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INFLUENCE OF ST.PETERSBURG FLOOD PROTECTION BARRIER ON WATER REGIME IN NEVA BAY

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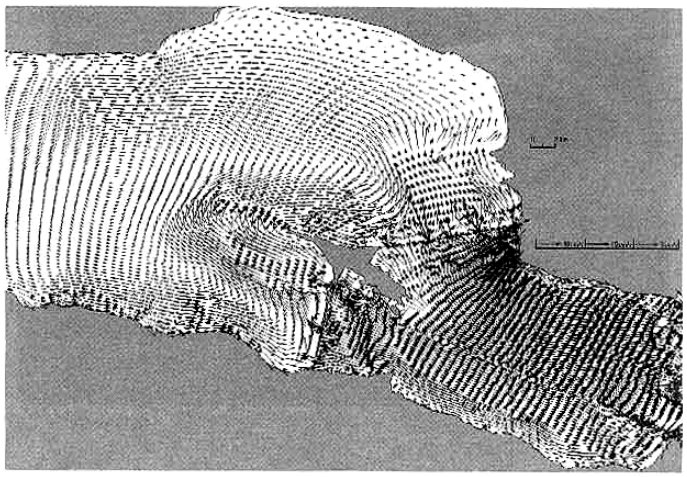
The paper presents results of simulated changes in dynamics of currents and propagation of pollutants in Neva Bay and the Eastern Gulf of Finland (EGF), obtained with the modeling system CARDINAL (*Klevannyy, 1999*). Great number of crib and poling barriers on the bottom is one of the difficulties of current's simulations in Neva Bay. These barriers were built in XVIII–XIX centuries to protect the City from enemy ships. In a shallow Neva Bay bottom contour influences on water streams dominantly. Mean grid step in the model is 244 m (min – 20 m). Due to this and also due to the fact that the navigational maps do not give enough information about these objects, they are described in the model approximately. Another problem of modeling Neva Bay is that changes appeared as a result of different works are not always reflected in the maps. Widths of water sluices of the Barrier is 240-288 m. With curvilinear boundary-fitted coordinates their description is possible in case of grid condensation in the openings.

Three situations were considered for the estimation of the Barrier influence: 1) before the construction, 2) the modern state and 3) the project state. Ratio of open areas in South and North gates of Neva Bay for these three situations are the following: 1) 38200/41800 m^2 (48/52 %), 2) 9910/4281 m^2 (70/30 %) and 3) 5120/4490 m^2 (53/47 %). Calculations were made in two-dimensional approach until steady states of current and concentration fields were achieved. On the eastern boundary of the area, which cross the Neva River near Novosaratovka, yearly mean river discharge in 2500 m^3/s was assigned. Constant water level was assigned on the western border of the area near Shepelevo. Western wind with 3 m/s speed was assigned under the whole area. General phosphorus was selected as a pollutant. Its sources are: 1) Neva – concentration 0.04 mg/l, which gives loading 100 g/s, 2) Central Treatment Plant (CTP) – concentration 1.2 mg/l, loading – 21 g/s, 3) South-West Treatment Plant (SWTP) – 1.0 mg/l, 3.82 g/s, 4) North Treatment Plant (NTP) – 0.5 mg/l, 3.57 g/s, 5) Treatment Plant in Petrodvorets – 2.1 mg/l, 1.28 g/s, 6) Treatment Plant in Kronshtad – 1.6 mg/l, 0.53 g/s и 7) discharge from Lomonosov – 2.3 mg/l, 0.13 g/s. Unconservativity of phosphorus was taken equal to 0.01 day^{-1}.

Obtained current fields for all situations on the Barrier have common features, which are correspond in general to the field observations. Neva waters flow into Neva Bay and in broad front move to the west with speed 6-5 sm/s (Fig.1).

