Larisa Sergeeva

AN ASSESSMENT OF THE POTENTIAL IMPACT OF THE CONSTRUCTION OF A DEEPWATER SEAPORT ON THE HYDROLOGICAL REGIME OF THE VISTULA LAGOON

This article focuses on the level fluctuation in the Vistula Lagoon. In view of the planned construction of a deepwater seaport in its waters, the author emphasises the negative impact on its hydrological regime: rise in the levels which could lead to the flooding of the territories adjoining the mouth of the Pregolya river, increase in salinity, extinction of hydrobionts, and destruction of the ecological systems.

Key words: level fluctuation, surface of reference, storm surges, salinity increase, roiling.

Kaliningrad — the western-most Russian port — is situated in the mouth of the river Pregolya. Vessels enter the Baltic Sea via the Kaliningrad sea canal of a length of 43.15 km, a width of 50—80 m, and a depth of 9—10.5 m.

The development of international maritime traffic and container transport fleet requires further expansion of seaports. In this connection, the Ministry of Transport Fleet of the Russian Federation considers a project of construction of a deepwater seaport, which could receive modern large-capacity vessels with deep draught and introduce container transportation into the transport and technological systems of cargo handling on the basis of modern terminals. It would increase the freight turnover of the port's marine transportation substantially and expand the range of freight transported.

The selection of a site for the deepwater port construction involves a multiaspect solution to a number of problems and, first of all, requires a research-based assessment of the impact of the waterside structure and its operation on the hydrological regime of the Vistula lagoon and the mouth area of the river Pregolya.

The fairway of the designed canal should stretch from the Strait of Baltyisk, past island Nasypnoy to Cape Severny (the Balga Castle area), almost across the north-east part of the Vistula Lagoon, most of which is of a depth of 2—3 m.

The designed length of the canal is more than 10 km, the estimated depth — 18 m, the width — 260 m.

One can assuredly say that the process of seaport construction, its exploitation characteristics and future operation will adversely affect the hydrological regime of the area in question. The consequences can include the flooding of the adjacent territories and industrial facilities, Kant island and the Cathedral, and the deterioration of water supply of the city, the disturbance of ecological balance in marine ecosystems, and the extinction of hydobionts. It will inevitably lead to an unpredictable economic damage and even irreversible environmental implications.

A realistic estimate of the impact requires a brief analysis of the hydrological regime of the water area under consideration.

Its specific feature is the acyclic water level events at the coast of the South-East part of the Baltic Sea in the Pregolya mouth. This phenomenon involves complicated interaction of the sea, lagoon and river waters.

The water level events at the sea coasts and river mouths have been described in a number of works [1—3; 6].

On average, 2—4 cases of storm surges up to the dangerous level of 95 cm BS (BS — the Baltic height system using the Kronstadt datum) are registered in the Pregolya mouth in the vicinity of Kaliningrad annually. Four especially dangerous sea level rises — above 155 cm BS — have been registered over the last 150 years.

Given the absolute maximum of 188 BS (1983) and the minimum of -128 cm BS (1904), the water level fluctuation amplitude is 316 cm. In the coastal part of the Baltic Sea the water level events are more moderate. So, in the vicinity of Baltyisk, water level fluctuation amplitude is 219 cm, given the maximum of 117 cm BS (1983) and the minimum of -102 cm BS (1937).

The water-level events are linked to the passing of cyclones with a steep atmospheric pressure gradient from the Atlantic Ocean over the Baltic Sea at a speed of 50—70 km/h. At the same time, westerly winds, which cause storm surges, reach a speed of 20—25 m/s, with gusts of 30 m/s. The higher the speed of the wind is and the longer it lasts, the steeper is an increase in the energy and the height of a surge. The most frequent recurrence of storm surges is registered in autumn and winter.

Figure 1 shows an extreme case of water-level events in the Pregolya mouth. The dangerous level of 188 cm BS — the absolute maximum — was registered in the vicinity of Kaliningrad on January 19, 1983.

