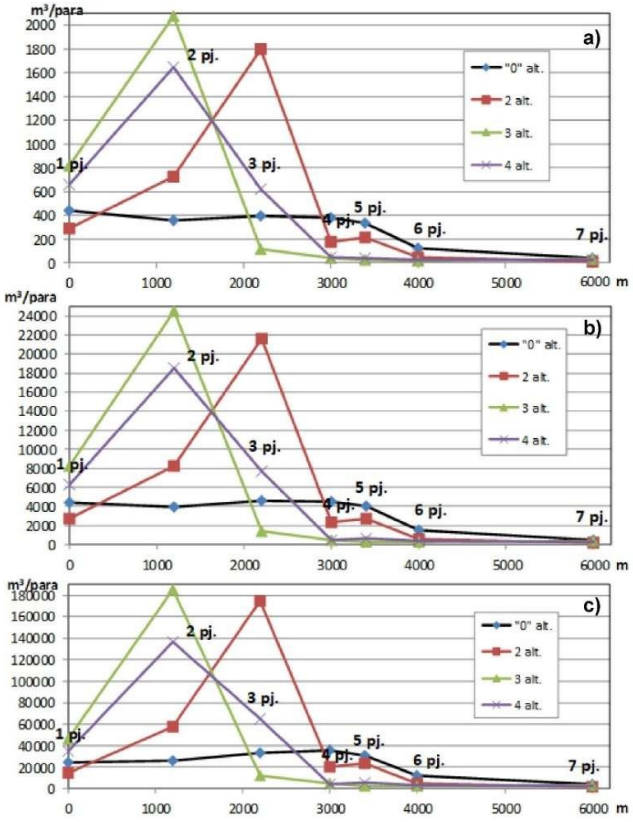
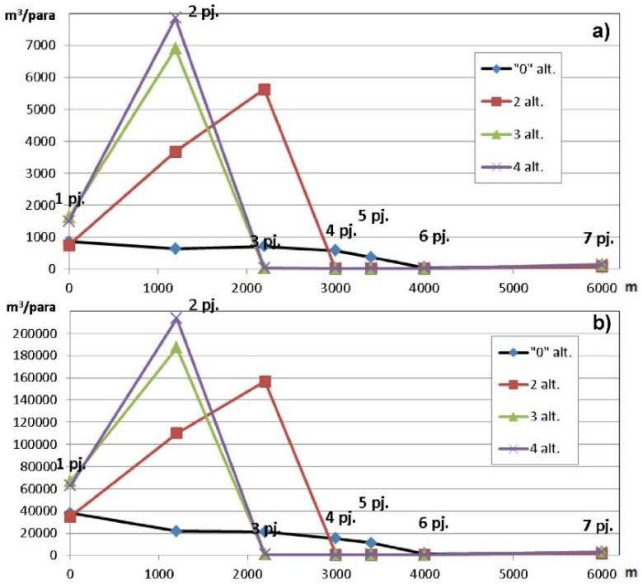


4.1.2.32 Fig. Variation in the Nešmenai discharge (m³/day) in the port basin (the locations of 7 cross-sections are shown in Fig. 4.1.2.22b), when 1,620 (a), 2,700 (b) and 4210 m³/s (c)



4.1.2.33 Fig. Variation in sediment discharge (m³/s) in the port basin (7 cross-section locations shown in Fig. 4.1.2.22b) when a flow of 1725 (a), 3206 m³/s (b)

Changes in the transport of suspended sediments (silt) in the Klaipėda Strait and the northern part of the Curonian Lagoon

Suspended sediment flow modeling was performed by LEI specialists using the MIKE 21 MT model with flow directed only from the Curonian Lagoon to the Baltic Sea, as the majority of sediment entering the strait from the sea consists of bedload (sand).

Most of the turbid water entering the Curonian Lagoon comes from the Nemunas River. Based on long-term observations of the Nemunas near Smalininkai, it was determined that the average long-term concentration of suspended solids (water turbidity) is 0.039 kg/m³; in spring – 0.044 kg/m³, in summer and autumn – 0.027 kg/m³, and in winter – 0.019 kg/m³. Therefore, suspended sediments were modeled at initial concentrations of 0.04 kg/m³ when flow rates of 660, 950, 1620, and 2700 m³/s pass through the strait.

With a flow rate of 660 m³/s from the lagoon to the sea and an initial concentration $_{of\ Cpr}$ = 0.04 kg/m³, the distribution of water turbidity for different PŪV alternatives is shown in Figures 4.1.2.34–4.1.2.35. Flow velocities in the strait and the lagoon are very low (up to 0.2 m/s), so sediment particles accumulate in the northern part of the lagoon (from the boundary of the model to Section 1, Fig. 4.1.2.22). Turbidity concentrations in the Klaipėda Strait for various PŪV alternatives decrease very rapidly from 0.04 kg/m³ in the northern part of the lagoon to 0.00005 kg/m³ at section 7 in the Klaipėda Strait (Fig. 4.1.2.34b). For different PŪV alternatives, the distribution of turbidity concentrations in the planned southern port entrance water area differs only slightly, while in the Klaipėda Strait (Section 7), turbidity values are already zero.

At the average annual flow rate (950 m³/s) and with $_{Cpr}$ = 0.04 kg/m³, flow velocities in the strait increase to 0.4 m/s. Turbidity concentration varies from 0.04 kg/m³ in the northern part of the lagoon to 0.010 kg/m³ at Section 7 for Alternative 0 and to 0.007–0.009 kg/m³ for the other three PŪV alternatives (Figs. 4.1.2.36–4.1.2.37). At flow velocities greater than 0.3 m/s, erosion of the water body's bottom will occur in the planned southern port entrance basin, resulting in an increase in flow turbidity. Depending on the selected PŪV alternative, the nature of water turbidity in the channels of Kiaulės Nugaros Island will change. In the case of Alternatives 0 and 2A, a higher concentration of suspended solids will be observed in the western channel, while in the case of Alternatives 3A and 4A—in the eastern channel.

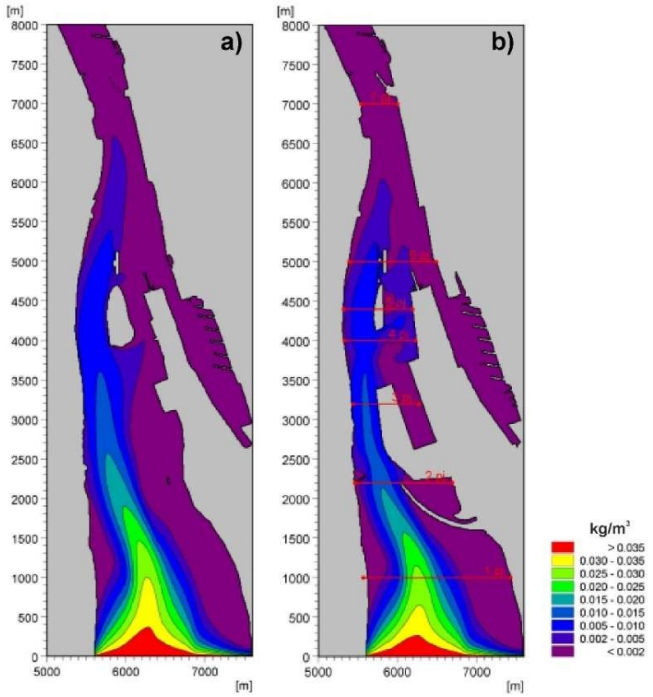
Significant differences in turbidity concentrations will occur between the northern part of the lagoon and Section 7 in the Klaipėda Strait when higher water flows from the Curonian Lagoon to the Baltic Sea. At a flow rate of 1,600 m³/s and $_{a\ Cpr}$ of 0.04 kg/m³, the turbidity concentration varies from 0.04 kg/m³ in the northern part of the lagoon to 0.025 kg/m³ at Section 7 in Alternatives 0 and 3A, and to 0.020–0.024 kg/m³ in Alternatives 2A and 4A (Figs. 4.1.2.38–4.1.2.39). At a flow rate of 2,700 m³/s, the turbidity concentration in Alternative 0 ranges from 0.04 kg/m³ in the northern part of the lagoon to 0.035 kg/m³ at Section 7, while in the remaining three PŪV alternative cases, it ranges from 0.030 to 0.033 kg/m³ (Figs. 4.1.2.40–4.1.2.41). During high flow rates, in the case of Alternative 0, water masses with high turbidity concentrations flow through the northern part of the lagoon and, after passing through the channels (especially the western channel), enter the Klaipėda Strait. In the case of the PŪV alternatives, the turbidity concentration changes significantly and redistributes from the planned southern port gates to the LNG terminal's water area in the Klaipėda Strait.

The distribution of settled sediments on the seabed of the strait is well reflected by the simulated average sediment accumulation values in the vertical direction (g/m²). At a flow rate of 660 m³/s and $_{a\ Cpr}$ of 0.04 kg/m³, the distribution of sediment accumulation values over a 12-hour period is similar for all PŪV alternatives (Figs. 4.1.2.42–4.1.2.43). Larger amounts of sediment (up to 600 g/m²)

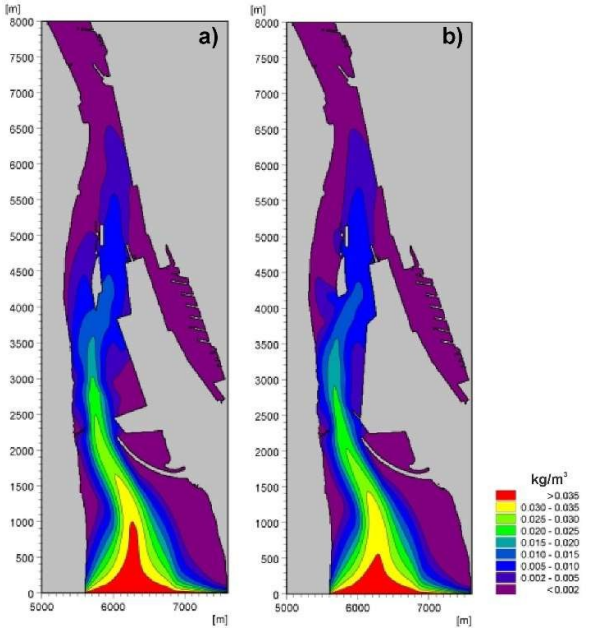
will accumulate only in the northern part of the Curonian Lagoon. At a flow rate of 950 m³/s, in Alternative 0, sediment will accumulate in front of and behind Kiaulės Nugaros Island. The largest water area where sediment accumulation is possible was identified when the port expansion is carried out according to Alternative 3A. This is the water area from the planned southern port gates to Kiaulės Nugaros Island and the eastern and western channels (Figs. 4.1.2.44–4.1.2.45). The impact of Alternative 4A on sediment accumulation is smaller, so less sediment will accumulate in the channels of Kiaulės Nugaros Island.

At a flow rate of 1,620 m³/s and a_{Cpr} of 0.04 kg/m³, in the case of Alternative 0, sediment accumulation will occur in the Klaipėda Strait LNG terminal water area and in the eastern channel near Kiaulės Nugaros Island. In the case of Alternatives 2A, 3A, and 4A, the locations of sediment accumulation would be in the northern part of the lagoon (Figs. 4.1.2.46–4.1.2.47). In the case of Alternative 2A (the ship turning area south of Kiaulės Nugaros Island and the eastern channel), where sediment accumulation may reach up to 1,000 g/m². In the case of Alternative 3A, sediment will accumulate in the eastern part of the lagoon from the southern gates to Kiaulės Nugaros Island and in the western channel. Sediment accumulation would be lower in the case of Alternative 4A, as there will be less sludge accumulation in the western channel.

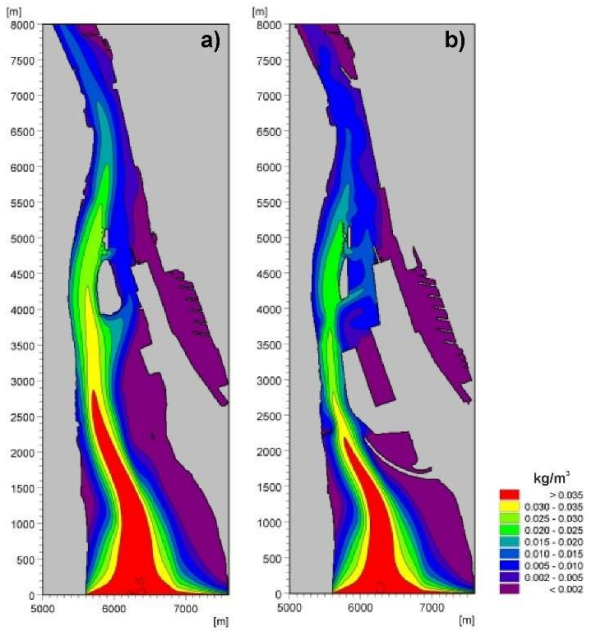
The identified trends will intensify at a flow rate of 2,700 m³/s (Figs. 4.1.2.48–4.1.2.49); sediment volumes will be higher and more concentrated in smaller water areas, while water with higher turbidity will flow through the fairway into the Baltic Sea. Sediment accumulation trends are determined by flow velocities in the study area. During high discharge rates, the flow velocity can vary between 0.2 and 1.0 m/s, which reduces the area of sediment accumulation in the water bodies, as the sedimentation rate often does not exceed 0.3 m/s.



