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# FLOW-3D software for substantiation the layout of the port water area

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**Abstract.** It is necessary to exclude the occurrence of significant waves in the inner water area of the port and at the berthing facilities when designing breakwaters. The article presents the results of the calculations of water movement in the harbor area. The most secure options for the location of the port entrance and its size for a given object were identified. The possibility of using the FLOW – 3D program to select planned and constructive solutions at the stage of the preliminary layout of the port water area is substantiated.

## 1. Introduction

It is necessary to arrange the territory of the port with the choice of the most rational configuration of the mooring line and layout of the port water area when designing the port. The layout of the port water area in the Russian Federation is carried out following the requirements of the design standards for sea channels, fairways, and maneuvering zones, containing specifications for port water area elements [1, 2].

Port waters should be protected from waves, sediment accumulation, and ice.

When compiling the port plan, such a degree of protection of the water area from waves must be provided that normal conditions are created for the mooring of ships during loading and unloading and other port operations, as well as during maneuvering and offshore moorage of ships. Design decisions are made based on physical or mathematical modeling when designing a new or developing an existing port [2].

The calculated parameters of the water flow in port water areas are recommended to be taken on the basis of the results of hydrometeorological surveys, long-term field observations, and laboratory studies. If the engineering-hydrometeorological survey data are insufficient, the wave parameters of the design storm can be determined on the basis of calculation methods. The conformity of the used calculation methods to the methods (models) adopted for the same purposes in international practice is recommended to be shown [3].

## 2. Methods

The structure of the seaport and its layout design includes calculation of diffraction (attenuation) of waves penetrating through the entrance to the port water area protected by breakwaters. The problems associated with the propagation of waves and currents in a protected water area, taking into account the choice of the optimal location of the breakwaters, have rather complicated solutions or are currently not fully solved [4-6].

In general, the wave regime in harbors is affected by diffraction of waves at breakwaters; wave transformation and refraction at decreasing depths; reflection of waves from structures and steep banks; interference of waves in water areas.

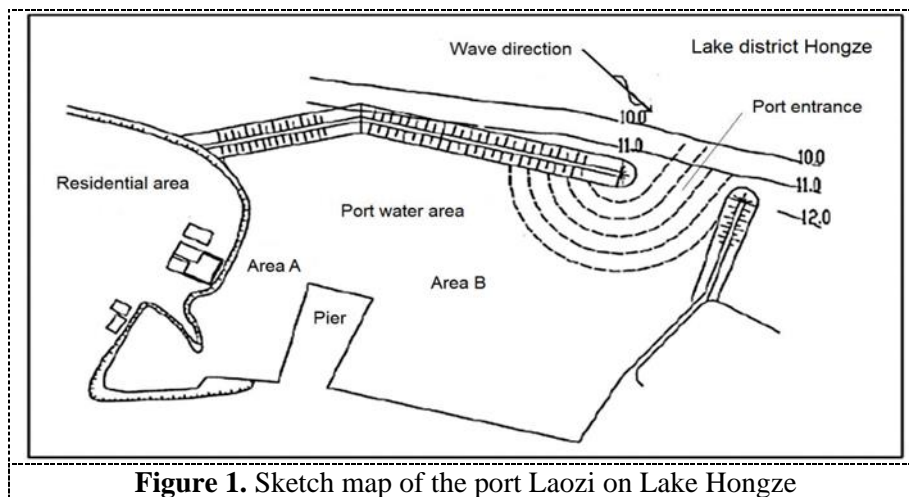


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Breakwaters should be predominantly straightforward, preferably at shallow depths; the most common is the use of two converging breakwaters. The orientation of the port entrance (port gates), taking into account the prevailing winds and the direction of the shoreline is a difficult decision. The results of experimental or mathematical studies substantiating design decisions for specific hydraulic objects are presented in the scientific and technical literature mainly [7–13].

The main purpose of this article is to justify the use of the FLOW-3D program when choosing of breakwaters location at the preliminary design stage. FLOW-3D is a high-performance simulation tool that can be applied to various engineering areas based on various physical models defined by the user [14-16]. FLOW-3D can describe complex flow motions, and methods for constructing blocks from several grids can significantly increase computational efficiency [17-19]. FLOW-3D provides high-precision modeling of flows with a free surface using the finite volume method [20].

