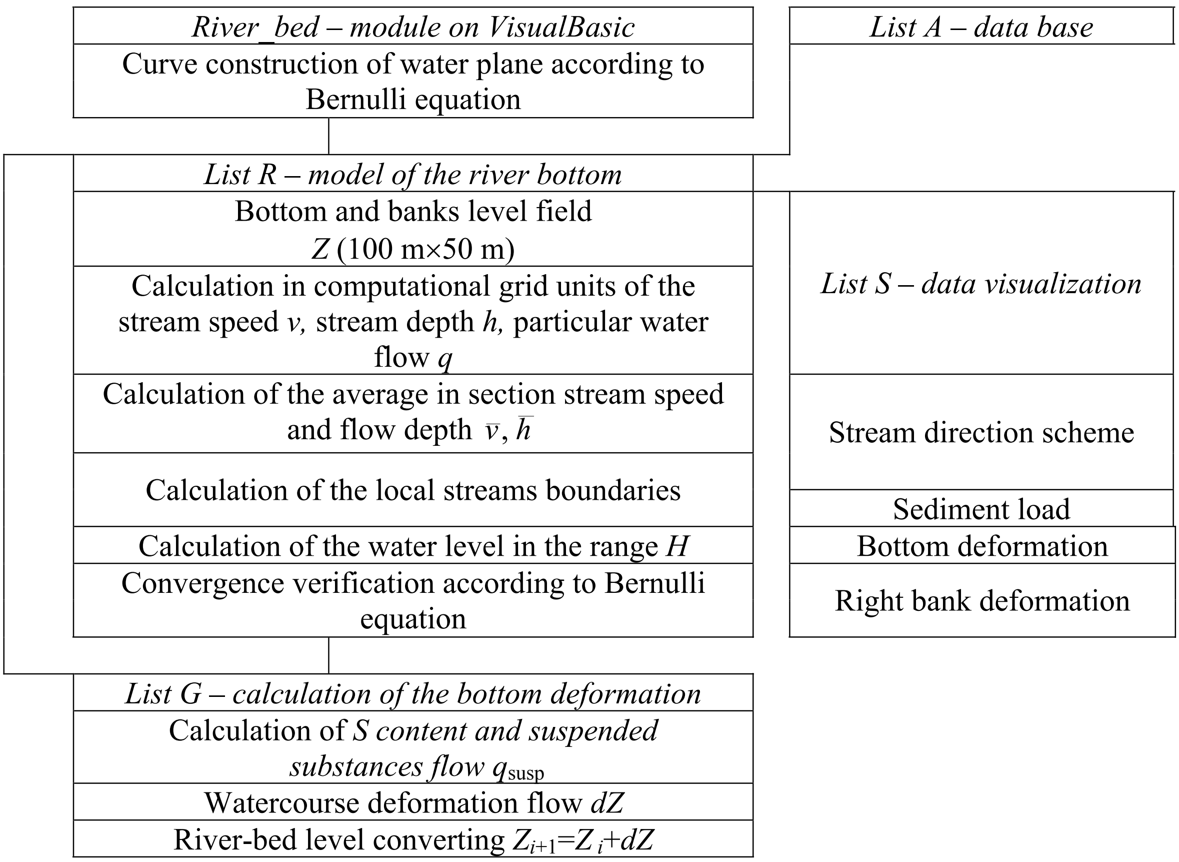

Fig. 2. *Structure of simulator of watercourse deformation of the river Tom, Tomsk. In MS Excel*

Calculation variants

Mathematical simulation was conducted for various hydrological conditions and variants of factual and probable Tom river change at the section from TCHEM hydrorange in Tomsk (74,8 km from the river mouth) to Seversk (58,3 km from the river mouth). The following variants of hydrological conditions were used:

1. spring tide of average water content – water flow Q=6860 m^3/s; water level H in hydrorange count to 630 sm before «zero» of post; water surface slope at hydrorange I=0,16 % (05.23.2004 data);
2. spring tide of low water content – Q=3640 m^3/s; H=350 sm; I=0,088 % (05.23.2003 data);
3. end of spring tide (conditions close to average annual) – Q=1090 m^3/s; H=70 sm; I=0,14 % (06.20.2004 data);
4. spring-summer mean water – Q=472 m^3/s; H=–48 sm; I=0,28 % (09.22.2003 data).