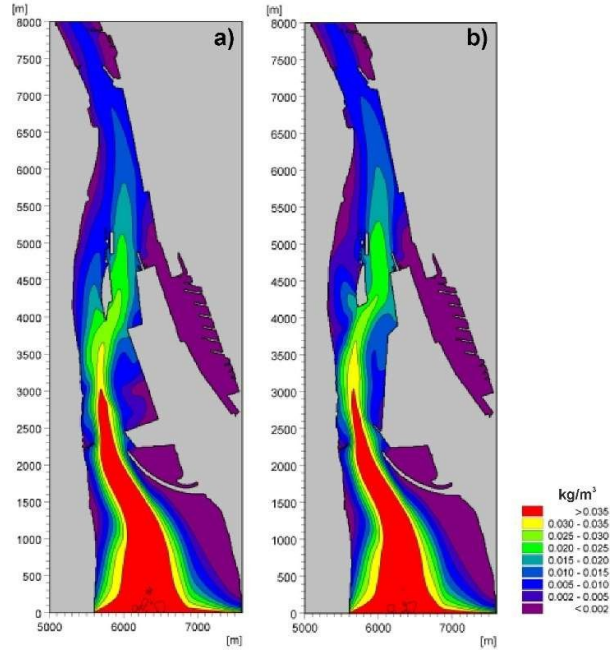
4.1.2.34 Fig. Distribution of turbidity ($^{kg/m^3}$) in the Klaipėda Strait and the northern part of the Curonian Lagoon for alternative scenarios 0 (a) and 2A (b), where a flow rate of 660 m³/s flows through the strait from the Curonian Lagoon into the Baltic Sea (initial turbidity concentration is 0.04 $^{kg/m^3}$)



4.1.2.35 Fig. Turbidity ($^{kg/m^3}$) distribution in the Klaipėda Strait and the northern part of the Curonian Lagoon for Alternatives 3A (a) and 4A (b), when a flow rate of 660 m³/s flows through the strait from the Curonian Lagoon into the Baltic Sea (initial turbidity concentration is 0.04 $^{kg/m^3}$)

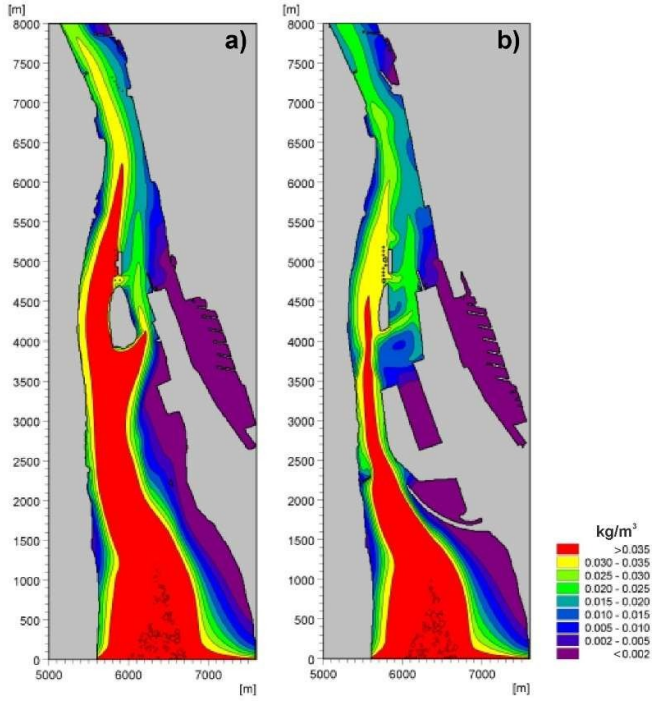


4.1.2.36 Fig. Distribution of turbidity ($^{kg/m^3}$) in the Klaipėda Strait and the northern part of the Curonian Lagoon for Alternatives 0 (a) and 2A (b), when a flow rate of 950 m³/s flows through the strait from the Curonian Lagoon into the Baltic Sea (initial turbidity concentration is 0.04 $^{kg/m^3}$)



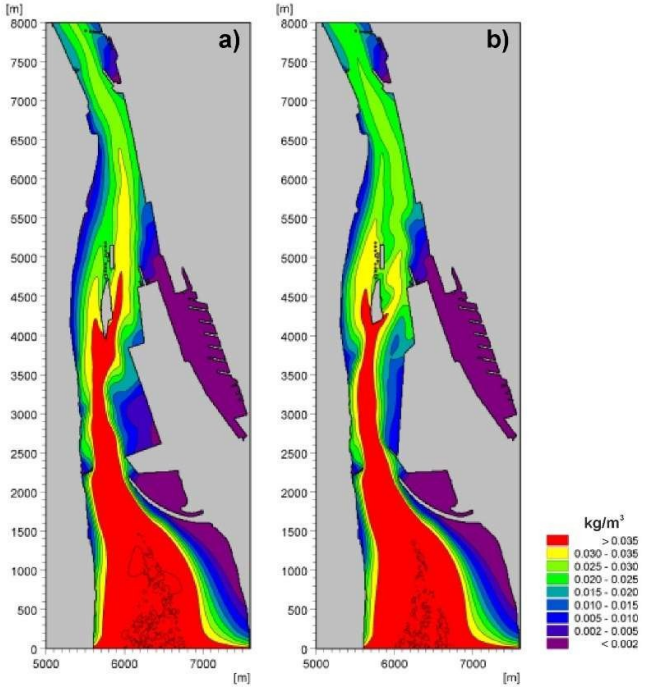
4.1.2.37 Fig. Turbidity ($^{kg/m^3}$) distribution in the Klaipėda Strait and the northern part of the Curonian Lagoon for alternatives 3A (a) and 4A (b), when a flow rate of 950 m³/s flows through the strait from the Curonian Lagoon into

the Baltic Sea (initial turbidity concentration is 0.04 $^{kg/m^3}$)



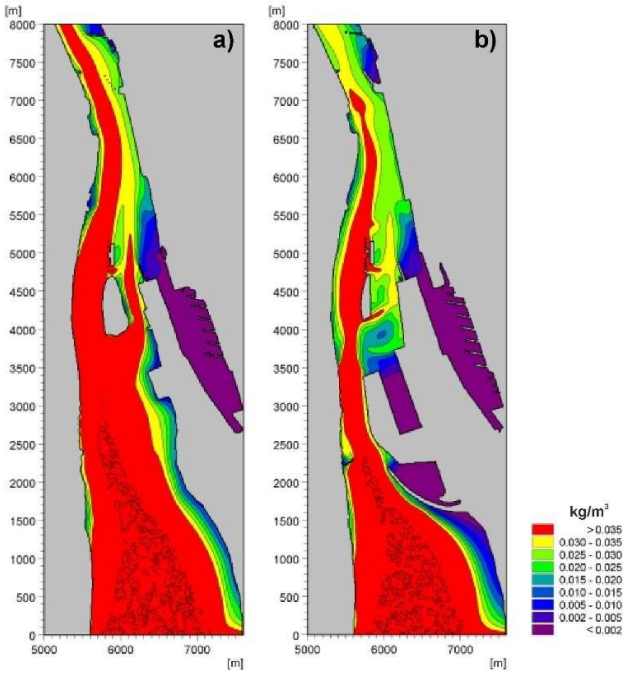
4.1.2.38 Fig. Distribution of turbidity ($^{kg/m^3}$) in the Klaipėda Strait and the northern part of the Curonian Lagoon for alternatives 0 (a) and 2A (b), when a flow rate of[1,]620 m³/s from the Curonian Lagoon

to the Baltic Sea (initial turbidity concentration is 0.04 $^{kg/m^3}$)



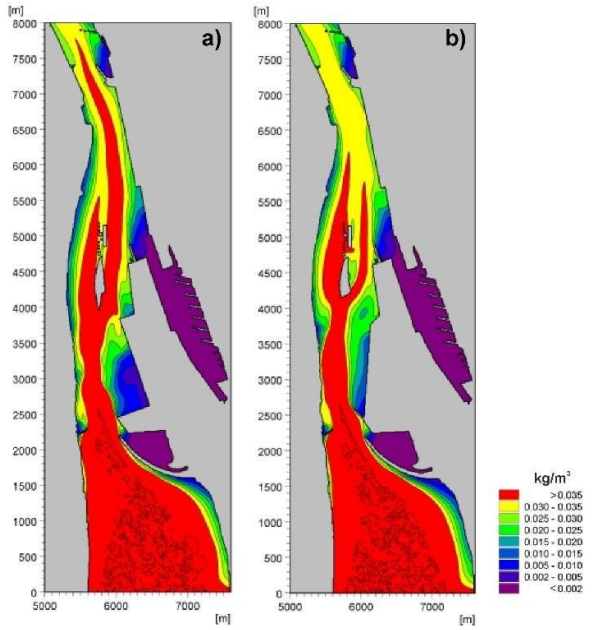
4.1.2.39 Fig. Turbidity ($^{kg/m^3}$) distribution in the Klaipėda Strait and the northern part of the Curonian Lagoon for Alternatives 3A (a) and 4A (b), when a flow rate of^{1,620}m³/s flows through the strait from the Curonian Lagoon to

the Baltic Sea (initial turbidity concentration is 0.04 $^{kg/m^3}$)



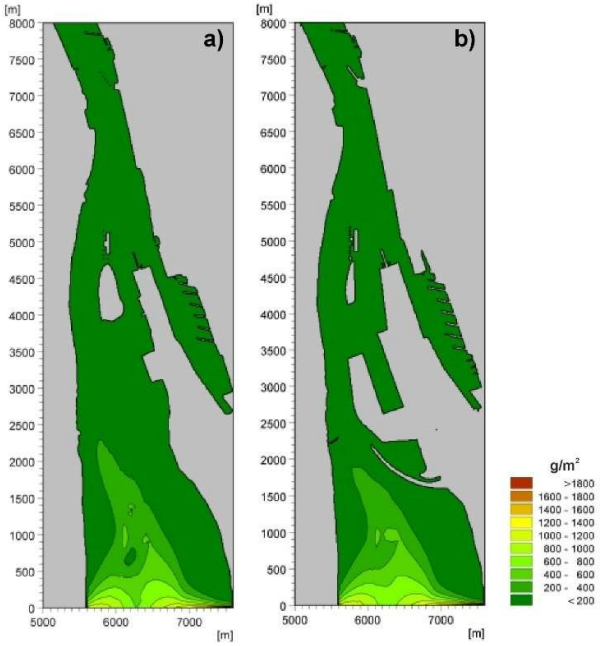
4.1.2.40 Fig. Turbidity ($^{kg/m^3}$) distribution in the Klaipėda Strait and the northern part of the Curonian Lagoon for Alternatives 0 (a) and 2A (b), when a flow rate of^{2,700} m³/s flows through the strait from the Curonian Lagoon into

the Baltic Sea (initial turbidity concentration is 0.04 $^{kg/m^3}$)

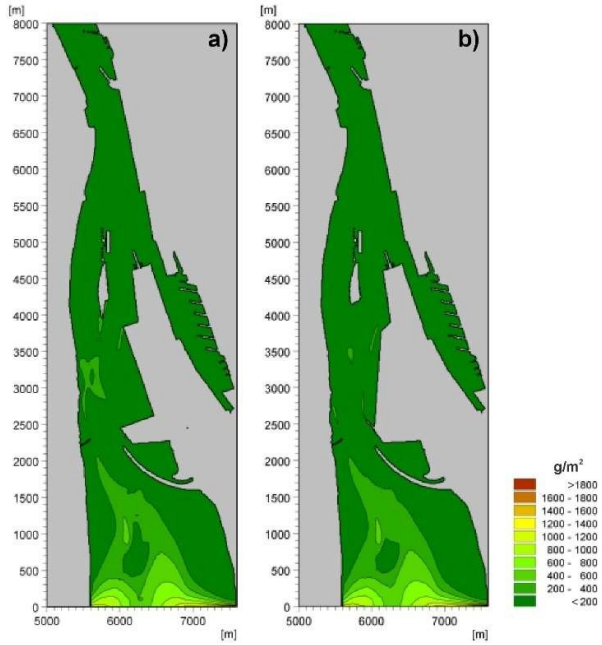


4.1.2.41 Fig. Turbidity ($^{kg/m^3}$) distribution in the Klaipėda Strait and the northern part of the Curonian Lagoon for alternatives 3A (a) and 4A (b), when a flow rate of^{2,}700 m³/s flows through the strait from the Curonian

into the Baltic Sea (initial turbidity concentration is 0.04 $^{kg/m^3}$)