The port Laozi on Lake Hongze in the PRC was chosen as the object. The influence of the different positions of the entrance gate to the port on the movement of water flows in a protected port water area was considered. Figure 1 shows the port plan.



**Figure 1.** Sketch map of the port Laozi on Lake Hongze

The initial data for the design are:

design wind speed of 20 m/s;

design wave height 1.0 m; period  $T = 5$  s;

design water levels: lowest water level – 11.50 m; operating (construction) level – 12.00 m; highest water level – 15.00 m.

**Table 1.** Presents the five variants for placing the port entrance

Variant	The location of the port entrance (the location of the entrance between breakwaters)	Entry width, m
1	At the top	40
2	Double entry	40
3		40
4	In the lower part	20
5		60

Figure 2 shows the location of the port entrance on Lake Hongze.

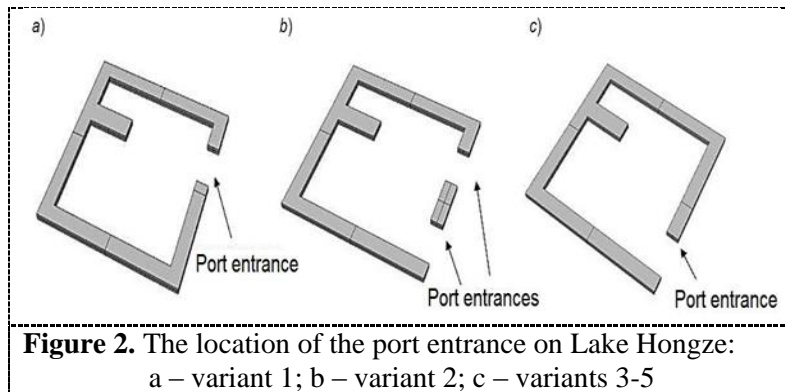
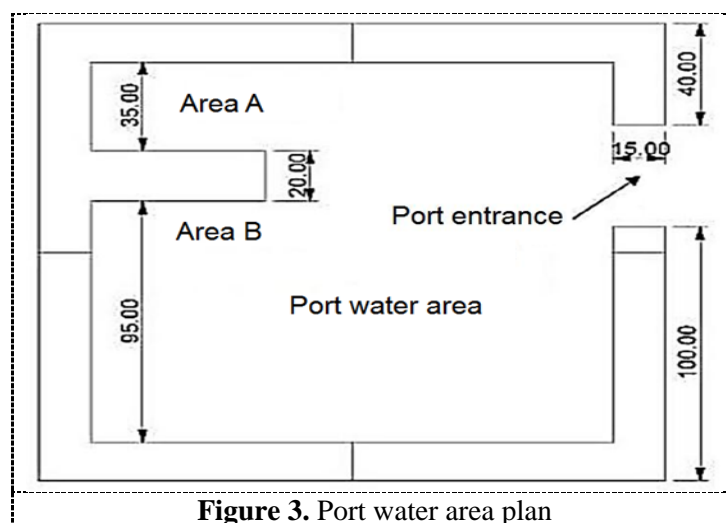


Figure 3 shows all the plan dimensions of the port water area used in the calculations.



The objectives of the work are:

investigation of the movement of water flow in a harbor;

study of conditions for safe mooring and maneuvering of ships;

substantiation of the size of the entrance gate to the port and its planned position.