Fig.1. Velocity vectors in Neva Bay and the Eastern Gulf of Finland with Barrier in the design state. Neva Discharge 2500 m^3/s, west wind 3 m/s. Every other arrow is shown



Above crib and poling barriers and the Lomonosov bank velocities rise up to 10 sm/s. Nearer to the southern and northern shores velocities decrease to 3-1 sm/s, and western wind forms here some whirlpool zones with width less than 1 km. In the southern part of the bay width of small velocities zone is larger than in the northern one. To the west of Neva Bay, in the southern part of water area, the eastern current develops under the western wind. Without the Barrier it met Neva waters on the Lomonosov bank and turned here to the north and went back to the west together with Neva waters taken from the south shore. These mixed waters enveloped Kotlin in the south and turned to the east again. To the east from the Fort Obruchev they met with Neva waters, moving to the west through the North gates of Neva Bay. After meeting, flow moved to the west through the northern part of the EGF. In the northern part of the EGF, to the north from cross-section Pesochnoye-Repino, wind forms another whirlpool zone.

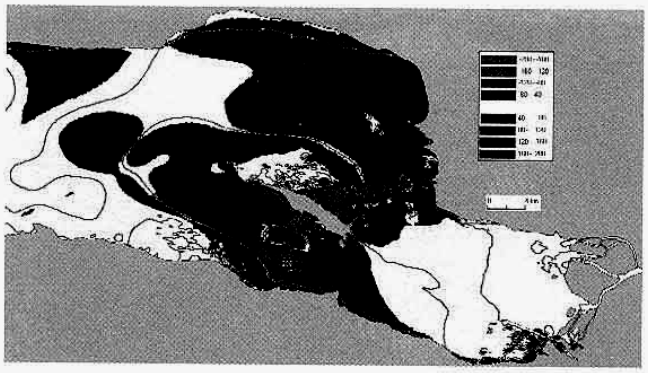
When the Barrier exists, this common current field is the same, but the eastern flow near the southern shore turns not above the Lomonosov bank, but behind the southern dams of the Barrier. In the openings of the barrier increase of velocities up to 20-30 sm/s is obtained, and in the front of the dams of the Barrier, which are in project state, little (100-300 m width from the dams) zones of slow water exchange appear.

In the modern state wide zone of slow water exchange appears only to the south from dam D-7 (between temporal opening TM-D7 and opening B-4, 4160 m length at present time). Unpitching embankment of TM-D7 is in accident condition nowadays, and question about filling this opening has arisen. In that case the length of the dam will increase up to 4580 m, and overgrowth of this area with macrofites starting from the Kotlin shore and including opening B-3 would be possible.

Results show, that before the Barrier construction 30% of Neva discharge passes through the South gates and 70 % - through the North gates in the case of constant western wind. Practically the same distribution was obtained after synchronous measurements from the ships in case of weak western winds: 29% и 71% (Hydrology of the Mouth Area of Neva Bay, Hydrometeoizdat, Leningrad, 1965). Under the modern state on the Barrier simulated ratio of discharges is 50 % and 50%. Measurements of currents, made by Hydroproject in 1991-1993 gave almost the same ratio for the ice-free period: 46% - South gates, 54% - North gates. Under the project state through the South gates according to the calculations will pass 39%, and through the Northern - 61%. These values coincide with results, represented in Feasibility Study of the Barrier (40% и 60%).

Comparison of results shows, that construction of the Barrier caused the decrease of velocities in the northern part of Neva Bay (to the west from the Verperluda Island) and in the northern part of the EGF, except areas around water sluices, near Fort Obruchev and coastal area between Pesochnoe and Repino (Fig.2).