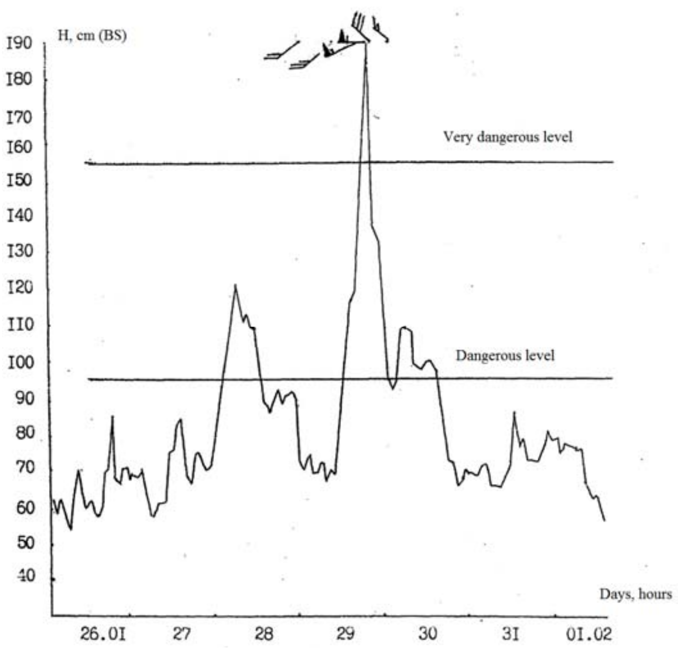

Fig. 1. Hourly fluctuation of the water level in the Pregolya mouth during the period of storm surges from January 26, 1983 to February 1, 1983

The cyclones crossing the Baltic Sea disturb the balance of its water masses. In particular, they form a long wave — a gently sloping rise. The height of such a wave in the central and southern parts of the sea is not more than 30—40 cm and the length is comparable to the dimensions of the sea [1]. The formation of such a wave is facilitated by both the static (the decrease in atmospheric pressure in the cyclone centre) and the dynamic effects (the winds blowing towards the cyclone centre). When moving, the cyclone entrains the wave towards the Strait of Baltyisk.

The further spreading of the storm surge over the mouth area riverbed of the Pregolya and the increase in the water level are caused by a backwater effect of the storm surge coming from the lagoon. During long and high surges, the salty water of the Vistula Lagoon often enters the Deyma (a branch of the Pregolya, 56 km away from the river's mouth) flowing into the Curonian Lagoon, where the excessive flow is discharged.

On average, the speed of the surge wave crest is 6—7 km/h, it increases up to 8—10 km/h in the river mouth as approaching Kaliningrad and decreases to 4—5 km/h in the vicinity of Gvardeysk.

The increase in the water level in the surge period is characterised by two types of surface level fluctuations: wind and wave-related ones.

The wind component determines the denivellation along the longitudal axis of the Vistula Lagoon directed from the South-West to North-East (azimuth 132 — 312º). Under the impact ofsouth-westerly and westerly stormy winds, a rise in water level is registered in one part of the lagoon and a decrease — in the other. A stable slope of water surface emerges; in such cases, the difference in water levels can reach more than 2 m at an average distance of 100—120 km (fig. 2).

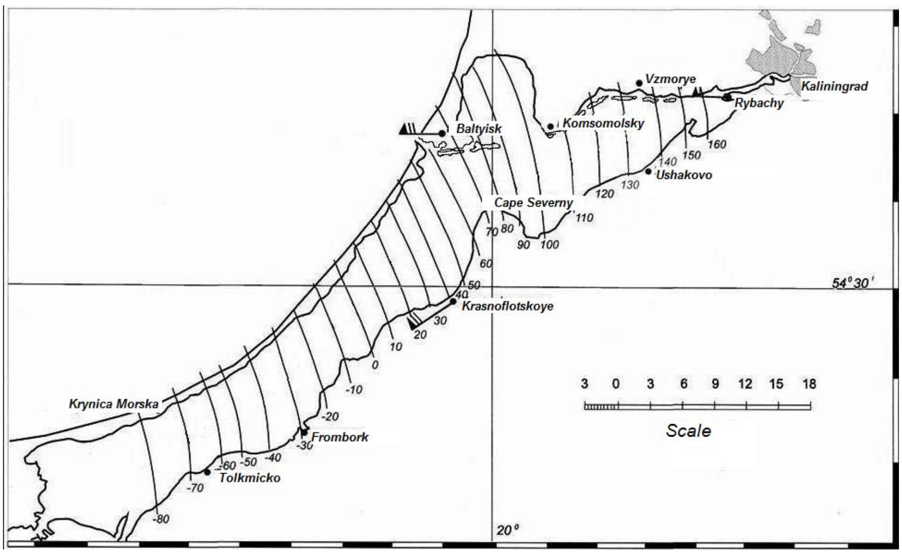

Fig. 2. The topography of level surface of the Vistula Lagoon surface
in the storm surge period on 18 October, 1967 at 7 a.m.