As design variants of channel improvement of the Tom river condition is regarded for autumn 2005; March 2006; August-September 2006 after channel improvement fulfillment; March 2006 (forecast) on the assumption of SGM storehouse distribution.

Attention during mathematical simulation of channel processes mainly was paid to current plan examining, changes of the alluvion flow meanings (suspended and tractional) in river length and deformations, determined by river drift shift.

Research results and their discussion

Currents plan. During a year, depending on the water level, in the examined territory, evident change in speed and stream of current is observed. The most compressed stream sectors during spring period are mentioned in the place of rock abruption «boyets» (74,0...73,8 km from the river mouth) and upper bridge (73 km from the river mouth) in the Tomsk south part. Certain stream compression takes place in the large islands area (Boyarskiy, Nizhniy Boyarskiy, Sobachiy islands). Along with water flow decreasing, definite stream reduction takes place, it becomes closer to the left bank in the 70,3...68,8 km district from the river mouth (4,5...6,0 km from hydrorange). At that, stream contours on the plan become more sharp because of water mass flow of islands, their influence on speed field become noticeable at the water flow level of 3000...3500 m^3/s. Stream narrowing maximum is timed to low-flow period, when water flow is not exceeding 500 m^3/s. This time water one can observe mass shift to the left bank in the «boyets» area, in the upper bridge, Nizhniy-Senniy rift (71,5...70,5 km from the river mouth) to the right bank in 73,4...73,2 km from river mouth and downstream from TSU building № 6, located approximately 72 km from the river mouth.

Load drainage. Analysis of space-time changes in alluvion load along the river length from hydrorange to Seversk proved that their maximum meaning is timed to the following: according to time – to spring tide, according to space – in the territory from Ushayka river mouth (69 km away Tom river mouth) to Seversk (Fig. 4). As water drainage is decreasing in the end of May – beginning of July, absolute and relative changes in alluvion load along river length occurs, with it maximum in the Tomsk south part (in the place of rock abruption in 74,0...73,8 km from river mouth). Besides, during water flow reduction, suspended solids part is decreasing in the cumulative load drainage. Nevertheless, the river Tom within the limits of Tomsk city is characterized by regular prevalence of sediment load suspended constituent.

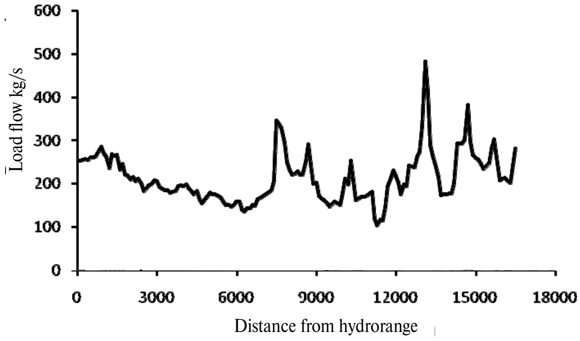

Fig. 3. *Measurement of total load flow of the Tom river, on the territory of 74,8...58,3 km from river mouth (hydrorange – Bolshaya Kirgizka river mouth); Q=6860 m^3/s*

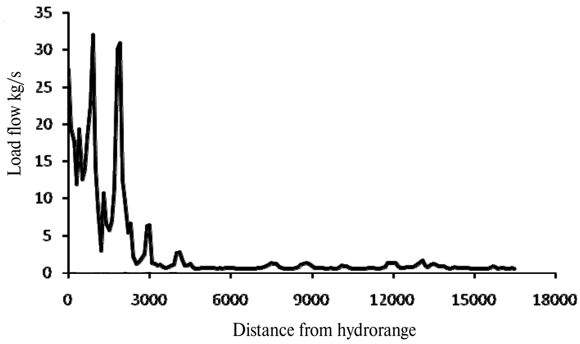

Fig. 4. *Measurement of total load flow of Tom river, in the territory of 74,8...58,3 km from river mouth; Q=472 m^3/s*

Deformations of the river bottom. Space and time changes of deformation are determined not only by load flow meaning, but by channel geometry. Taking this into consideration, channel deformation tendency can differ greatly from tendency of sediment load change. According to simulation results, the largest bed movement was revealed for «boyets» area. However, deformation in this case is regarded as potential, not factual, as the simulator leaves out of account low washing out of rocks in this area. It should be mention, that bed movement and backup can be observed concurrently on different areas of transverse river-bed profile, under relatively slight changes of bottom deformation, average in section meaning. Load backup near islands can be observed even during extremely high spring water flow (Fig. 5).