Fig. 2. Izolines of velocity differences (%) in Neva Bay and the Eastern Gulf of Finland between "no Barrier" state and the Design state of the Barrier. Red colors indicate zones where velocities are increased due to the Barrier on more than 5%. Blue colors indicate decrease of velocities on more than 5%. Thick red line is zero izoline. Neva Discharge 2500 m^3/s, west wind 3 m/s



Increase of velocities was observed in the South gate of Neva Bay, near south coast and in the wide area to the west from Kotlin (until West Tolbuhin bank). This result is the same in the project and in the modern situations. Comparison of modern and project states shows that completion of the Barrier will cause increase of velocities in the approaches to the navigation passage C-2 and in the wide area behind it in the EGF. Velocities near the southern coast of Kotlin will increase too. Velocities will decrease in the South gate and to the west from them and also along the southern coast of Neva Bay. It should be noted that velocities will further decrease at the project state in comparison with the modern state in area between the northern coast of Kotlin and the middle part of the dam D-7 in Neva Bay. This area already has tendency to overgrow with macrofites. It is important to consider the necessity of deepening the approaches to B-3.

Consider results of simulations of phosphorus propagation. Neva waters create zones with relatively low phosphorus concentrations in comparison with four zones of high pollution, which are created by the treatment plant outfalls. TP in Petrodvorets creates the highest pollution – rather low amount of waste waters goes into the area of Neva Bay with small veloities and closed whirlpool zones. NTP makes narrow plume of polluted waters, which in the beginning propagates in about 1 km from the coast to the west and envelopes the Verperluda Island from the south. Behind cape Lisiy Nos the plume goes to the coast and than propagates along recreation zone of Repino, than it goes from the coast and moves to the west. The barrier at its modern state turns this plume to the south and causes decrease of pollution from NTP in the recreation zone. The completion of the Barrier will cause return of the NTP plume to its previous position, but the plume after passing through the opening B-6 will become less concentrated. Waste waters from CTP, despite the highest capacity of this plant, enter into the high velocities zone and become diluted very quickly. Without the Barrier this plume enveloped Kotlin mostly from the north (Fig.3), and after the Barrier completion – mostly from the south (Fig.4). Waste waters from SWTP propagate to the south of the CTP's plume and in parallel to it. These two plumes interflow coming to the south-eastern end of the Kotlin Island. Waste waters enveloping Kotlin from the south turn backwards to the east and then to the west in accordance with the current system.

Transition from the state 'no Barrier' to the modern state leaded, besides above mentioned decrease of concentrations near the northern coast of the bay, to decrease of concentrations near the northern coast of Kotlin from Neva Bay side due to moving of plume from CTP to the south. This moving cased increase of concentrations to the south of Kotlin and around it from the west. Pressing of polluted waste waters of TP Petrodvorets to the south coast cased increase of concentrations in this area from Petrodvorets to Bolshaya Izghora. After the completion of the Barrier situations will be practically as before the Barrier near the northern coast of the bay. Only in area Gorskaya-Tarhovka less concentrated and therefore more wide plume will cause increase of concentrations near the shore. Pollution near the western part of Kotlin will increase. The main zone of pollution decrease is area near the north-eastern coast of Kotlin and also in the zone there waters passing through water sluices B-3 and navigation passage C-2.

Fig.3. Steady state phosphorus concentrations (mg/l) in Neva Bay and the Eastern Gulf of Finland without Barrier. Neva Discharge 2500 m^3/s, west wind 3 m/s

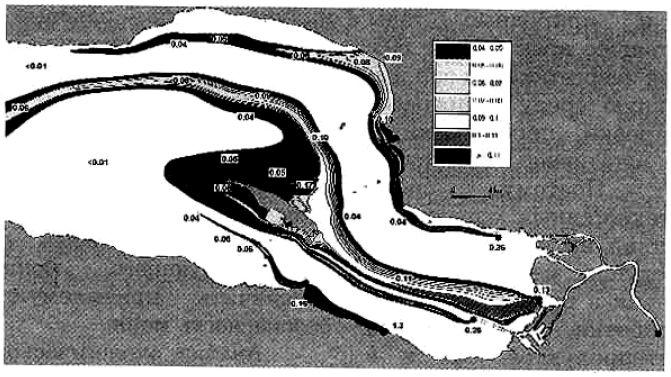


Fig. 4. Steady state phosphorus concentrations (mg/l) in Neva Bay and the Eastern Gulf of Finland with Barrier in the modern state. Neva Discharge 2500 m^3/s, west wind 3 m/s