The wave component regulates the water exchange between the lagoon and the sea. It affects the increase and decrease in water level throughout the lagoon. At the same time, the water exchange through the Strait of Baltyisk is characterised by two types of wind currents — incoming and outgoing ones. A contribution into the surge development is made by the incoming wind current, which emerges under the influence of westerly winds and accounts for the water inflow rate Q (m^3/s).

$$Q = V \cdot \acute{\omega},$$

where V — the current speed, m/s;

$\acute{\omega}$ — the area of water section, m^2.

To first approximation, the extent of water exchange through the Strait of Baltyisk can be characterised by the area of water section at Baltyisk, more precisely, by the height position of the level surface in the strait, since the higher the level is, the larger is the area of water flow and, hence, the water inflow rate.

According to the observations, over the last three decades (1970—2000), the level increased throughout the analysed water area. The rise was considered eustatic, since it was caused by the increase in water inflow through the Denmark Straits as a result of the strengthening of the western form of atmosphere circulation [3].

The data obtained correspond to the results of the official forecast developed by the Intergovernmental Panel on Climate Change (IPCC). Thus, according to the moderate — the most probable — scenario, the sea level will have risen by 18 cm by 2030; the rise intensity will amount to 4.5 mm/year or 2mm/year in the Baltic Sea [8].

A rise of water in the Pregolya to extremely dangerous levels of 200 cm BS and higher is possible once in 100 years [5].

According to the archived data, severe storms were monitored over the Baltic Sea and a heavy flood in the mouth of the Pregolya from April 7, 1829 to April 14, 1829. The ground floor of one of the buildings of the Königsberg University, situated in the North-West part of today's Kant island, was flooded. The whole island was affected, since the water level rose above the waterfront structures.

The analysis of the impact of the designed waterside structure parameters on the hydrological regime of the studied areas helped identify the negative and possibly irreversible implications. Let us consider the results obtained.

Given the currently maintained navigation depth at the entrance of the Strait of Baltyisk of 10.5 m (in contrast to the planned 18 m) and a width in the bed of the canal of 260 m, as well as the deepening of the canal slopes, the area of water flow will increase, which will lead to a rise in the water inflow rate. It will ensure unimpeded inflow of sea waters and contribute to an increase in the water content throughout the Vistula Lagoon. The level surface position will overtop the average values registered over many years. In view of the high water content of the lagoon, even a small surge (accounting for a 30—40 cm water level increase in the course of water level events) can cause a dangerous water level rise, i. e. the higher the initial level is, the more dangerous water level events of any intensity are.

The implications may include the flooding of the adjacent territories and disturbance of the operation of the industrial facilities situated along the river up to its cessation. It is established that, at a level of 95 cm BS and higher, when westerly winds gain storm force and the incoming current increases, the vessels passing the Kaliningrad sea canal list heavily and are drifted across the canal, which poses a threat of hitting the shoreline. Moreover, the power supply units of navigation equipment might be flooded in such conditions.

As we know, in Kaliningrad, water supply depends on the level regime of the mouth area of the Pregolya. Observations prove that, in the period of water-level events, when the river course reverses, chlorides and roiled water get into the water intake structure. It happens not only at a level of 95 cm BS, but also at lower levels, which can affect drinking water supply to the city. A more frequent recurrence of water-level events increases this danger.

Moreover, several complications relate to a less studied object of the hydrological regime — the lagoon currents. The assessment of current velocities helps register erosion of cohesive soils and deterioration of the designed canal edges.

Storm surges increase the specific energy of the stream E, which is in direct proportion to the greatest depth h and the current velocity v^2:

$$E = h + \alpha v^2 / 2g,$$

where h is the greatest depth in the given section z;

v is mean current velocity;

α is a coefficient accounting for the influence of uneven distribution of current velocities in the water section on the stream energy;

g is gravitational acceleration.

It is difficult to forecast the sediment accumulation rate in the fairway of the designed canal, which will not be protected by dikes. Westerly stormy winds will determine the direction of water streams rich in silt and sand particles through the canal's fairway rather than along it. The fairway will play the role of a sedimentation tank, where, as the depth increases and the speed of the water stream decreases, suspended and near-bottom particles will settle. It will contribute to the siltation of the canal. These circumstances will require annual repair cleaning in the deep fairway, and its cost may exceed similar exploitation costs of the whole Kaliningrad sea canal.