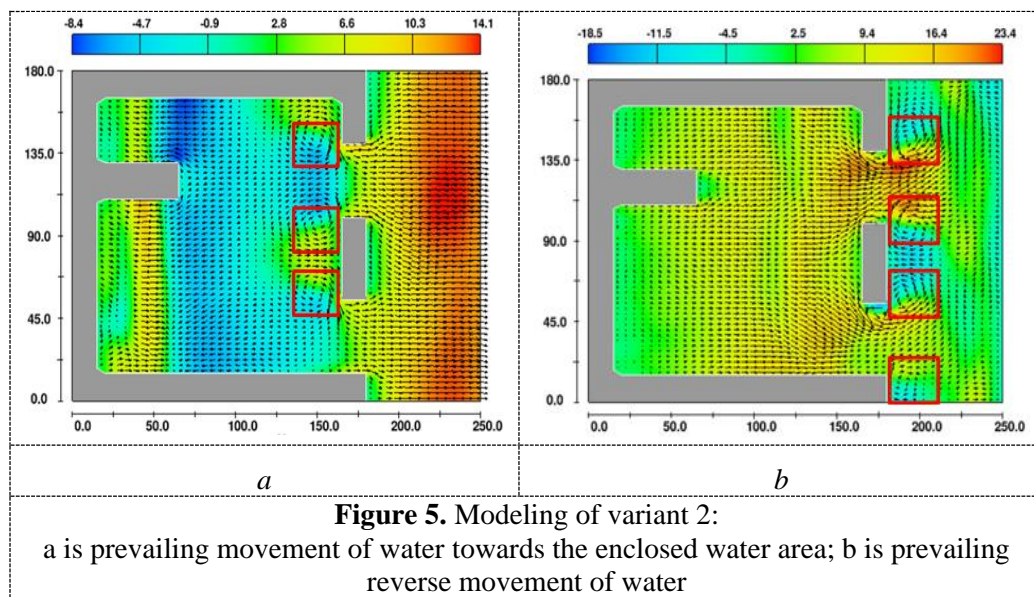
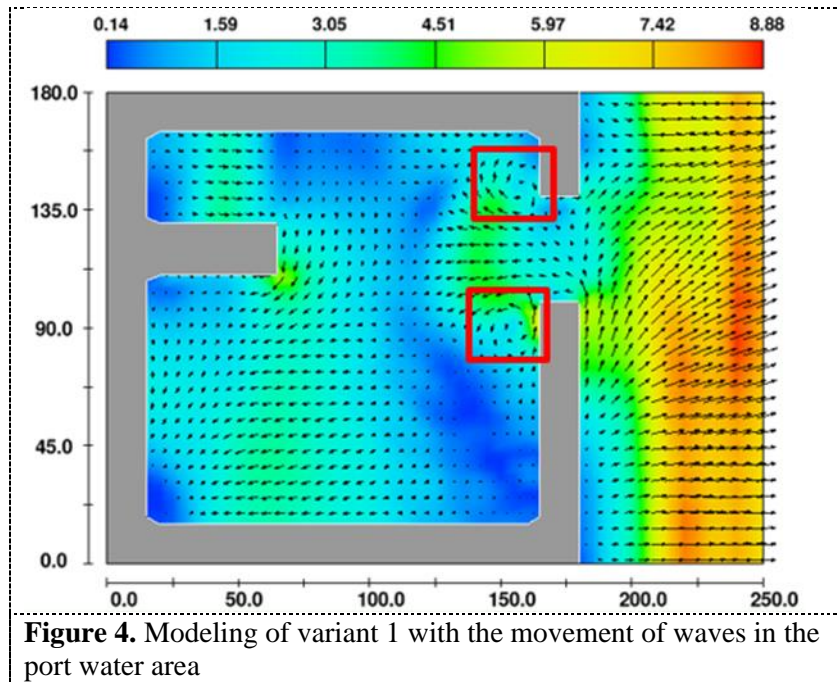
### 3. Results and Discussion