During flood fall, or during low water level flood, backup of suspended load can take place on the larger stretch of the examined area of Tom river, and simultaneously, bed movement occurs, due to tractional particles transport on separate river areas, timed to river mouth narrowing and depth overfall in the places of channeling. At the end of flood – beginning of the summer mean water, over a length of the river, slight backup of suspended load is observed together with areas of water flow and backup of tractional load alternation. Water flow, noncompensible by backup of suspended load, is observed only in the «boyets» and upper bridge area (Fig. 6). During summer-autumn mean water, backup of tractional load mainly is observed. The most intensive sediments are observed near TSU building № 6, above Ushayka river mouth and near Boyarskiy, Nizhniy Boyarskiy and Sobachiy islands.

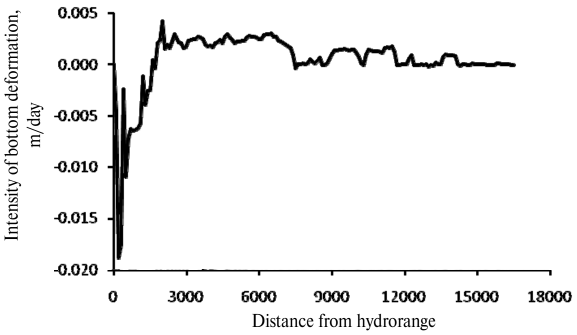

Fig. 5. *Changes of average in section intensity of deformation of the Tom river bottom, 74,8...58,3 km from the river mouth; Q=6860 m³/s*

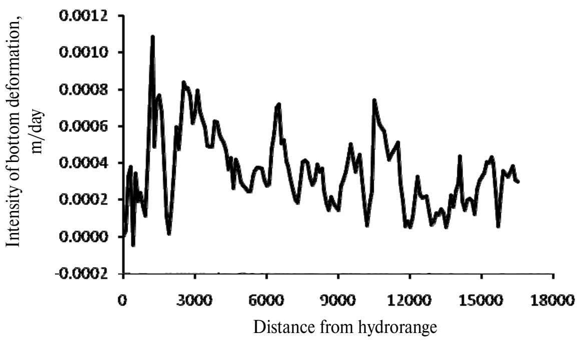

Fig. 6. *Measuring of the average in section deformation intensity of the Tom river bottom, 74,8...58,3 km away from river mouth; Q=1090 m³/s*

Factual and forecasting channel processes changes due to channeling, carried out in 2005–2006. After channeling fulfillment in the Tomsk south part, flattening of flux occurred, it shifted to the channel centre due to deepening of some watercourse areas. During a flood, at the place of channeling directly, average at the section negative bottom deformations decreased, of practically stopped. It proves effectiveness of performed work. The character and scale of bottom deformation changed insignificantly during summer – autumn mean water.

Within the next few years some flattening of flux should be expected, approximately at 71 km from the river mouth, water mass should shift to the left bank in 70,3...68,8 km from the river mouth. Taking this into account, erosion of the left bank and bottom is possible together with the following resiltation in the downstream area and oseredoks forming. Slight change of load drainage during spring tide is expected. During mean water, intensity of flow should reduce, as in the channeling areas, 71 km away from the river mouth, and in the upstream areas. Change of load drainage near the river-boat station (68,1 km away from the river mouth) should be slight. Similar tendencies are peculiar for spatial watercourse deformation dynamics. So, changes in the bottom deformation during flood peak is supposed to be insignificant near Nizhniy-Senniy rift and river-boat station, but during low-water period load accumulation should reduce upstream from sand-pit, 71 km away Tom river mouth. Load accumulation will be defined in sand-pit directly.