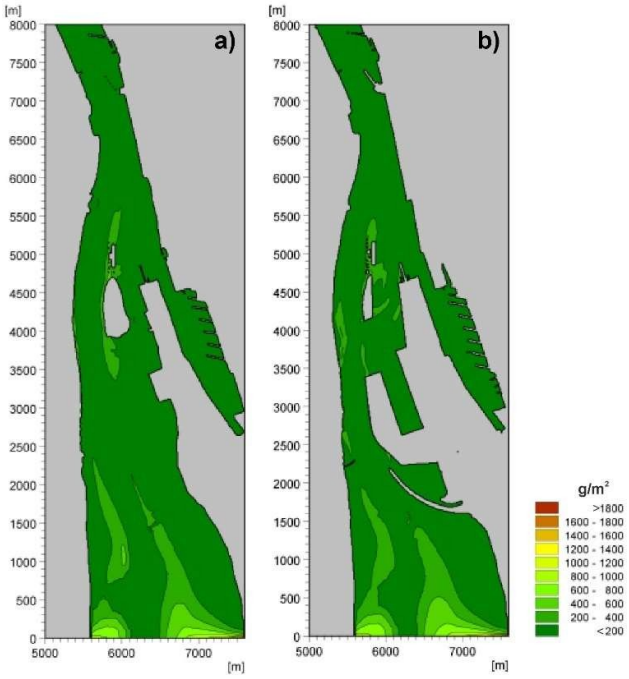


4.1.2.42 Fig. Sediment accumulation values over a 12-hour period ($^{g/m^2}$) in the Klaipėda Strait and the northern part of the Curonian Lagoon for Alternatives 0 (a) and 2A (b), when a flow rate of 660 $^{m^3}$/s from the Curonian Lagoon to the Baltic Sea (initial turbidity concentration is 0.04 $^{kg/m^3}$)

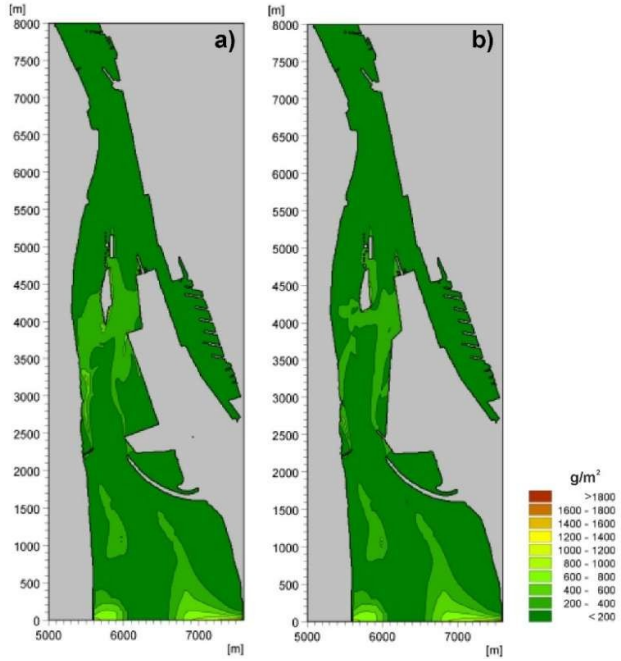


4.1.2.43 Fig. Sediment accumulation values over a 12-hour period (g/m^2) in the Klaipėda Strait and the northern part of the Curonian Lagoon In the case of alternatives 3A (a) and 4A (b), when a flow rate of 660 m³/s flows through the strait from the Curonian Lagoon into the Baltic Sea (the initial turbidity concentration is 0.04

kg/m^3)

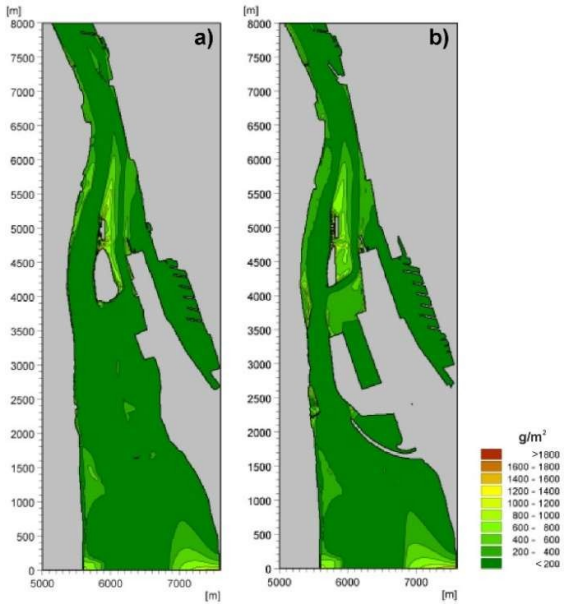


4.1.2.44 Fig. Sediment accumulation values over a 12-hour period ($^{g/m^2}$) in the Klaipėda Strait and the northern part of the Curonian Lagoon for Alternatives 0 (a) and 2A (b), when a flow rate of 950 $^{m^3}$/s from the Curonian Lagoon to the Baltic Sea (initial turbidity concentration is 0.04 $^{kg/m^3}$)

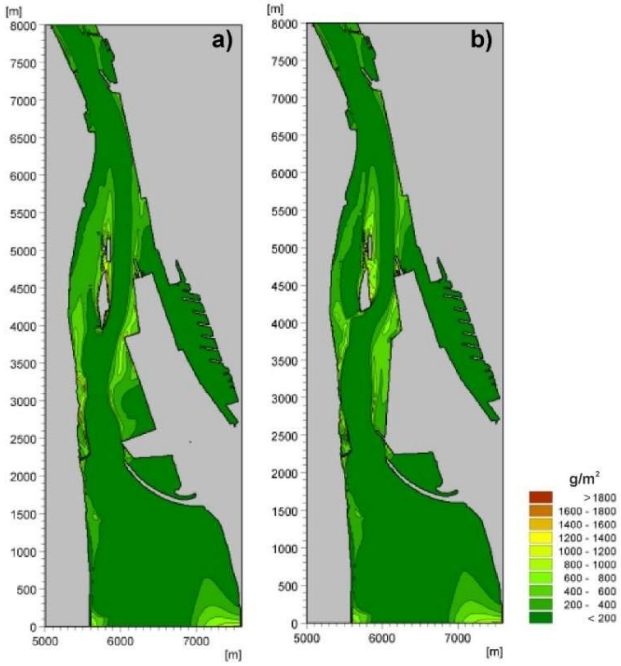


4.1.2.45 Fig. Sediment accumulation values over a 12-hour period (g/m^2) in the Klaipėda Strait and the northern part of the Curonian Lagoon In the case of alternatives 3A (a) and 4A (b), when a flow rate of 950 m³/s flows through the strait from the Curonian Lagoon into the Baltic Sea (the initial turbidity concentration is 0.04

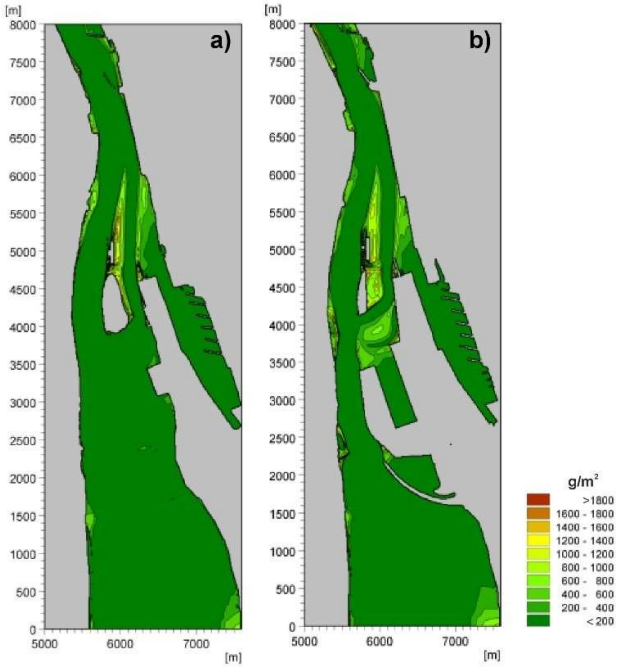
kg/m^3)



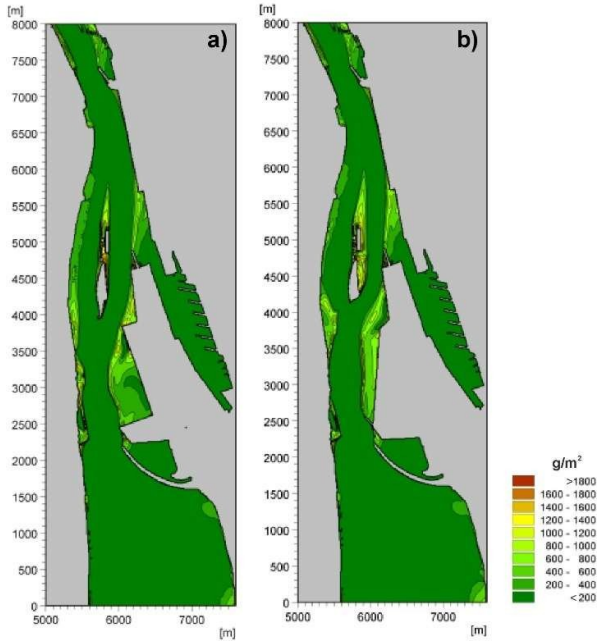
4.1.2.46 Fig. Sediment accumulation values over a 12-hour period ($^{g/m^2}$) in the Klaipėda Strait and the northern part of the Curonian Lagoon for Alternatives 0 (a) and 2A (b), when a flow rate of 1·620 $^{m^3}$/s from the Curonian Lagoon to the Baltic Sea (initial turbidity concentration is 0.04 $^{kg/m^3}$)



4.1.2.47 Fig. Sediment accumulation values over a 12-hour period ($^{g/m^2}$) in the Klaipėda Strait and the northern part of the Curonian Lagoon for Alternatives 3A (a) and 4A (b), when a flow of
a flow rate of 1·620 $^{m^3}$/s from the Curonian Lagoon to the Baltic Sea (initial turbidity concentration is 0.04 $^{kg/m^3}$)



4.1.2.48 Fig. Sediment accumulation values over a 12-hour period ($^{g/m^2}$) in the Klaipėda Strait and the northern part of the Curonian Lagoon for Alternatives 0 (a) and 2A (b), when a flow of 2·700 $^{m^3}$/s from the Curonian Lagoon to the Baltic Sea (initial turbidity concentration is 0.04 $^{kg/m^3}$)



4.1.2.49 Fig. Sediment accumulation values over a 12-hour period ($^{g/m^2}$) in the Klaipėda Strait and the northern part of the Curonian Lagoon for Alternatives 3A (a) and 4A (b), when a flow of

a flow rate of 2,700 $^{m^3}$/s flows from the Curonian Lagoon to the Baltic Sea (the initial turbidity concentration is 0.04 $^{kg/m^3}$)

By comparing the calculated average turbidity values at the cross-sections, it is possible to determine whether sediment accumulation will occur in the water area between the cross-sections (positive difference in turbidity between the two cross-sections) or bottom erosion (negative difference in turbidity between the two cross-sections).

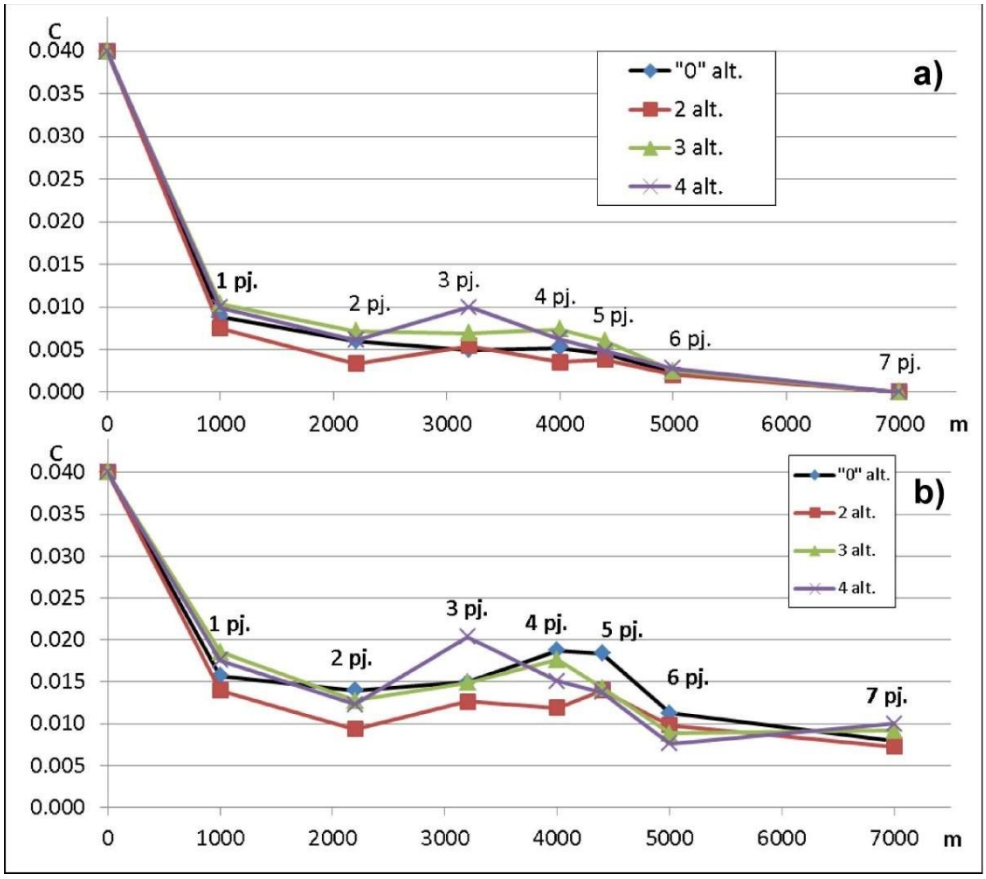
When a low flow rate (660 m³/s) flows through the strait from the Curonian Lagoon into the Baltic Sea, and with an initial turbidity concentration of 0.04 $^{kg/m^3}$, a decreasing trend in turbidity concentration is observed from cross-section 1 to 7 in Alternatives 0 and 3A. The concentration will change most significantly between cross-sections 5 and 6, so sediment accumulation sites are expected in the LNG terminal's water area (Fig. 4.1.2.50a). Solutions for Alternatives 2A and 4A will cause changes in sediment processes in the water area from cross-sections 2 to 4—bottom erosion 1 km away from the planned southern port gates toward Kiaulės Nugaros Island and sediment accumulation beyond the erosion zone up to the island. With a discharge of 950 m³/s flowing through the strait from the lagoon to the sea, the greatest changes in turbidity would occur between cross-sections 2 and 4 in the case of Alternative 4A (4.1.2.50b).