#### 3.1. Investigation of water flow movement in the harbor

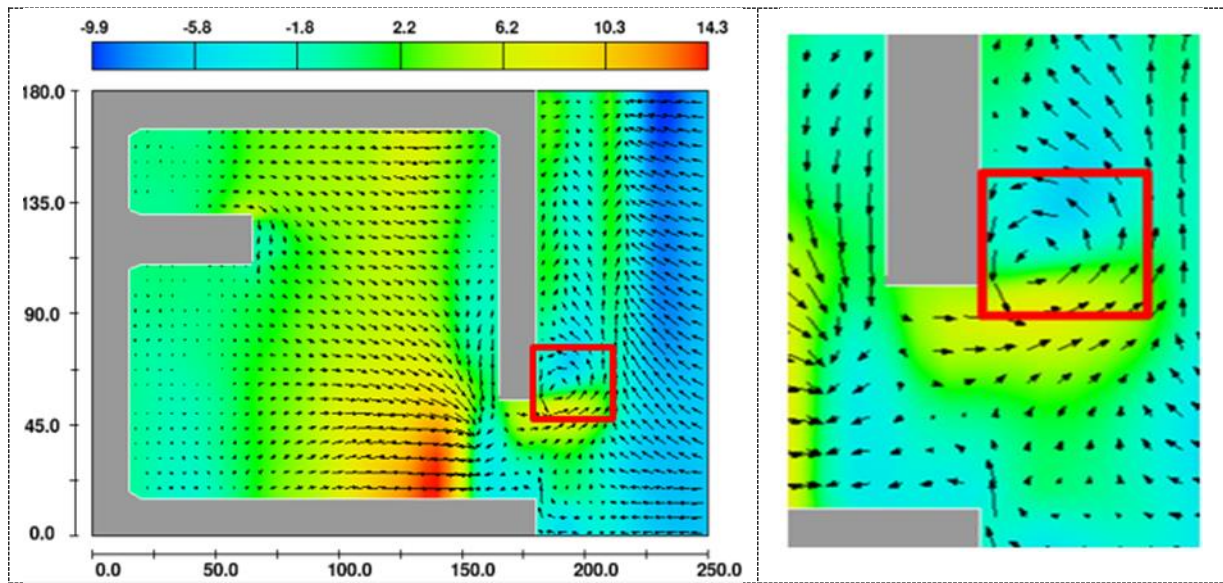
Consider the results of modeling the flow velocities distribution for all the proposed location variants of the port entrance (Figures 4-7).

Figure 4 shows the simulation results of variant 2 of the port entrance location. At the rear of both breakwaters, two areas of water circulation are formed.

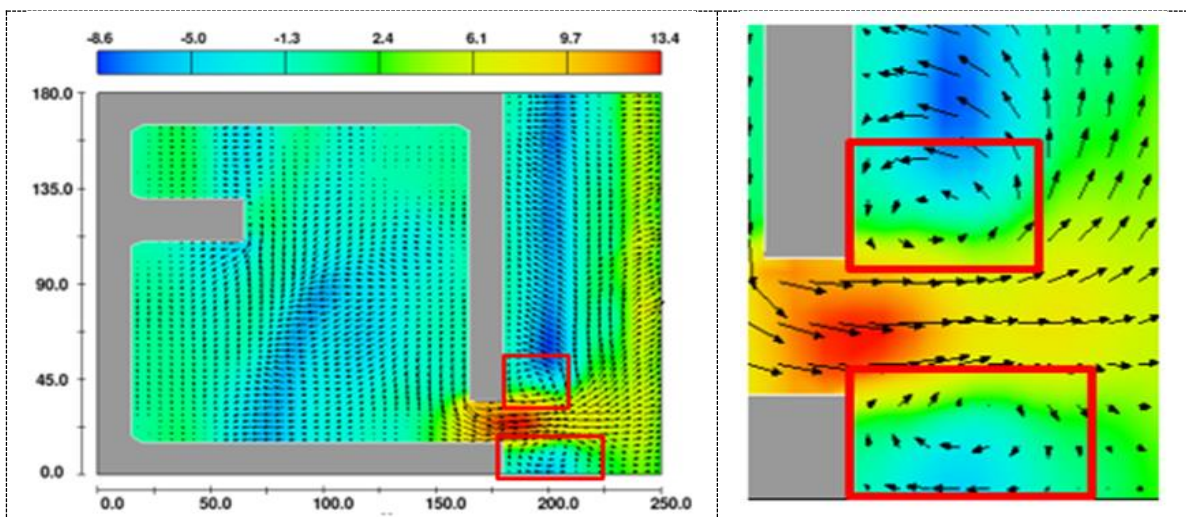
Figure 5 presents the modeling process of variant 2 with two entries to the port. It is seen from the presented results that three areas of water circulation form on the rear sides of the breakwaters during the prevailing movement of water towards the enclosed water area. And four zones of water circulation form on the front side of the protecting structures during the prevailing reverse movement of water.