Forecasting change of channel processes due to SGM underwater storehouses in Tom river mouth. Simulation results analysis shows that, without additional channeling, arrangement of SGM underwater storehouses near the bank can lead to stream shift and strengthening of bottom erosion between the storehouse and next bank. The storehouse influence would be mostly noticeable during the flood fall. Particularly, washing out of a part of the waterside during mean water is possible when storehouse is located 70,3 km away from river mouth. Less visible, but still significant water mass shift to the river centre is expected in the Eushtinskiy canal area (60,4...60,2 km away from river mouth). Relatively noticeable changes of the load drainage is probable during flood fall – in the beginning of summer mean water, when stream speed increases due to narrowing of the effective cross-section. Changes in the water flow during low and high water level would be hardly noticeable. Storehouses influence would affect not only in sediment load change and waterside wash out, but in suspended sediments backup strengthening during mean water in the areas within which stream speed decrease would take place.

Resume

1. The mathematical model of channel processes is developed and evaluated at the example of the river Tom within the limits of Tomsk city. It allows to forecast the change in the speed field, sediment load and watercourse deformations. It further usage effectiveness is determined by the necessity to renew and specify data about bottom contour and riverside.
2. During the year, on the length of the river, significant changes in sediment load and watercourse deformation intensity is taking place, depending on water drainage size and channel geometry.
3. Definite water mass shift to the centre of the river near TSU building № 6 (approximately 72 km away from river mouth) occurred as the result of channeling. Generally, influence on the channel in 2005–2006 is regarded as moderate, and channeling effectiveness as satisfactory.
4. In the near future (with no additional man-made watercourse changes) a definite flattening of flux should be expected, approximately 71 km away from

river mouth, and some water mass shift to the left bank 70,3...68,8 km away from river mouth. Considering these, left bank and bottom erosion is probable together with the following resiltation in the downstream area and oseredoks forming.

5. Arrangement of SGM underwater storehouses near the bank can lead to stream shift and strengthening of bottom erosion between the storehouse and next bank (especially during flood fall) and it can increase frazil ice drift density (during the floating of ice).
6. Considering all these, it is not recommended to arrange storehouses at the places of stream narrowing and in the curvilinear areas. The least negative consequences are expected, when SGM storehouses are arranged at the low part of Enekov island (63,0...61,5 km away from river mouth) along with prior shore drawdown and storehouse arrangement within old boundaries of the island.
7. Watercourse of the Tom river within the limits of Tomsk city in the south part (in upper bridge range, 73 km away from river mouth) during 2003–2006 is generally stable. Downstream from the bridge significant deformations are marked within some part of cross-section (more than error estimation 0,58 m), but deformations are generally insignificant within vertical section (less than 0,58 m).
8. If natural and man-made conditions of sediment load forming of the Tom river within the limits of Tomsk city, definite river-bed level lowering is probable downstream from upper bridge, 73 km away from the river mouth.

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RADIOGRAPHIC RESEARCHES IN RADIOECOLOGICAL MONITORING

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The possibilities of one of the radiographic methods – the method of fission-fragment radiography for evaluation of radiographic condition of territories, which are characterized by different source of man-caused and natural radiating loading, are considered.

Monitoring research of radiation condition plays a great role in state of environment control. To perform a proper evaluation one needs a great number of data on concentration of radioactive elements, its forms of presence and some other various parameters in different objects of natural environment.

High-accuracy methods should be applied to define an accumulation level of radioactive nuclides in the objects of natural environment, which are characterized both by high and relatively low concentration. Radiographic methods give complete information about a character of radioactive elements distribution in the objects of research. Among well-known radiographic methods a special place occupies a method of fission-fragment radiography (*f*-radiography). Fission-fragment radiography is a unique method of fissioned radionuclide analysis in various objects. This method allows defining with high accuracy the quantitative content of fissioned radionuclide, their spatial distribution and forms of presence in the objects of research [1]. This method is an instrumental one and allows performing an analysis without chemical preparation and sample destruction.

The basis for f-radiography method is a reaction of atom nuclear division of some elements (uranium, plutonium, etc.) under the influence of thermal neutrons and registration of fission fragments on the detector. Here, the detector, lavsan pellicle can be used as to perform this function, fixates the traces from fission fragments (tracks), which can be observed in an electronic microscope, and, after proper processing, in an optical microscope. The tracks quantity is proportionate to radionuclides content in the given point of the object of research [1].