When high flow rates (1,620 and 2,700 $^{m^3}$/s) pass through the strait, the nature of sediment transport processes will change (Fig. 4.1.2.51). In the case of Alternative 0, water turbidity concentrations will change slightly in the northern part of the Curonian Lagoon and will decrease in the LNG terminal water area between sections 5 and 6. At high flow rates, the differences in turbidity changes between the various PŪV alternatives become more pronounced in the water area from cross-sections 2 to 5. In the case of Alternative 4A, the area of bottom erosion due to significantly increased flow velocities in the narrowed water area caused by the PŪV is located 1 km from the planned southern port gates toward the Klaipėda Strait, whereas in the case of Alternatives 2A and 3A, this area will be wider—from the planned southern port gates to the channels of Kiaulės Nugaros Island. From the perspective of bottom erosion, Alternative 2A would be the most dangerous.

After assessing changes in sediment dispersion for the different port development alternatives, it was determined that sediment accumulation zones and transport will change most significantly in the northern part of the Curonian Lagoon (from the planned

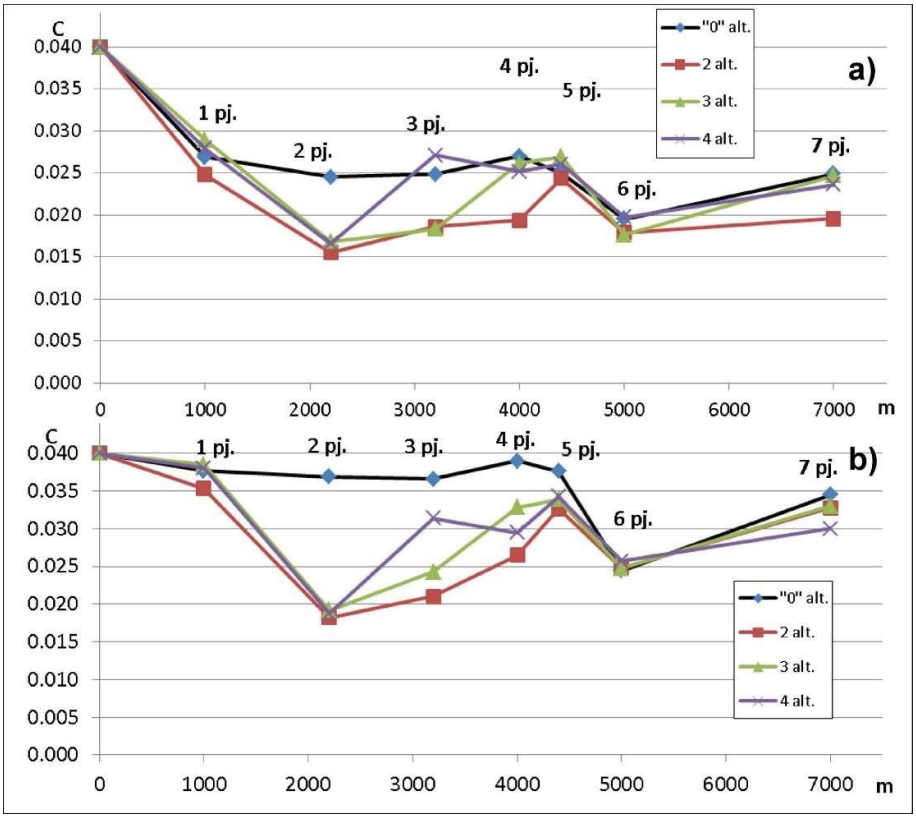
southern port gates to Kiaulės Nugaros Island), in the western and eastern channels, and in the LNG terminal's water area. When low flows pass through the strait, the distribution of water turbidity in Alternative 3A is most similar to the sediment transport processes of Alternative 0. However, when high flows pass through the strait, the distribution of turbidity concentrations in Alternative 4A would differ the least compared to the current situation.

The average turbidity curves plotted for selected cross-sections of the harbor basin (Figs. 4.1.2.50–4.1.2.51) were used to calculate changes in the sediment balance in the harbor basin during years with varying water levels.



4.1.2.50 Fig. Changes in average turbidity ($^{kg/m^3}$) for all PŪV alternatives in 7 sections of the port basin (Fig. 4.1.2.34b), when 660 (a) and 950 m³/s

(b) (initial turbidity concentration is 0.04 $^{kg/m^3}$)



4.1.2.51 Fig. Changes in average turbidity (kg/m^3) for all PŪV alternatives at 7 cross-sections of the port basin (Fig. 4.1.2.34b), when 1,620 (a) and 2,700 m³/s

(b) (initial turbidity concentration is 0.04 kg/m^3)

Changes in the sediment balance in the KVJU water area

By summarizing the sediment transport and accumulation processes occurring in the Klaipėda Strait, the sediment balance in the port basin was calculated for years with varying water levels. Such a balance is necessary to assess the potential impact of port breakwater reconstruction solutions on the sediment regime in the Klaipėda port basin and on port operating costs.

Based on the calculated long-term water balance data for the Curonian Lagoon, a curve of the annual discharge distribution in the strait was plotted for the period 1961–2020, when the flow runs from the Curonian Lagoon to the Baltic Sea. Specific years with corresponding water levels were selected from the probability curve: a wet year—1981 (5% probability) and an average year—2004 (50%). Wet years may occur once every 20 years, while average years may occur once every 2 years. The monthly discharge rates and the number of days when the flow was directed from the Curonian Lagoon to the Baltic Sea for wet and average years are presented in Tables 4.1.2.2 and 4.1.2.3. Based on the monthly discharge rates for wet and average years, a sediment balance was calculated for Alternatives 0, 2A, 3A, and 4A: calculated amounts of bedload and suspended sediment deposited in the northern part of the Curonian Lagoon and the Klaipėda Port water area between cross-sections 1 and 7 (a 6 km-long water area, Fig. 4.1.2.34b) and in the water areas between the adjacent seven cross-sections.

A sediment balance for all PŪV alternatives between sections 1 and 7 was compiled for wet and average years (Tables 4.1.2.2 and 4.1.2.3). Sediment flow is highly dependent on discharge and flow velocities. Bedload (sand) is transported along the channel if the transport velocity exceeds 0.3–0.5 m/s. The highest bedload discharge was recorded during the wet year of 1981

, when flow rates of 2,206 and 1,823 m³/s, respectively, flowed through the strait into the sea in November and December. Higher flow rates also occurred through the strait during the spring flood (average flow rate in March – 1,698m³/s). During those months, under all PŪV alternatives, the greatest amount of bedload would accumulate in the port basin between sections 1 and 7 (Table 4.1.2.2). When low flow rates (up to 900 m³/s) pass through the strait, the transport of bedload sediment is low.

The accumulation of bedload sediment over all months in a wet year is highest for Alternative 3A (266.94 thousand m³) and lowest for Alternative 2A (90.55 thousand m³). Compared to Alternative 0 (135.45 thousand m³), Alternative 3A would result in nearly twice as much suspended sediment accumulation in the study area.

The amounts of suspended sediment (silt) were calculated by multiplying the corresponding flow rate by the difference in turbidity concentrations between sections 1 and 7. Silt can accumulate in the water area when flow velocities are 0.1–0.3 m/s. Therefore, high flow rates do not cause sediment accumulation, as water with high turbidity flows further into the Baltic Sea. In wet years, the least amount of sediment would accumulate in the port basin between sections 1 and 7 under Alternative 0 (82.64 thousand m³), while in the case of the remaining three alternatives, more sediment would settle in the port basin (from 110.17 to 124.73 thousand m³). The calculated amounts of sediment deposited in the port basin in different months vary by up to 2.5 times in the case of Alternative 0, while the amount of suspended sediment deposited can vary by up to 179 times in different months. In the case of Alternatives 2A, 3A, and 4A, the amount of settled suspended sediment compared to Alternative 0 may vary by up to 2 times, while the amount of sediment will vary by only up to 1.5 times. In wet years, more suspended sediment and sediment will settle in the port basin.

Table 4.1.2.2. Amount of deposited suspended sediment (numerator) and suspended sediment (denominator) (m³/year) in the harbor basin between sections 1 and 7 (Fig. 4.1.2.34b) during wet years for all alternatives

Month	Monthly discharge, Q, m³/s	Average flow duration, days	Alternatives			
			0	2A	3A	4A
I	1489	29	9633 5,898	6523 11,840	18,793 10,688	15,040 10,170
II	1652	25	12,724 4,235	8,575 10,655	24,943 8,991	19,700 9,393
III	1698	29	19,136 5,260	12,826 12,259	37,648 10,937	29,456 11,818
IV	1534	25	8917 4,726	6,037 10,380	17,399 9,035	13,920 8,747
V	914	28	866 10,285	609 8,836	1,663 12,366	1,393 10,128
VI	730	22	285 6,951	204 5,937	539 8,228	458 7,479
VII	901	24	714 8,733	502 7,500	1,369 10,490	1,147 8,646
VIII	1013	22	1521 7,861	1043 7,354	2946 9,790	2401 7911
IX	926	28	899	632	1,726	1,446

			10,379	8,920	12,490	10,168
X	1233	22	4199 6293	2851 8,108	8181 9,011	6571 7820
XI	2206	22	50943 6883	33,695 8,459	101,096 12522	77,307 16649
XII	1823	24	25,619 5130	17,051 9919	50,637 10,186	39,138 11,844
Year	1343	300	135,455 82,636	90,548 110,167	266,940 124,735	207,977 120,774

Table 4.1.2.3 presents the amounts of sediment deposited in an average year. In 2004, a year of average water availability, the largest amounts of sediment were deposited in March and November, as the highest discharge rates (1,401 and 1·426 m³/s) occurred during those months. The lowest amounts of transported sediment will settle in all months under Alternative 2A (26.66 thousand m³), while the highest amounts will settle under Alternative 3A (76.27 thousand m³). The amounts of settled sludge in years of average water availability will be higher than in years of high water availability—ranging from 88.71 thousand m³(Alternative 0) to 118.49 thousand m³(Alternative 3A). The calculated amounts of settled sludge in the port basin vary by up to 1.7 times across different months under Alternative 0, while the amount of settled suspended sediments will vary by up to 39 times across different months. In years with average water levels, more sludge than suspended sediment will settle in the port basin.

4.1.2.3 Table. Amount of settled suspended sediment (numerator) and suspended sediment (denominator) (m³/year) in the harbor basin between sections 1 and 7 (Fig. 4.1.2.34b) in an average year for all PŪV alternatives

Month	**Monthly discharge, Q, m³/s**	**Average flow duration, days**	**Alternatives**			
			0	**2A**	**3A**	**4A**
I	882	26	725 9,323	511 8,003	1,389 11,183	1,165 9,308
II	1238	24	4645 6,828	3153 8,863	9050 9812	7,268 8529
III	1401	27	7651 6,262	5184 10,653	14,922 10,333	11,952 9,513
IV	1389	30	8308 7,071	5630 11,782	16,203 11,538	12,980 10,577
V	844	23	554 7,999	391 8,658	1,060 9,565	891 8,129
VI	897	20	586 7,252	412 6,228	1,123 8,708	942 7,194
VII	678	27	212 8,141	156 6,939	396 9,585	343 9,013
VIII	895	21	611 7,603	430 6529	1,172 9,129	982 7549
IX	963	19	797 7,091	553 6,206	1536 8,605	1,270 6,850
X	1106	25	3019	2056	5870	4,737

			8,177	8,720	10,750	8946
XI	1426	24	7137 5,370	4835 9,564	13,921 9,088	11,147 8,445
XII	1245	25	4940 7053	3353 9,260	9,626 10,191	7,729 8881
Year	1080	291	39,186 88,171	26,665 99,604	76,268 118,486	61,407 102,935

In years with varying water levels, the largest amount of sediment will accumulate in the Klaipėda Port water area between sections 1 and 7 upon implementation of Alternative 3A (Table 4.1.2.4). This will be caused by changes in the flow structure of the Klaipėda Strait and the northern part of the Curonian Lagoon due to the planned construction of the port's southern gates, the narrowing of the water area at the planned southern gates, and the vessel turning area located beyond the southern gates. Sediment flows passing through the narrowed channel will settle in the large, deepened water area due to the reduced flow velocity. The amounts of sediment accumulated in Alternatives 0 and 2A will be very similar. In Alternative 4A, the amount of sediment accumulation will be intermediate compared to Alternatives 2A and 3A. The determined amount of accumulated sediment depends on changes in the hydrodynamic regime according to the different PŪV alternatives. The greatest changes in the water flow capacity of the strait compared to Alternative 0 would occur in the case of Alternative 3A.

