The bed deformation of the reservoirs and rivers located in permafrost regions under simultaneous effect of the water flow and warming

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Introduction: Global climate changes on the Earth in recent decades inevitably lead to more frequent catastrophic events including floods caused by ice phenomena. Their negative effects on the rivers in permafrost may be exacerbated by significant channel deformations caused by not only the influence of the water flow, but by the change of the structure of the frozen soil under the conditions of warming.
The work is devoted to the investigations of the influence of the water flow and increase its temperature on the deformation of the coastal slopes composed of permafrost with the inclusion of ice layers.

Methods: Methods of investigation are the laboratory and mathematical modeling. The basis of a three-dimensional mathematical model of the coastal slopes thermo erosion of the reservoirs and rivers located in permafrost regions, and its verification are the results of laboratory experiments carried out in the hydraulic tray.
The model consists of three blocks: the hydrodynamic, thermal and deformation. In thermal block Stefan equation is solved to calculate the movement of the surface of phase transition "ice-water", in the deformation block sediment transport is modeled in the channel bed and in a thawed cavities. The hydrodynamic block of the model is designed to simulate the non stationary fluid motion, that is characteristic for the wave propagation of different origin, such as waves, floods and high water, the effect of which together with the impact of the heat flux leads to melting of niches. The block consists of a two-dimensional time-dependent equations of motion and the continuity equation.
The model describes the process of lateral channel deformations and in particular the so-called niching process allowing to answer the questions posed long ago in this area, for example, what role the icing process plays on the soil erodibility.

Results: As a result of calculations, the three-dimensional distribution of horizontal velocities in the open flow and in thawing niches, two-dimensional distribution of the bed and slopes (deformation of the coast) were obtained. The model is verified for the special case of steady flow in the tray. Analysis of the results of mathematical and laboratory modeling showed that the coastal deformation of the reservoirs and rivers in the permafrost region vastly different from the deformation of the coasts composed of soils not affected by the phase transition "water-ice." The increase in water temperature by 2 ˚ C resulted in increased the deformation volume on the average by 25%, which confirms the findings obtained during field observations and other methods of modeling.

Discussion: Increasing of the water and air temperatures leads to the melting of permafrost and ice formations included in the ground and induces integral-differential multidirectional effect on riverbed deformation caused by wave action: intensification of an erosion and accumulation at a single site with a decrease in the total volume of transported sediment.
The increase in amplitude of the wave leads from the total siltation to the total erosion. The increase of the wave length causes a tendency to silting. This conclusion applies only to the case when the non-blurry surface lies below the eroded soil (in the case of a laboratory experiment - the bottom of the tray, in the nature - bedrock). Increasing the connectivity of the soil leads to a transition from erosion (negative amount of deviations of the bottom surface) to the sediment accumulation. The mathematical model can describe the processes adequately and provide prognostic assessment of their dynamics under the conditions of the climate change.

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