Figures 6 and 7 show the velocity distribution for variants 3 and 4, which differ in the width of the entrance. A comparison of the variants shows that the circulation area increases with a decrease in the width of the port entrance gate.

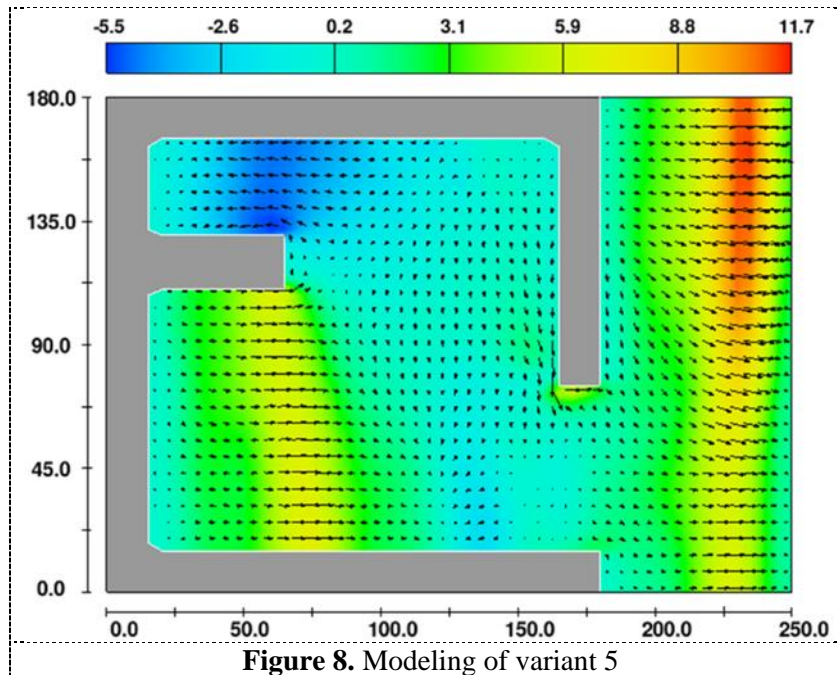


**Figure 6.** Modeling of variant 3



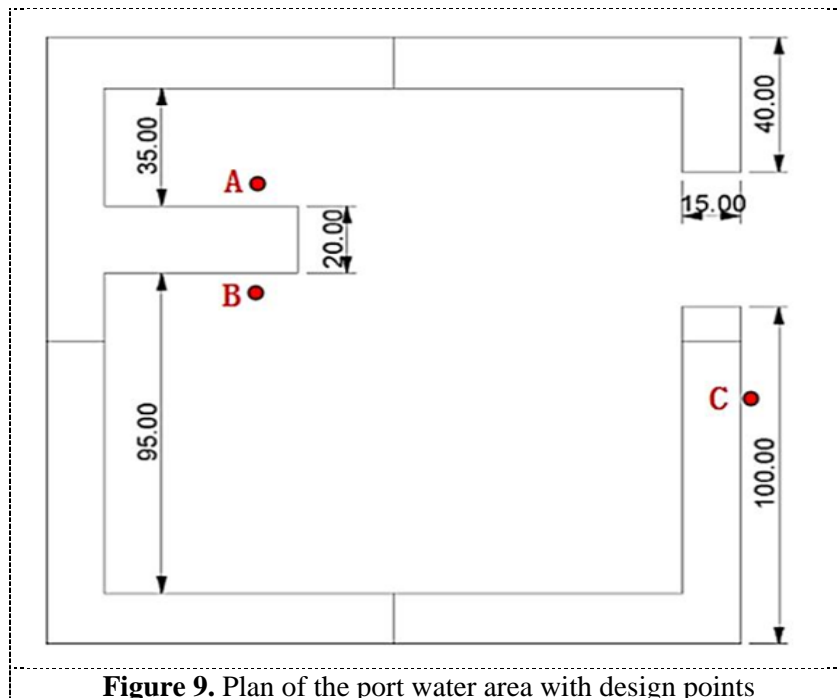
**Figure 7.** Modeling of variant 4

Breakwaters practically do not influence the diffraction of waves with an increase in the entrance width to 60 m, and waves from the open sea practically do not change upon entering the inner water area (Fig. 8).