4.1.2.4 Table. Annual amounts of sediment deposited (m^3/year) in the Klaipėda Port water area between sections 1 and 7 in years with varying water levels

Water level	**Alternatives**			
	0	**2A**	**3A**	**4A**
Year with average water availability Q = 1,080 m^3/s	127,357	126,268	194,754	164,342
Wet year Q= 1,343 m^3/s	218,091	200,714	391,676	328,751

Both bottom erosion and sediment accumulation processes are occurring in the Klaipėda Port water area. Therefore, the water areas between sections 1 and 7 were studied in greater detail (Fig. 4.1.2.34b). By summing the sediments in the studied water areas, the total accumulated sediment volume in the water area between sections 1 and 7 is determined.

In both wet and average-precipitation years, Alternative 0 results in a slight redistribution of bedload and suspended sediment flows in the northern part of the Curonian Lagoon. However, the sediment flow entering the channels near Kiaulės Nugaros Island decreases, resulting in sediment (especially silt) accumulation in the water area up to the LNG terminal.

Sediment processes will significantly intensify in the northern part of the Curonian Lagoon in Scenarios 2A, 3A, and 4A. The largest area where sediment flow redistribution occurs is identified in Scenario 2A. Here, the flushing of suspended sediments is possible in the water area from sections 1 to 3, which is 1 km north of the planned southern port gates. Accumulation of suspended sediments will occur in the water area up to Kiaulės Nugaros Island (sections 3 and 4). In the case of Alternative 2A, the trend in the redistribution of suspended sediments is the opposite. Silt accumulation will occur in the water area of sections 1 and 2, while minor erosion processes will occur from sections 2

to 5 (in the water area of the LNG terminal). The maximum amounts of washed-out and accumulated suspended sediment are observed in Alternative 3A, in the water areas of Sections 1 to 3, respectively. This is because port expansion under this PŪV alternative most significantly alters the hydrodynamic regime of the port water area. In the case of Alternative 4A, the impact on suspended sediment processes is similar to that of Alternative 3A, except that the amounts of sediment removed or

accumulated sediment volumes are smaller. However, this PŪV alternative is characterized by a large volume of dredged sediment from the 2nd and 3rd sections of the harbor basin (1 km north of the planned southern harbor entrance).

In terms of sediment balance, Alternative 3A is the least favorable, as such port expansion would cause the greatest sediment accumulation in the northern Curonian Lagoon water area. When comparing Alternatives 0 and 2A, the total sediment balance is similar, however, the economic activities associated with Alternative 2A (a long, narrowed channel between the Curonian Spit coast and the newly formed landmass on the eastern shore, along with a designated turning area for ships) will cause significant flushing and accumulation of suspended sediments in the northern part of the Curonian Lagoon. The most environmentally favorable option would be port expansion according to Alternative 4A, as its impact would not drastically alter sediment transport processes, unlike the other PŪV alternatives.

Conclusion: From the perspective of sediment balance, Alternative 3A would be the least favorable, as such solutions for the development of the southern part of the port would cause the greatest accumulation of sediment in the waters of the northern part of the Curonian Lagoon. The least sediment accumulation was observed in the case of Alternative 2A, however, the long, narrowed channel between the Curonian Spit coast and the newly formed land on the eastern shore, as well as the installed ship turning area, would cause significant flushing and accumulation of suspended sediments in the northern part of the Curonian Lagoon. The most environmentally favorable option would be the development of the southern part of the port according to Alternative 4A, as its impact would not drastically alter sediment transport processes, unlike other project alternatives.

In all PŪV alternatives, compared to Alternative 0, sludge accumulation and water turbidity in the LNG terminal's water area will not increase. Therefore, the implementation of the project alternatives will not have a significant impact on LNG terminal operations (including the regasification process) or on dredging works in the terminal's water area.

Changes in water salinity

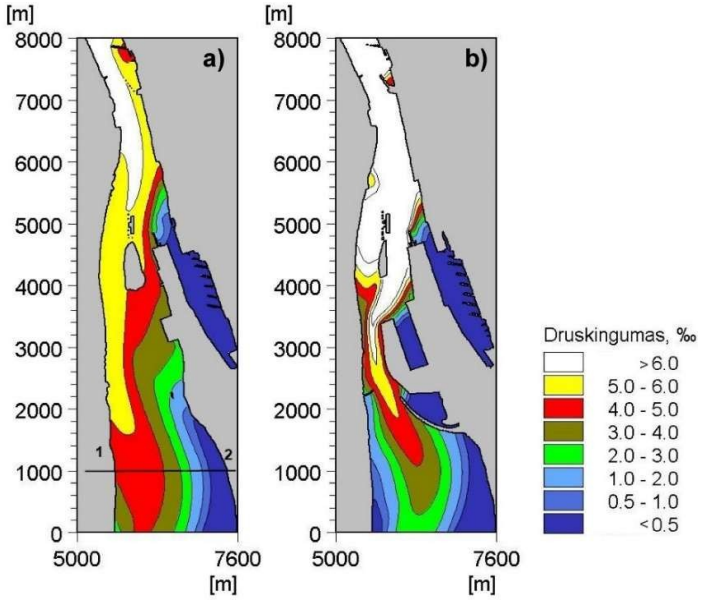
When selecting a PŪV alternative (solutions), it is important to assess potential changes in salinity compared to Alternative 0. To this end, using the MIKE 21 AD model, changes in salinity in the port basin were simulated when flow rates of 950, 1,725, and 3,206 m^3/s flow through the strait from the Baltic Sea into the Curonian Lagoon. The average salinity of the Baltic Sea in Lithuanian territorial waters is 7–8‰ (AAA, 2013), however, according to monitoring data, the average salinity of the Baltic coastal waters near Melnrage was 5.33‰ from 1961 to 1990 and 5.13‰ from 1991 to 2020. The salt content in the Curonian Lagoon depends on the inflow of seawater, as during storms the water level of the Baltic Sea rises and exceeds that of the Curonian Lagoon, or the Curonian Lagoon's level drops due to low river inflow. Such seawater inflows are observed on average about 80 days per year. When modeling salinity distribution, it was assumed that water with a salinity of 7.0‰ enters the strait through the northern port gates.

4.1.2.52 Figs. 4.1.2.54a, 4.1.2.56a, and 4.1.2.56a illustrate the dispersion of saline water under current conditions (Alternative 0), when flows of varying rates from the Baltic Sea into the Curonian Lagoon pass through the strait over a 24-hour period. Data from the 2019–2020 monitoring reports of the Klaipėda State Seaport were used to verify the model, during which water flow rates and salinity were measured at the cross-section near Kiaulės Nugaros Island. A correlation was established between flow rates and salinity values (Fig. 4.1.2.58). When the flow rate exceeds 450 m^3/s, water salinity at the channel cross-section may exceed 6‰. Modeling results show that under current conditions (Alternative 0, Fig. 4.1.2.52a), salinity values in the channel cross-section range from 5.4 to 5.9‰ and differ little from the measured values. The difference between measured and modeled

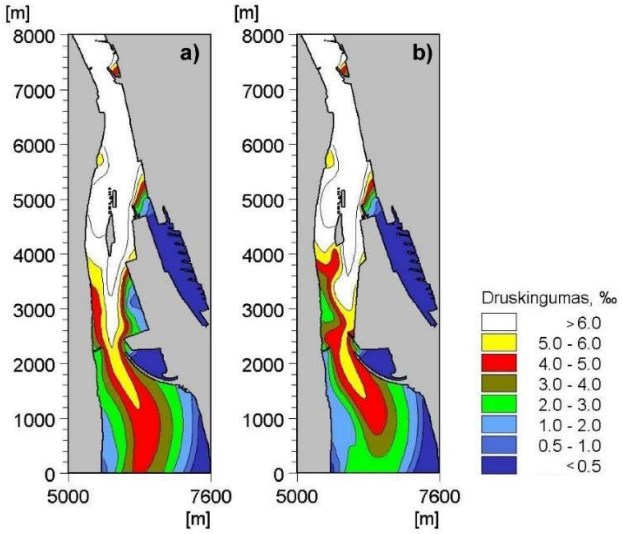
salinity values may be due to

the different duration of the inflow from the sea. The duration of the inflow from the sea was not assessed during the monitoring measurements.

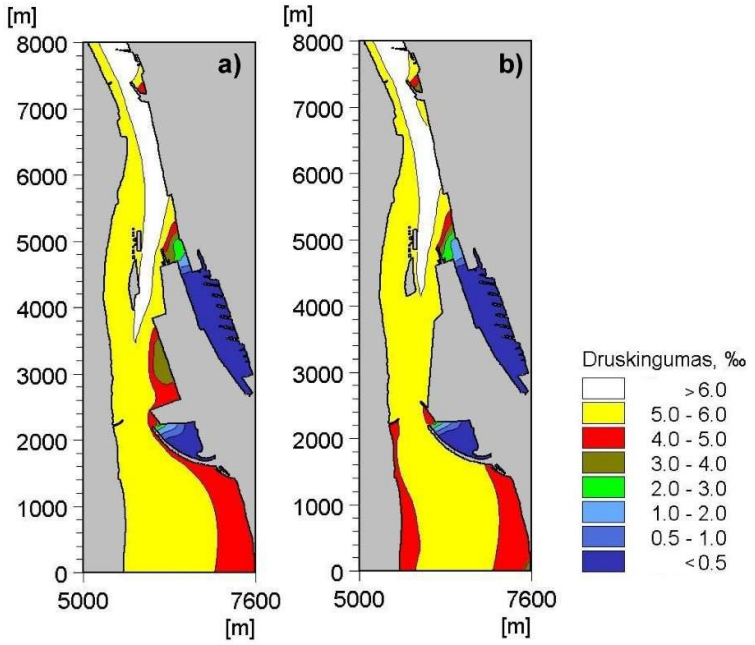
The salinity distribution for various PŪV alternatives in the northern part of the Curonian Lagoon and in the LNG terminal's water area differs slightly. These differences are determined by the configuration of the planned southern port gates, the size of the formed land area, and the ship turning area (water area dredged to a depth of 17 m).



4.1.2.52 Fig. Salinity changes in the Klaipėda Strait and the northern part of the Curonian Lagoon for Alternatives 0 (a) and 2A (b), where a flow rate of 950 m³/s from the Baltic into the Curonian Lagoon (analysis of salinity changes performed in sections 1–2), ‰

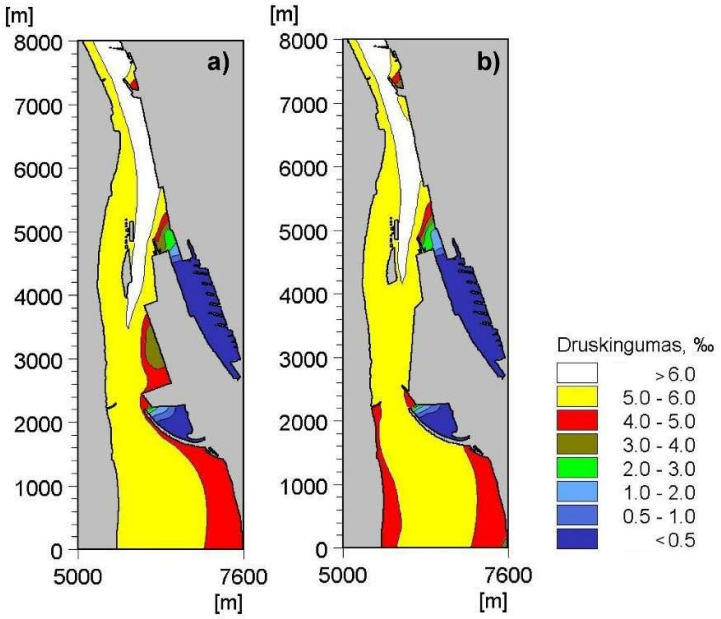


4.1.2.53 Fig. Salinity changes in the Klaipėda Strait and the northern part of the Curonian Lagoon for Alternatives 3A (a) and 4A (b), when a flow rate of 950 m³/s flows through the strait from the Baltic into the Curonian Lagoon