The absence of dikes increases the threat to safe navigation during moderate and harsh winters, when the maximum thickness of ice in the lagoon can reach 70 cm. Drifting ices pose another obstacle to navigation.

The roiling of water masses, an increase in salinity, and noise pollution will have an adverse affect on the life and reproduction of marine organisms. One cannot exclude that the diking of deepwater fairway will affect migration routes of fish (salmon, eel, pikeperch, etc) from the Baltic Sea to the Vistula lagoon and back.

An optimal solution to most of these problems could be the creation of an autonomous water area of the deepwater port with a direct entrance to the Baltic Sea, which would not be connected to the lagoon.

As to the engineering aspects of the solution, a number of experts suggest using a part of the water area of Primorsky Bay, isolated from the lagoon by a 7-km impermeable dike. The exit to the Baltic Sea can be reconstructed at the site of the Strait of Lochstädt.

This variant also eliminates the need to consider the issues relating to the protection of the city from flooding.

As a result, an isolated basin of moderate depth, with the help of dredging, can become a site for harbour and moorage construction, providing sufficient amount of soil for the development of an industrial zone, building of a dike, and road construction.

Similar works were performed during the construction of port terminals of OOO Lukoil-KMN.

To ensure the connection between Kaliningrad and Baltyisk, it is reasonable to build a railroad and a motorway on the crest of the dike. Experts believe that the northern and southern slopes of the dike should be strengthened in view of the depths, and wave and ice loads in order to protect it from natural impacts and dynamic forces relating to the operation of all means of transport. It is suggested that the feet of the slope should be strengthened with Larssen sheet piles to prevent the sliding of soils from the dike and the exit to the Baltic Sea protected with breakwaters. The construction of a new breakwater will be more rational than the revision of the parameters of those built in Baltyisk in the course of the recent repair and reconstruction works. Moreover, the entrance and exit of vessels will be easier due to the absence of currents, which pose an obstacle to navigation in the Strait of Baltyisk.

The construction of a port with an autonomous exit to the Baltic Sea will not affect the operation of the existing port terminals and navigation of vessels.

Due to the difficult hydrological conditions of the Vistula lagoon, designers cannot come to a certain decision. This gap should be filled through building a hydraulic model, which will give adequate answers to the existing questions.

Comprehensive consideration of all possible variants of the engineering approach to the problem, their economic justification and comparative analysis will help to make the best decision in view of the main objective, i. e. maintaining the hydrological regime of the Vistula lagoon — a unique natural site.

References

1. *Volcinger, V. E. Pjaskovskij, R. V.* 1977. Teorija melkoj vody. Leningrad.

2. *Velander, P.* 1964. Chislennoe predskazanie shtormovyh nagonov. Leningrad, pp. 10—46.

3. *Sergeeva, L. G.* 2005. Povyshenie urovennoj poverhnosti morja i temperatury vozduha v jugo-vostochnoj chasti Baltijskogo morja kak projavlenie global'nyh processov. In: Bezopasnost' moreplavanija i nadezhnost' sudovyh tehnicheskih sredstv. Saint Petersburg, pp. 180—185.

4. *Sergeeva, L., Krasnov, E.* 2001. The Baltik — Sea-level events in the system of global change. Third Study Conference on BALTEX. Assembly Hall of Alands Parlament Building Mariehamn, Aland, Finland, pp. 119—120.

5. *Sergeeva, L. G.* 2003. Mehanizm nagonnyh javlenij i ego osobennosti u poberezh'ja juzhnoj chasti Baltijskogo morja. In: Jekologija regiona Baltijskogo morja. Kaliningrad, pp. 12—18.

6. *Inzhebejkin, Ju. I.* 2003. Kolebanija urovnja Belogo morja. Ekaterinburg.

7. *Davydenko, L. I., Ljadvik, N. S.* 2001. Kaliningradskij morskoj kanal. Kaliningrad.

8. *Mihajlov, V. N.* 1998. Geografija, №37, pp. 1—3.

About author

Dr Larisa Sergeyeva, Associate Professor, Baltic State Fishing Fleet Academy.

E-mail: ecogeography@rambler.ru