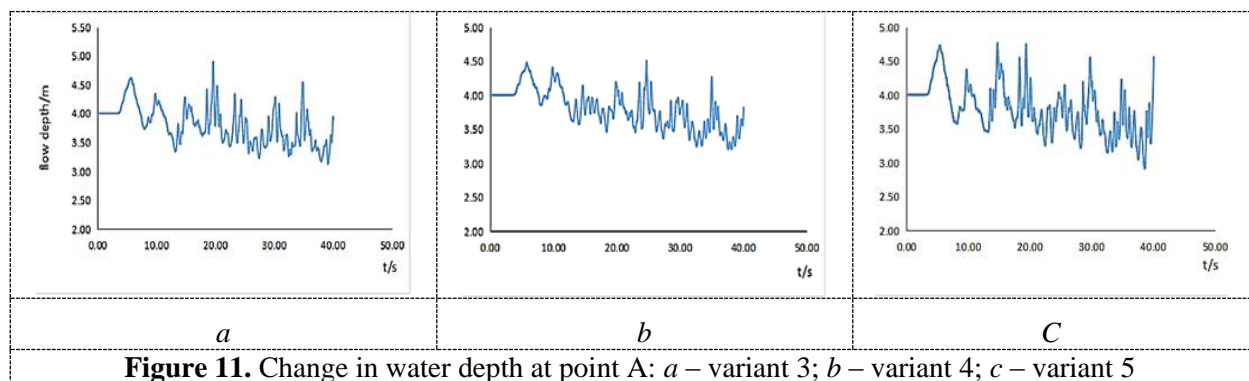
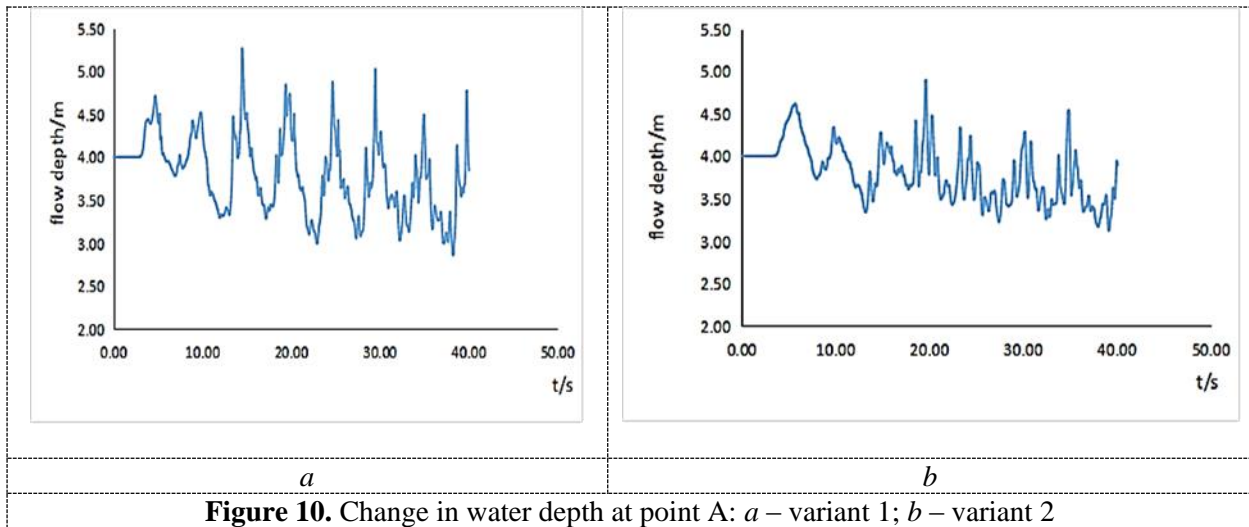
*3.2. Mooring conditions study*

One of the main functions of the breakwaters is to counteract sea waves and ensure safe mooring conditions in the port. In the work, the possibility of mooring at several points with an allowable wave height  $h < 1.5$  m was evaluated (Figure 9).