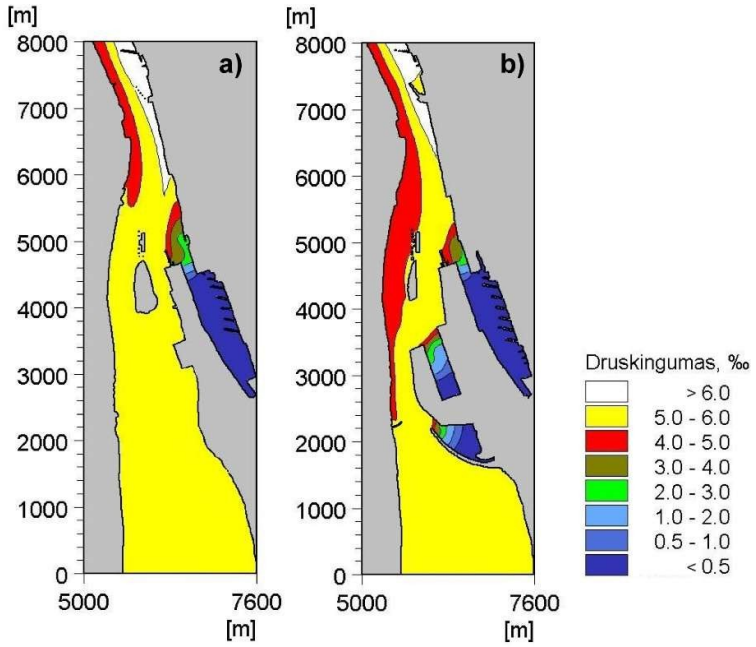
4.1.2.54 Fig. Salinity changes in the Klaipėda Strait and the northern part of the Curonian Lagoon for Alternatives 0 (a) and 2A (b), when a flow rate of$^{1,725\ m^3}$/s flows through the strait from the Baltic

to the Curonian Lagoon

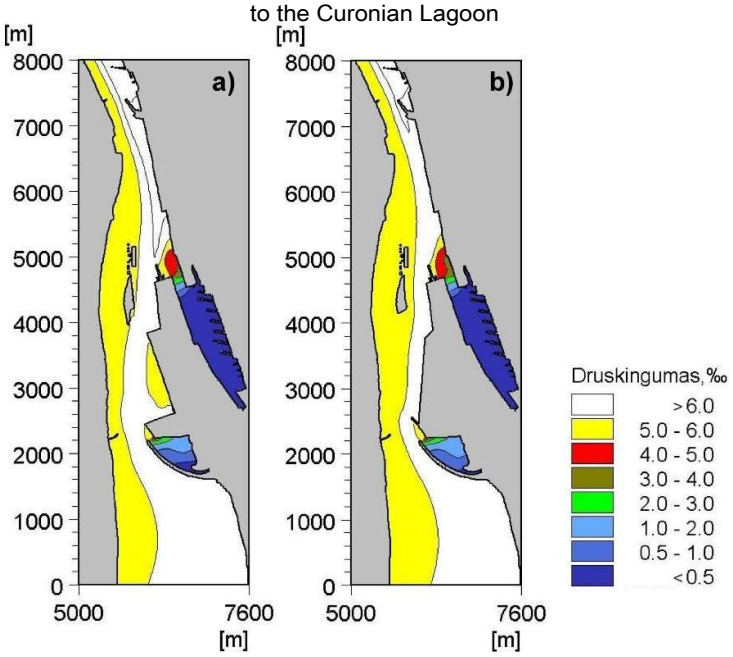


4.1.2.55 Fig. Salinity changes in the Klaipėda Strait and the northern part of the Curonian Lagoon for alternatives 3A (a) and 4A (b), when a flow rate of $1^{,72^{5\ m^3}}$/s flows through the strait from the Baltic

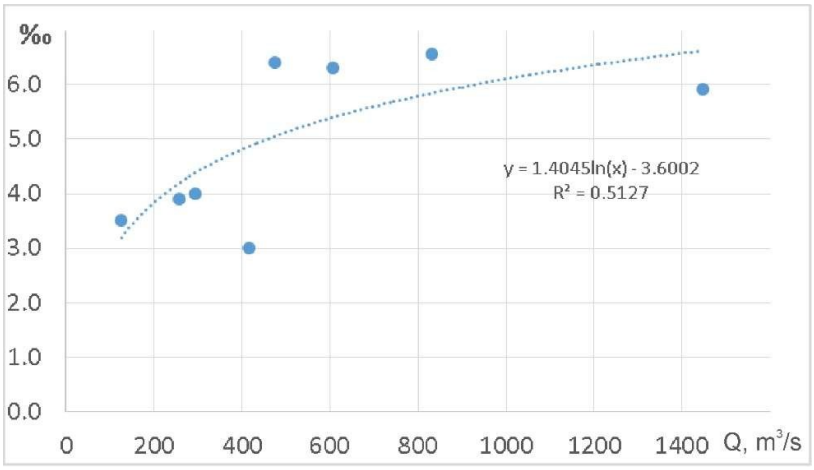
to the Curonian Lagoon



4.1.2.56 Fig. Salinity changes in the Klaipėda Strait and the northern part of the Curonian Lagoon for alternatives 0 (a) and 2A (b), when a flow rate of 3206 m^3/s flows through the strait from the Baltic to the Curonian Lagoon



4.1.2.57 Fig. Salinity changes in the Klaipėda Strait and the northern part of the Curonian Lagoon for alternatives 3A (a) and 4A (b), when a flow rate of 3206 m^3/s flows through the strait from the Baltic to the Curonian Lagoon



4.1.2.58 Fig. Salinity as a function of water flow in the cross-section of the Kiaulės Nugaros Island channels, when the flow is directed from the Baltic Sea into the Curonian Lagoon (KVJU monitoring data from 2019–

2020)

When a flow of 950 m³/s passes through the strait from the sea to the lagoon, the flow of saline water reaches the Kiaulės Nugaros Island channel within a day (Figs. 9.1–9.2). In the Curonian Lagoon basin, water salinity decreases depending on the selected alternative. When the flow through the strait is higher, at 1,725 and[3,]206 m³/s (Figs. 4.1.2.54–4.1.2.57), water with higher salinity will enter the Curonian Lagoon over the course of a day.

To assess changes in water salinity at the southern boundary of the port basin under various flow rates, the average salinity changes for different alternatives were determined in cross-section 1-2 (Fig. 4.1.2.52a) (Table 4.1.2.5). In this cross-section, a decrease in water salinity of 2.7–4.3% was determined when comparing Alternatives 0 and 2A, while comparing Alternatives 0 with 3A and 4A shows an increase in salinity of 11.8–13.7% and 10.9–12.4%, respectively. The higher the flow rate in the narrower channel, the smaller the changes in salinity compared to Alternative 0.

4.1.2.59 Fig. 4.1.2.52b shows the salinity distribution in cross-section 1-2 of the northern part of the Curonian Lagoon for all PŪV alternatives, where various flow rates pass through the strait from the Baltic Sea into the Curonian Lagoon over a 24-hour period. When higher flow rates occur (Fig. 4.1.2.59b, c), for all PŪV alternatives, due to high flow velocities and intense mixing, the saline water is distributed throughout the entire cross-section. The salinity curves can be divided into two groups based on their similarity. The curves for Alternatives 0 and 2A, as well as those for Alternatives 3A and 4A, differ only slightly from one another.

4.1.2.5 Table. Average salinity changes for PŪV alternatives in cross-sections 1–2 (Fig. 9.1a) compared to Alternative 0, where the differences in water levels between the Baltic Sea and the Curonian Lagoon are 0.04, 0.15, and 0.66 m, corresponding to the 950, 1725, and 3206 m³/s flows from the sea to the lagoon flowing through the strait for one day in the case of Alternative 0 (numerator: average salinity, ‰; the denominator represents the change in salinity, %)

Alternatives	**Average salinity, ‰ Change, %**		
	0.04 m	**0.15 m**	**0.66 m**
0	2.33	4.90	5.50
2A	2.23 -4.3	4.74 -3.3	5.35 -2.7

3A	2.65 13.7	5.51 12.4	6.15 11.8
4A	2.62 12.4	5.45 11.2	6.10 10.9

According to the latest water balance data for the Curonian Lagoon from 1991 to 2020, inflow from the Baltic Sea into the Curonian Lagoon occurred on average 80 days per year. Inflow events lasting 1 day were recorded on average 39 times, those lasting 2 days—12 times, and those lasting 3 or more days—5 times per year. Saltwater intrusion modeling was performed for a 36.6% probability of a 950 m³/s flow rate, a 14.8% probability of a 1,725 m³/s flow rate and a 3.4% probability of a 3,206 m³/s flow rate. This means that, on average, these flow rates can recur every 2.2, 5.4, and 23.5 days, respectively, over an 80-day period each year.

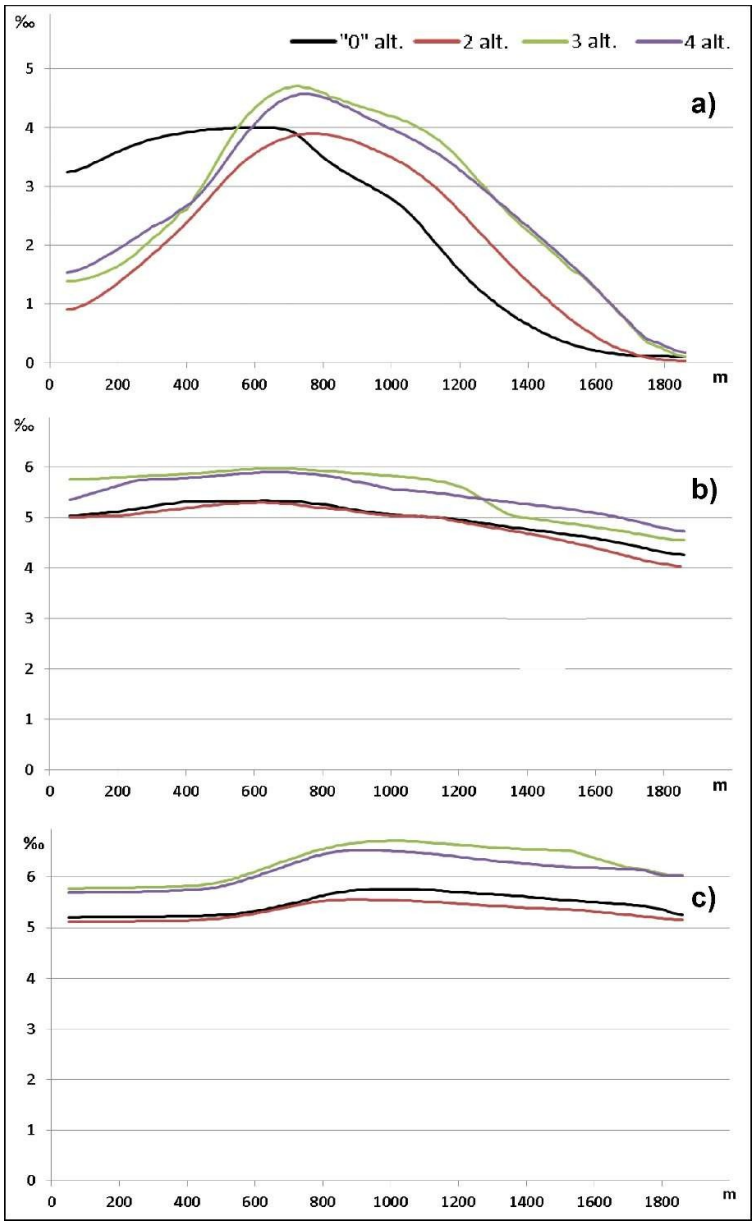
A hypothetical comparison was performed to show how water salinity would change from the sea inlet gate to Juodkrantė. Fig. 4.1.2.59 shows the salinity values at three locations in the harbor basin (at the sea inlet gate, at the southern boundary of the harbor basin, and at Juodkrantė) for each simulated flow rate. The boundary condition of the salinity model is set such that, when simulating flow at different discharge rates through the strait, the water salinity at the sea inlet is 7 ‰. The average salinity values simulated for all PŪV alternatives are presented at the southern port boundary. According to Juodkrantė VMS salinity data, the average salinity values at 36.6% and 14.8% probability based on 1961–2011 data are 1.01‰ and 4.53‰. These values are adopted as the salinity levels at Juodkrantė under the current conditions (Alternative 0). For Alternatives 2A, 3A, and 4A, the salinity values at Juodkrante have been recalculated by reducing or increasing them by the corresponding percentage for each PŪV alternative and different flow rates. These percentages were determined by comparing the average salinity changes of the PŪV alternatives at the southern port boundary cross-section with Alternative 0 (Table 4.1.2.5).

At a flow rate of 950 m³/s, the water salinity at Juodkrante, according to VMS data, is 1.01 ‰ (Figure 4.1.2.60). We consider this salinity value to represent the current situation (Alternative 0). In the recalculated cases for Alternatives 2A, 3A, and 4A, salinity values range from 0.97 to 1.15 ‰. The maximum salinity deviation is 0.14 ‰ when comparing Alternative 3A with Alternative 0. Calculations of the Curonian Lagoon's water balance indicate that, with a 36.6% probability, a flow of 950 m³/s from the sea into the lagoon could occur on average 36 days per year. Thus, insignificant increases in salinity (up to 0.13–0.14 ‰) in the case of Alternatives 4A and 3A should not have a negative impact on the Curonian Lagoon ecosystem.

