Influence of the Southern area of the Ust-Luga commercial sea port on the channel regime of the Khabolovka river

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Abstract. The problem investigated in the framework of this work is devoted to the study of changes in the hydrological and channel regimes of the estuary region after the construction of the Southern Port area. The object of the study is the Khabolovka River, which flows into the Luga Bay. Based on the materials of channel surveys, the article gives a modern assessment of the general condition of the channel, presents data on man-made changes in the hydromorphological structure. After the conducted research, it was determined which consequences affecting the hydromorphological appearance of the considered section of the river have now occurred from the influence of various factors. Taking into account the performed and studied in detail analysis of riverbed transformations on the river section, it is possible to formulate the main conclusions and recommendations. As a result, a forecast of the further course and changes of the estuary area of the river is given if the necessary measures to protect against wind-wave influence are not carried out.

1 Introduction

The multipurpose Ust-Luga Commercial Seaport is now built in the Luga Bay of the Gulf of Finland, with a capacity of up to 180 million tons of various cargo per year. Ust-Luga port is located practically on the border of the Russian Federation and the European Union. It fits seamlessly into the transport network of the North-Western region, which plays an important role in organising the transit of cargo within the European transport infrastructure.

Over the years, various studies of the hydrometeorological and channel regime of the Luga Bay estuary have been carried out during the construction of port facilities. These materials have largely contributed to the quality design, construction and development of the modern port transhipment complex in Luga Bay. However, the questions of studying the hydrological and riverbed regimes of the mouth area of the Khabolovka river, which flows into Luga Bay, have not been raised so far.

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In this connection, the question of studying hydrological and channel regimes of the mouth area of the Khabolovka river, flowing into Luga Bay, where the southern district of the port is built, becomes relevant.

2 Methods and materials

During the final phase of construction of the main structures, the estuary of the river, on both its banks, was located between the retaining walls of the quay complexes (Yug-2 and SCB), between which a deep water area was created and new bank reclamation areas were formed, resulting in significant changes in the morphology of the estuarine area.

In the majority of cases, river estuaries are areas of unidirectional sediment accumulation. At the same time, river bed changes in estuaries are diverse and the river channel itself is generally less stable than in transit areas. The intensity and direction of deformation in the river mouths is affected by river discharge, sediment load and confining conditions, as well as by sea level, longshore drift and longshore drift (1).

Looking at the overall characteristic of the Khabolovka river channel process, one can say that along its entire length the valley is not clearly defined. In its upper reaches, at its source from Lake Khabolovo, the river flows in a gently winding, almost straightforward channel through a marshy area and without sediment load, in peaty, erosion-resistant banks. In the middle reaches, the river channel is formed in mineral soil. The channel is very sinuous and the floodplain is bilateral, crossed by old rivulets. The channel develops along the pattern of free meandering, but the rate of bend development is low due to the river's sparse sediment supply. The beaches in the bends are not developed and straightened bends are not silted up for a long time and retain a connection to the active river channel. In the lower reaches, from the crossing of the Ust-Luga - Kotly railway to the village of Koskolovo, the meandering riverbed is squeezed between steep ledges of the bank, up to 3 m high. The river floodplain is undeveloped - alternating, uneven, with remnants, varying in width. Channel width between the riverbanks varies from 8 to 16 m. Sloughs and rifts are not pronounced and bank erosion rates are slow. In the channel itself there is almost no alluvium in many areas and the river flows in boulder sediments formed by washed moraine. The channel process follows a limited meandering pattern. Closer to the estuary, 1 km from the bay shore, the river floodplain widens to 150-180 m, becomes two-sided, flat and waterlogged. The gradient of the river decreases. Bends become gently sloping, less developed. The width of the river increases to 20-30 m (2).

The comparative riverbed plans of the Khabolovka River for different years show that the river channel has been fairly stable. The meander at the mouth (see Figure 1) with its steep turning angle has lasted more than 100 years.

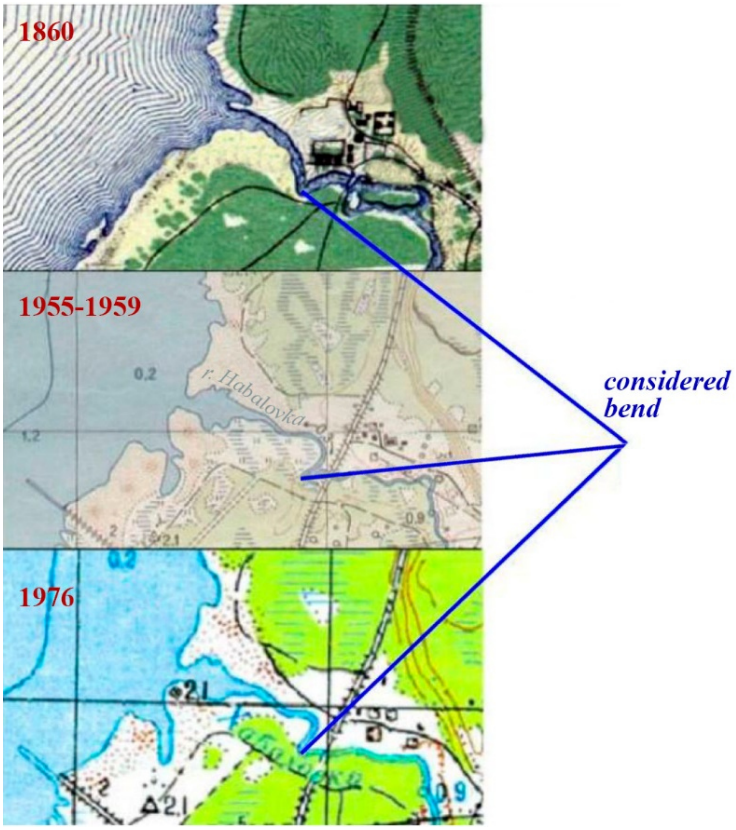

Fig. 1. Comparison of the outlines of the Khabolovka river channel at the mouth of the river according to different time mapping sources.