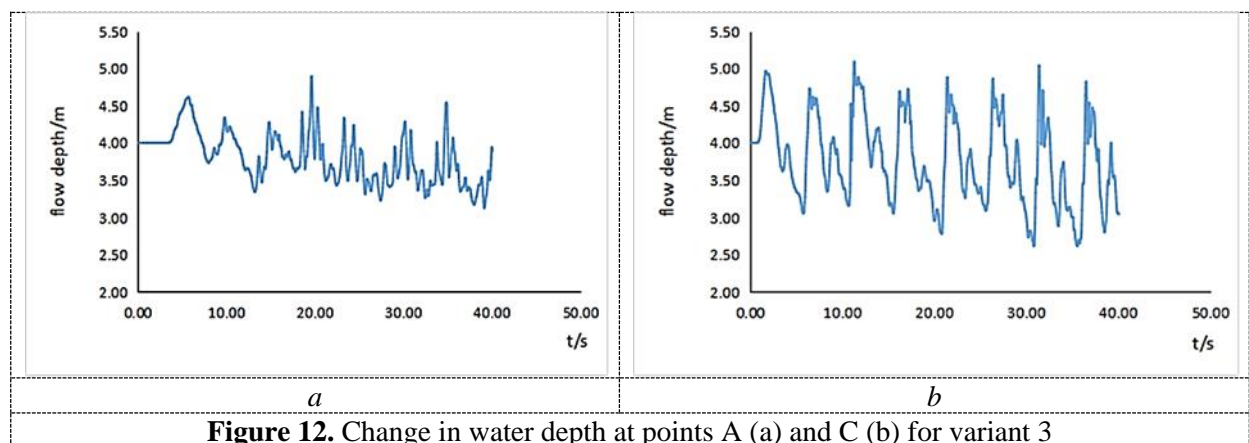
Figures 10-13 show the results of calculations to determine the depth at the points of the water area with different parameters of the port entrance.

Figure 10 presents a comparison of wave conditions for point A with the location of the entrance according to variants 1 and 2. Figure 11 shows a comparison of variants 3, 4, and 5, which differ in the port entrance width.

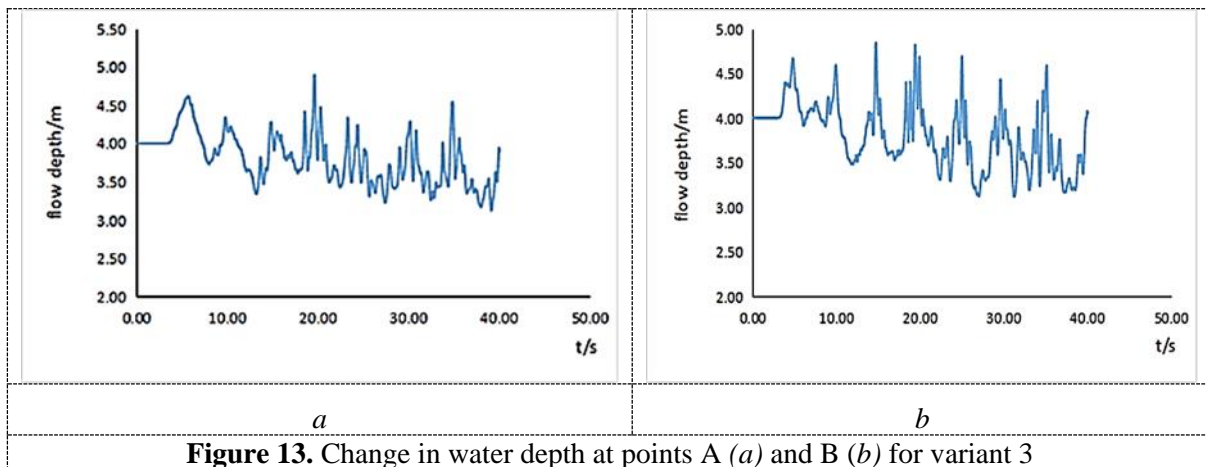


An analysis of Figures 10 and 11 shows that mooring point A satisfy the mooring conditions for both variants 3 and 4.