When the flow rate through the strait is 1,725 m³/s, the water salinity near Juodkrantė, according to VMS data, is 4.53 ‰ (Fig. 4.1.2.60, Alternative 0). In the recalculated cases for Alternatives 2A, 3A, and 4A, salinity values range from 4.38 to 5.09 ‰. The maximum salinity deviation is 0.56 ‰ when comparing Alternative 3A with Alternative 0. Calculations of the Curonian Lagoon's water balance indicate that, with a 14.8% probability, a flow rate of 1,725 m³/s from the sea into the lagoon would occur on average 15 days per year. The flow of particularly high discharges of 3,206 m³/s from the sea is unlikely—on average, such a discharge would occur for about 3 days per year during storms. If high flow rates were to occur for several days, salinity levels near Juodkrantė would not differ significantly from the salinity of the seawater entering the strait.

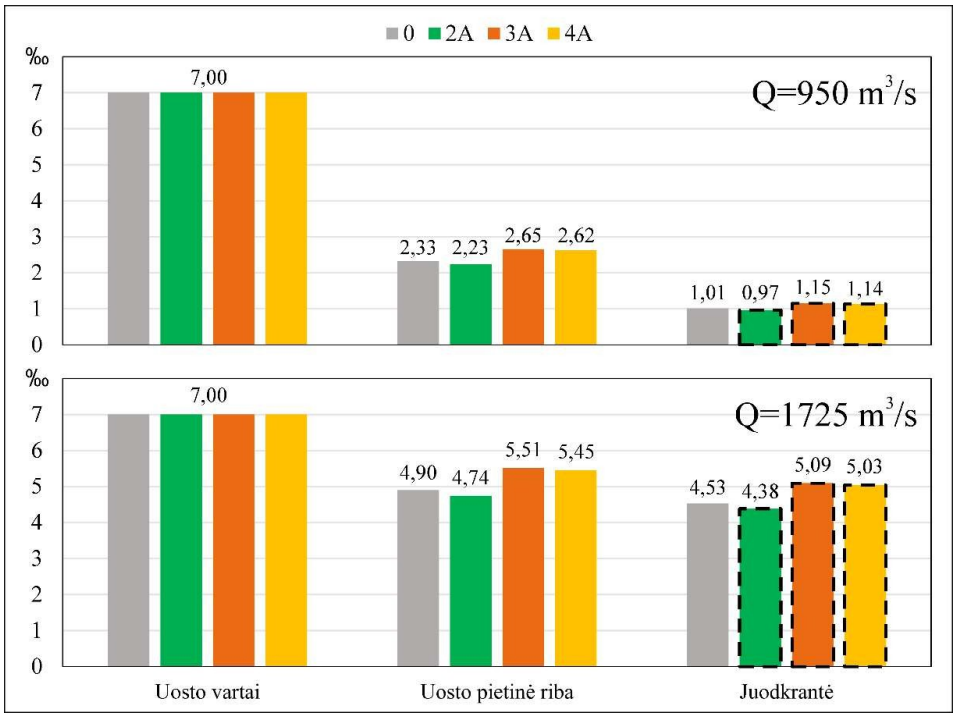
The changes in salinity observed in the northern part of the Curonian Lagoon (at the southern boundary of the port's water area) due to the implementation of the PŪV alternatives are insignificant and amount to up to 0.32 ‰ when low flow rates occur. When the inflow of seawater is higher (1,725 and 3,200 m³/s), this difference between Alternative 0 and the analyzed PŪV alternatives amounts to up to 0.80 ‰. Such salinity changes are rare and

short-lived (on average 15 days per year) and will not affect the Curonian Lagoon ecosystem, where environmental conditions are determined by random hydrometeorological factors—wind speed and direction, and sea and Curonian Lagoon water levels. Studies of the structure of fish communities in the Curonian Lagoon show that “during the period 1991–2000
, following the deepening and dredging of the Port of Klaipėda, the migration of migratory fish into the Curonian Lagoon and the Nemunas estuary intensified” (Virbickas, 2000). Scientific studies (Dainys et al., 2019) show how fish in the Curonian Lagoon respond to changes in salinity and other environmental factors. It has been established that changes in water temperature, but not salinity, determine the living conditions of fish communities.



4.1.2.59 Fig. Changes in salinity in cross-section 1-2 of the northern part of the Curonian Lagoon (Fig. 9.1b) for all alternatives, where the strait carries a flow rate of 950 (a), 1725 (b), and 3206 m³/s (c) from

the Baltic Sea into the Curonian Lagoon



4.1.2.60 Fig. Changes in water salinity values for all alternatives—at the port entrance, at the southern port boundary, and at Juodkrante—with flow rates of 950 and 1,725 m³/s from the sea into the lagoon

(salinity values simulated at the southern port boundary and recalculated based on VMS data in the water area near Juodkrante)

Conclusion: The changes in salinity identified in the northern part of the Curonian Lagoon (at the boundary of the southern port water area) due to the implementation of the PŪV alternatives would be insignificant at low flow rates (up to 0.32 ‰). At high flow rates (1,725 and 3,200 m³/s), salinity differences between Alternative 0 and the PŪV alternatives would be up to 0.80‰. Such changes in water salinity would be rare and short-lived (on average 15 days per year) and would not affect the Curonian Lagoon ecosystem.

Wave propagation in the northern part of the Curonian Lagoon

The MIKE 21 BW (Boussinesq Wave Module) of the MIKE 21 two-dimensional digital model system is used to model the dynamics of waves propagating through the Klaipėda Strait. Bathymetry of the northern part of the Curonian Lagoon was prepared for all alternatives to model wave propagation (Fig. 4.1.2.61).

There are no wave measurements in the modeled part of the Curonian Lagoon water area. Therefore, the height of the incoming waves into the modeled water area was calculated based on wind speed, the wave run-up distance, and the average depth (STR 2.05.15:2004). When calculating wave height, the three most hazardous wind directions were identified, along with the 2% probability wind speeds for those directions, and the 2% probability wave heights were calculated using the formula (STR 2.05.15:2004).

% probability wave heights.

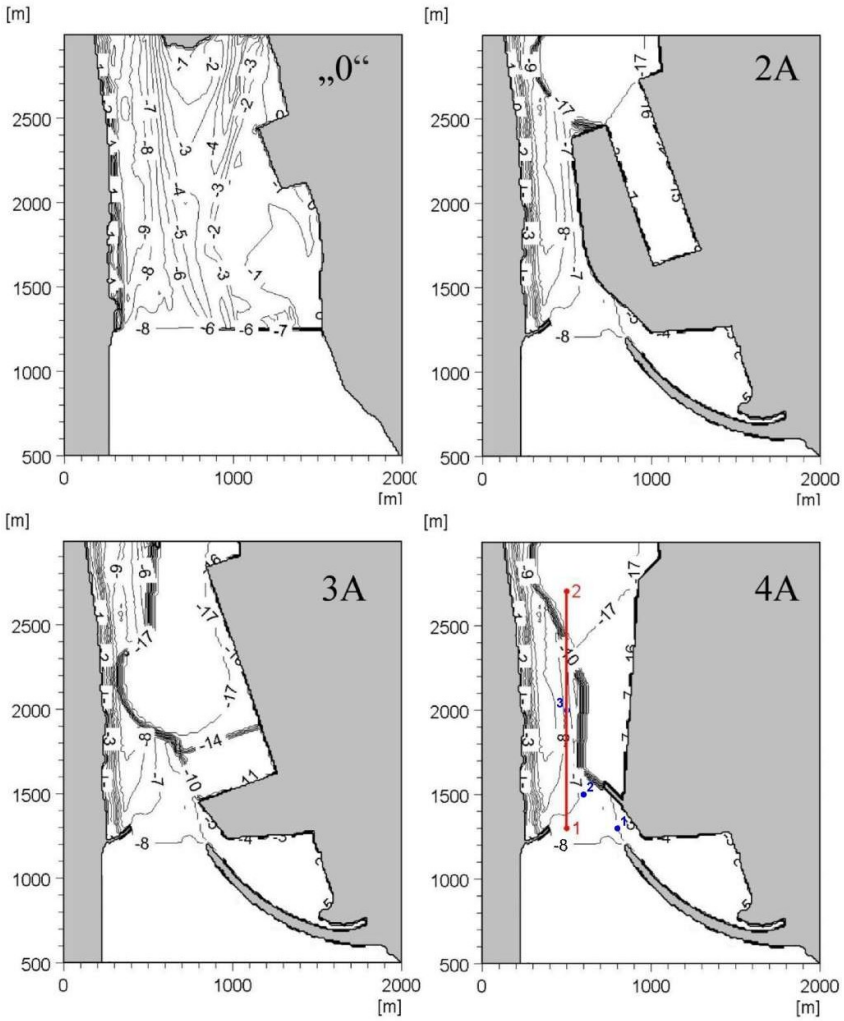
The wave height (H) in the Curonian Lagoon depends heavily on the wind run-up distance. If the prevailing wind directions are from the Klaipėda Strait side, the wind run-up path will be short. The most dangerous wind directions are from the Curonian Lagoon side in the range of 135°–245°. An analysis of wind data from the Klaipėda MS for 1961–2020

Analysis of wind data from the Klaipėda MS for 1961–2020 showed that maximum wind speeds occur in the PPR, P, and PPV directions (158°, 180°, and 202°, respectively). The 2% probability wind speeds for these directions

(12, 12, and 14 m/s). The 2% probability wave heights (Table 4.1.2.6) required for generating the incoming wave into the modeled water area were calculated.

4.1.2.6 Table. 2% probability wave heights at the open wall section of the modeled water area

Wind direction	Wind speed (m/s)	Wave run-up distance (m)	2% probability wave height (m)
PPV	14	84,000	1.44
P	12	80,000	1.26
PPR	12	50,000	1.16



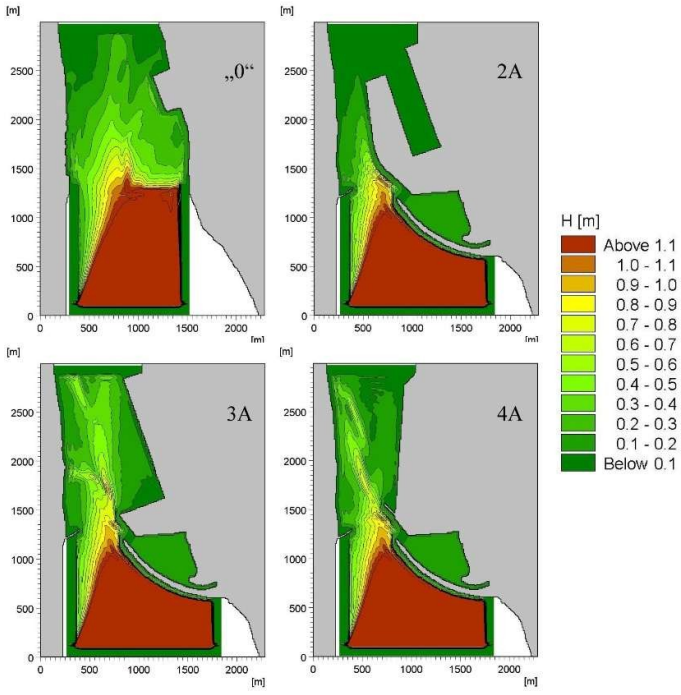
4.1.2.61 Fig. Bathymetry for wave dispersion modeling for Alternatives 0, 2A, 3A, and 4A (sections 1–2 show the comparative analysis of wave diffraction coefficients)

When modeling wave dispersion in the strait, it is necessary to account for partial wave reflection from quays and piers, expressed through the openness coefficient. For quays that will be constructed as vertical walls, the aperture coefficient is taken as 0.90, while for other quays, piers, and breakwaters, the coefficient is 0.64.

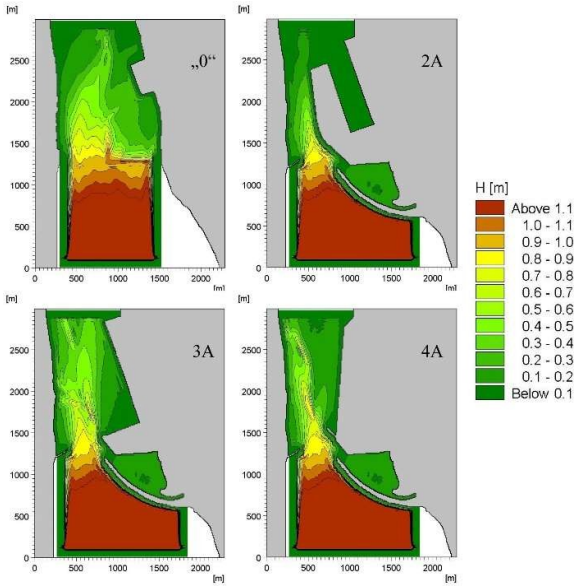
The results of wave dispersion modeling in the northern part of the Curonian Lagoon are the distribution of wave height (H) and the variation of the diffraction coefficient (K) under a 14 m/s PPV wind, a 12 m/s P wind, and

a 12 m/s PPR wind for various alternatives (Figs. 4.1.2.62–4.1.2.67). The modeling area covers the water area from the planned southern port gates to Kiaulės Nugaros Island. An additional water area has been created upstream of the modeled water area (the planned southern port entrance), through which a generated wave of varying heights propagates according to selected combinations of wind speed and direction.