This fact can be explained by the following circumstances:

- the river carries a small volume of sediment, the deposition of which over a century has not led to any significant accumulation in the estuary;
- high water levels coincide with low water levels and the absence of backwater spillways allows river load to move into the bay without accumulating at the mouth of the bay;
- lacustrine control ensures a steady, prolonged flood with relatively low discharge and there is little channel erosion;
- geological surveys have shown that the estuarial floodplain is composed of coarse marine sediments (sand-gravel with an admixture of pebbles and individual boulders) and is fairly resistant to scouring;
- The coastal part of the Luga Bay of the Gulf of Finland at the mouth of the Khabolovka River was shallow. Extensive shoals protected the mouth of the river from erosion by the surf, even in case of significant wind surges. At low water levels in the bay waves did not reach the estuary (3).

Of no small importance are man-made changes in the hydromorphological structure of the Khabolovka in the estuary area. For example, in the XIX and XX centuries there was

economic activity in the lower reaches of the Khabolovka influenced some parts of the river without a significant and lasting impact on the estuary. Thus, according to the map of 1860, in the second half of the XIX century, there were two dams on the river: the lower one, by the blacksmith's shop at the glassworks, the upper one, a mill dam in the village of Koskolova. The backwater from the lower dam caused flooding of the lower part of the floodplain and the formation of a double-channel channel with a slowed flow; the upper dam formed a pond about 100 m long and about 50 m wide.

In the 30s of the 20th century during construction of Ruchy naval base, Luzhlag prisoners created railway embankments and bridge crossings over Khabolovka in its lower reaches. Apparently at the same time a stone and concrete hydropower plant dam was built at the site of the mill dam near the village of Koskolovo, and a bend in the river was straightened in its downstream end during the construction of the discharge channel. In 1941, the dam was blown up by retreating Red Army units. At present the waterworks are completely destroyed. A general view of the fragments of the abutments is shown in Figure 2.

Fig. 2. Fragments of the Khabolovka River hydroelectric power station abutments.

As a result of the straightening of the bend in the downstream section of the HPP, a large amount of soil entered the river. The sediment in the downstream areas and probably a breakthrough wave after the collapse of the hydropower plant led to the straightening of the two bends in the near-river area in the later period. The old banks of the straightened bends can be seen in the satellite images.

At the same time, in the lowest estuary section of the river, which was formed under the dominant influence of the Luga Bay regime, there were no major changes in that period. Alongshore sediment transport and the influence of the water level regime in the Gulf of Finland offset the anthropogenic fluctuations in water and sediment load here.

3 Results and discussion

Construction of the Ust-Luga MTF had a significant negative impact, with changes in the hydromorphological appearance of the Khabolovka estuary and a drastic change in the hydraulic regime of the river, which was caused by the following activities:
- 5 bridge crossings (roads, railways and cable lines) were built in the estuary section, the approaches to which blocked the floodplain. Floodwater runoff in the 170 m section is now concentrated in the channel section;
- The floodplain between the bridge crossings and below the bridges to the estuary is constrained by spoil fill to non-floodable levels;
- In Luga Bay at the mouth of the Khabolovka River the dredging and construction of a quay wall was carried out, for which the bank and the estuarial bar were eliminated.

Due to the elimination of the estuarial bar and the formation of a deep water area in the Southern area of the Ust-Luga MTF, the character of channel changes in the estuarial area of the river has changed significantly in comparison with its former state. The bedloads transported downstream are deposited on the upstream scarp formed at the entrance to the seaport water area from the river side, causing the upstream scarp (the river water area boundary) to move downstream of the river. The rate of repositioning of the upstream scarp due to bedload deposition is very low, i.e., alluvial deposits must be removed at regular intervals by maintenance dredging to ensure navigable depths in the seaport waters [4, 5].

Another natural factor influencing the intensity of channel reformation in the mouth area of the Khabolovka River is wave action on the river bed and banks. The reason of activation of these processes in the mouth area is also the liquidation of the bank beach and the river bar as a result of the creation of water approaches to the piers built in the Southern part of the port. Under current conditions, after deepening of the port water area, under winds of north-western direction the conditions of wave impact on the bottom and banks of the Khabolovka river in the area of its mouth have changed. Moreover, with the completion of the LSP shore reinforcement these processes are intensifying further [6].

In contrast to river bed deformations caused by river discharge, the greatest intensity of wave impact is observed in autumn-winter period when winds of northern direction prevail. In addition, a concomitant factor of wave-induced channel deformations is the presence of a surge in the southern part of Luga Bay. Under the action of wind-driven wave action, the submerged coastal slope loses stability and collapses. The erosion material forms a shallow, gradually increasing in width bank, within which the wave energy is partially dissipated. Shoreline reshaping is complete when the bank reaches a maximum width sufficient to absorb all the wave energy capable of fracturing the shore slope.

4 Conclusion

Consequently, the following natural factors - river flow and wave action - have unilateral effects on the bottom and banks of the Khabolovka River in the estuarial area. The result is erosion of the river bed and banks and a gradual increase in the slope of the river bed at the junction of the river mouth and the seaport area.

Over time, as the level of the riverbed in the estuarine area decreases, the intensity of these processes will diminish.

Unless the estuarine area is protected from wind and wave action, wave action on the riverbed and banks will continue until the scarp in the estuarine area is removed and a new bar is formed at the mouth of the river.

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