The general wave-breaking effect is shown in Figure 12.



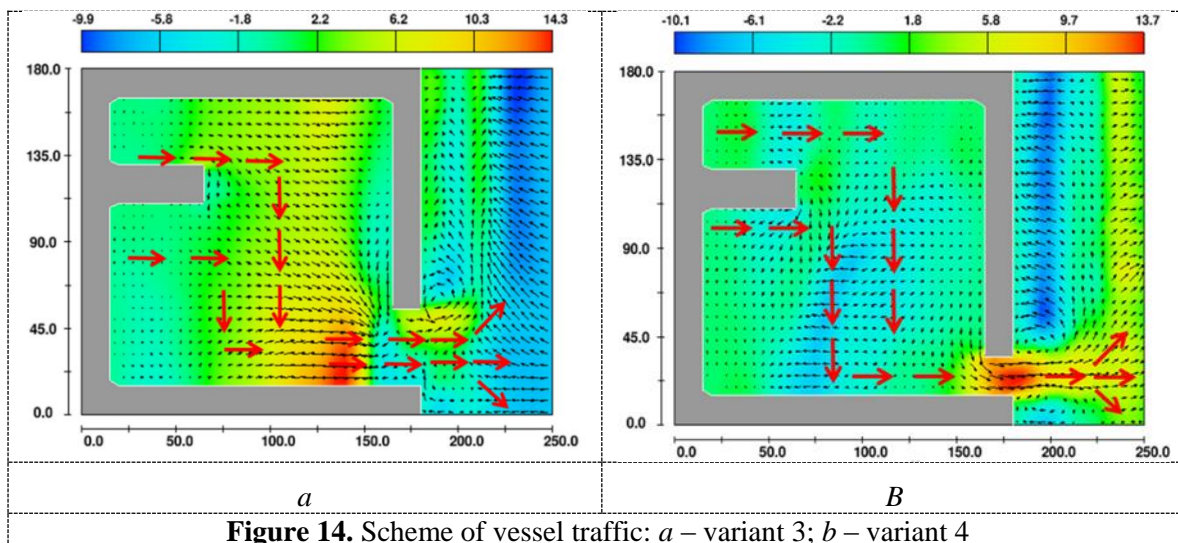
An analysis of the mooring conditions at the pier is shown in Figure 13.



When comparing the changes in the water depth at points A and B for variant 3, it can be seen that the wave height at point B is much higher than at point A, since when the entrance is located in the lower part (see Fig. 1), the wave first reaches point B.

**3.3. Substantiation of port entrance parameters**

The impact of the entrance gate dimensions and their position in the plan on the safety of navigation was evaluated. Figure 14 shows the movement patterns of the vessel when leaving the port.



A comparison of variants 3 and 4 shows that the entry and exit of vessels with the narrowest port gate width is the most difficult and does not provide conditions for safe maneuvering.

**4. Conclusions**

Based on the study, the following conclusions can be drawn:

1. Five modeling variants were created to calculate and analyze the state of water movement near the entrance gate and in the port water area for the conditions of Laozi port on Lake Hongze. The breakwaters do not sufficiently affect the excitement, which makes the mooring conditions in the port water area difficult in cases where the entrance to the port is located in the upper part and with the double entrance. The mooring condition in the port water area improved significantly, especially in the

area of point A at the pier when the entrance was located in the lower part. Mooring conditions are better here than at point B.

2. Many conflicting factors affect the choice of the optimal port entry width. If the width of the entrance is small, this can create a dangerous circulation zone near the entrance, which does not satisfy the requirements of shipping. A wide entrance is most convenient from the point of view of ensuring the safety of navigation, but it cannot prevent the penetration of waves from external to internal water, which worsens the conditions for maneuvering and mooring.

3. Variant 3 provides the most convenient and safe conditions for entry, maneuvering, and mooring of vessels in the port.

The results justify the possibility of using the FLOW-3D program for the selection of the breakwaters location and the port entrance configuration at the preliminary design stage.

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