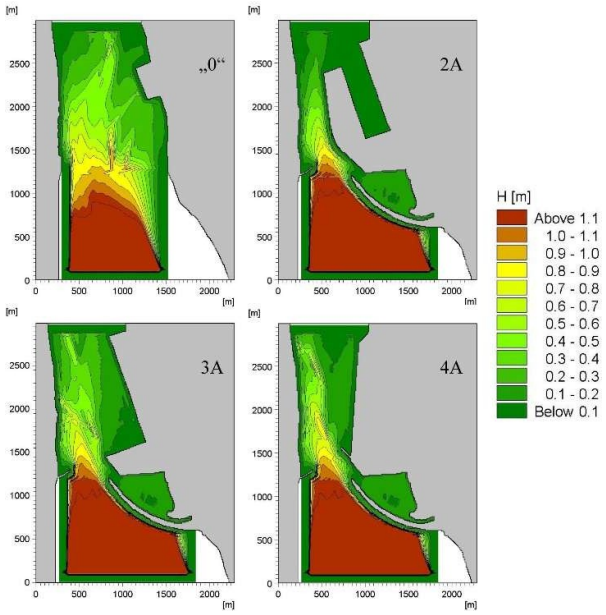
When a wind of 14 m/s blows from the PPV direction, the wave direction is toward the southern pier of the planned southern port entrance in the case of Alternatives 2A, 3A, and 4A (Fig. 4.1.2.62). The highest wave heights will be in the water area near the planned southern port entrance. In the current configuration (Alternative 0), waves spread across the entire modeled water area. With a 12 m/s wind blowing from the P direction, the wave direction is perpendicular to the modeled water area (Fig. 4.1.2.63). In the case of Alternative 0, higher waves will propagate closer to the coast of the Curonian Spit, as an 8-meter-high wave entering the cross-section of the planned southern port gates near the eastern shore quickly subsides due to a sudden decrease in water depth. In Alternative 2A, the greatest wave dissipation will occur near the landform on the eastern shore. The different configurations of the landform and the vessel turning areas will determine wave dissipation in Alternatives 3A and 4A. The highest waves will propagate through the planned southern port gates at the locations of the underwater slopes (between the deepened vessel turning areas and the significantly shallower current navigation area). The smallest waves were observed in the turning basins. In Alternatives 3A and 4A, larger waves will propagate toward the coast of the Curonian Spit. When a 12 m/s wind blows from the PPR direction, a similar wave propagation pattern is observed for all PŪV alternatives as when a wind blows from the P direction (Fig. 4.1.2.64). However, the higher waves are more oriented toward the Curonian Spit coast. The wave diffraction coefficient (K) characterizes the nature of wave propagation in the northern part of the Curonian Lagoon. When a wind blows from the PPV direction, the generated wave height is 1.44 m; for a P-direction wind, it is 1.26 m; and for a PPR wind, it is 1.16 m (Table 4.1.2.6).



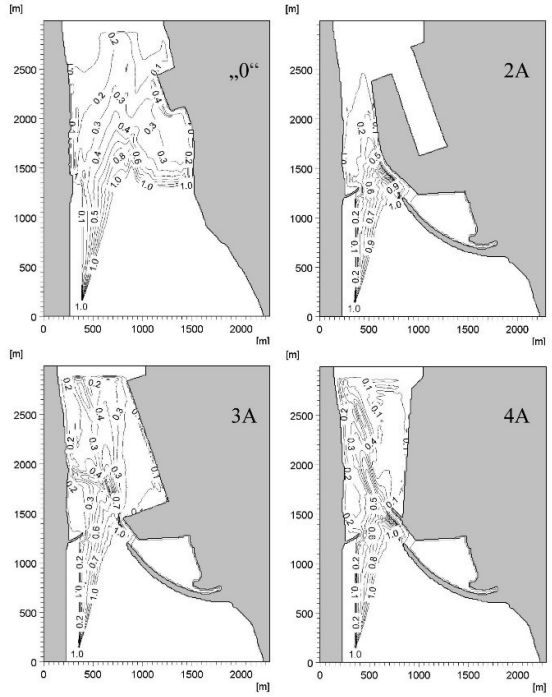
4.1.2.62 Fig. Wave height distribution in the northern part of the Curonian Lagoon with a 14 m/s wind blowing from the PPV direction for Alternatives 0, 2A, 3A, and 4A



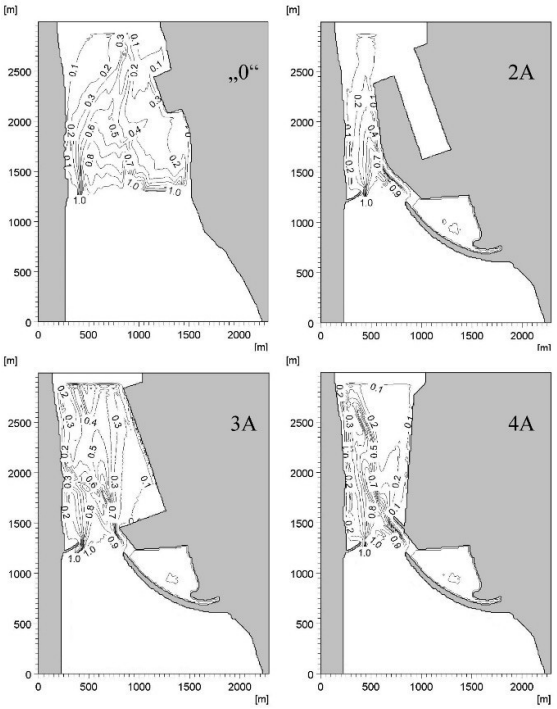
4.1.2.63 Fig. Wave height distribution in the northern part of the Curonian Lagoon with a 12 m/s P-direction wind in Alternative 0, 2A, 3A, and 4A



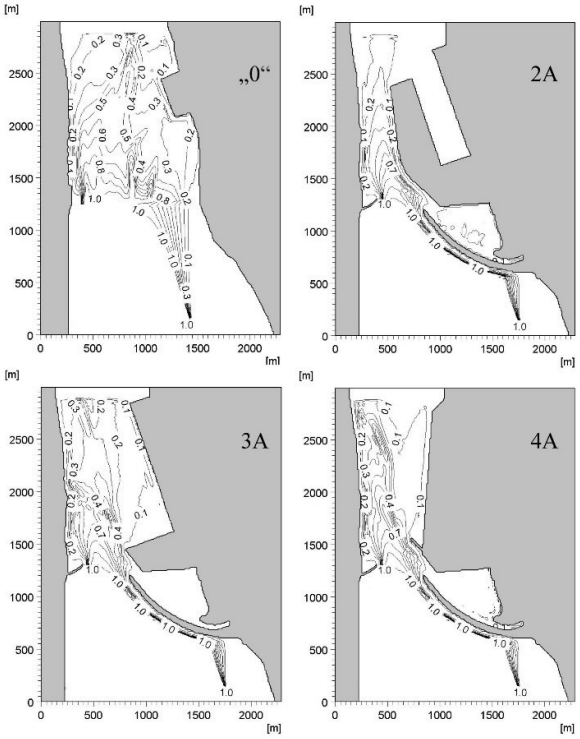
4.1.2.64 Fig. Wave height distribution in the northern part of the Curonian Lagoon with a 12 m/s wind blowing from the PPR direction for Alternatives 0, 2A, 3A, and 4A



4.1.2.65 Fig. Distribution of the wave diffraction coefficient in the northern part of the Curonian Lagoon with a 14 m/s wind blowing from the PPV direction for Alternatives 0, 2A, 3A, and 4A



4.1.2.66 Fig. Distribution of the wave diffraction coefficient in the northern part of the Curonian Lagoon with a 12 m/s wind blowing from the P direction in cases 0, 2A, 3A, and 4A



4.1.2.67 Fig. Distribution of the wave diffraction coefficient in the northern part of the Curonian Lagoon with a 12 m/s wind blowing in the PPR direction for alternatives 0, 2A, 3A, and 4A

When winds blow from the PPV, P, and PPR directions, under the current conditions (Alternative 0), waves will spread throughout the modeled water area (Figs. 4.1.2.65–4.1.2.67). The highest diffraction coefficients (0.3–0.8) are observed in the central part of the water area, while the lowest are near the eastern shore.

In the case of Alternative 2A, wave dispersion will be concentrated in the channel between the Curonian Spit coast and the formed landmass (Figs. 4.1.2.65–4.1.2.67). When a PPV wind blows, the diffraction coefficient (K) at the end of the channel (1 km from the southern gate toward Kiaulės Nugaros) will decrease from 1.0 to 0.1, and when a P or PPR wind blows, it will decrease to 0.2. This means that the wave height in the remaining part of the water area is 10 or 5 times lower than the height of the outer wave. When winds blow from the PPV and PPR directions, in the case of Alternatives 3A and 4A, in the water area 500 m from the planned southern port entrance toward Kiaulės Nugaros Island, the diffraction coefficient decreases from 1.0 to 0.7 (Figs. 4.1.2.65 and 4.1.2.67). As the waves propagate, they rapidly attenuate and K decreases to 0.1. Deeper wave penetration occurs when a P-direction wind is blowing (Fig. 4.1.2.66); the wave is reduced by half (diffraction coefficient 0.5) just 1.2 km from the planned southern port entrance toward Kiaulės Nugaros Island. When winds from the studied directions blow, the diffraction coefficient at the Curonian Spit coast is 0.2, while on the eastern coast it decreases to 0.1. In the case of Alternatives 3A and 4A, the distribution of diffraction coefficients is similar (Figs. 4.1.2.65–4.1.2.67). Only in the case of Alternative 4A are higher coefficients observed in the central part of the harbor basin due to the narrowing of the modeled basin and the underwater slope between the basin, which has been dredged to a depth of 17 m, and the shallow part of the Curonian Lagoon.

Wave parameters in the inner harbor basin were determined in longitudinal cross-section 1-2, which extends from the planned southern harbor gates to Kiaulės Nugaros Island (Fig. 4.1.2.61). The

cross-section is located 50 m from the pier toward the Curonian Spit shore. Fig. 10.8 shows the variation of diffraction coefficients in cross-section 1-2. With a PPV wind, the coefficients in cross-section 1-2 are similar for Alternatives 0 and 2A. The greatest fluctuations in K are observed in Alternatives 4A and 3A (Fig. 4.1.2.68a).

A similar variation in diffraction coefficients is observed when a P-direction wind is blowing (Fig. 4.1.2.68b). Only in Alternative 2A are the coefficients lower. The distribution of coefficients is different when a PPR wind is blowing. The highest coefficients were found in the case of Alternative 0, and the lowest in the case of Alternative 2A. The greatest variation in coefficients was found in the case of Alternative 4A. An analysis of diffraction coefficients at the selected cross-section showed that the variation in wave heights depends heavily on the wind direction and the selected PŪV alternative. Selecting a different cross-section location may reveal different trends in wave variation.

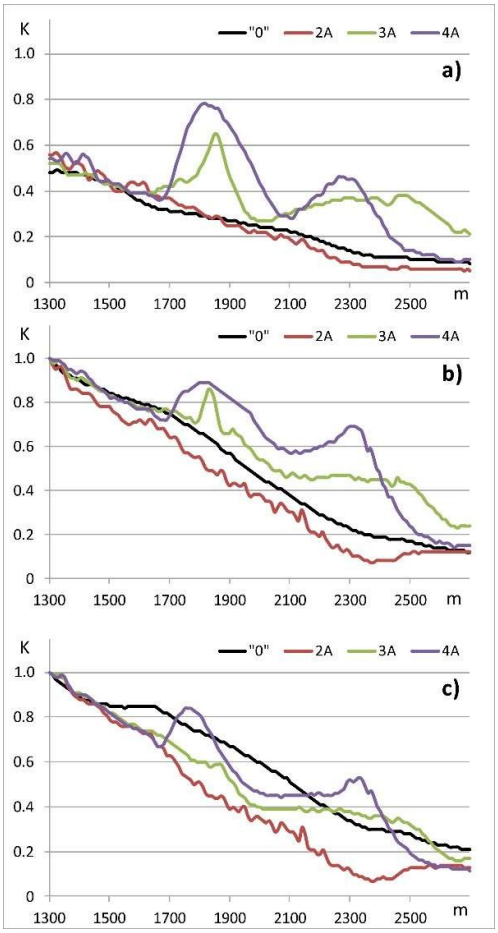
To assess navigation conditions when entering the planned marina for recreational and small vessels, three control points were selected, located at the marina's entrance channel and near the newly formed land (Fig. 4.1.2.61). The diffraction coefficients at these points were calculated for all PŪV alternatives and wind directions (Table 4.1.2.7).

4.1.2.7 Table. Wave diffraction coefficients (K) at three points in the northern part of the Curonian Lagoon (Fig. 4.1.2.61) with winds blowing from the PPV, P, and PPR directions

Alternative	Point 1			Point 2			Point 3		
	PPV	P	PPR	PPV	P	PPR	PPV	P	PPR
0	0.98	0.97	0.88	0.55	0.86	0.86	0.24	0.46	0.60
2A	0.55	0.50	0.27	0.57	0.74	0.55	0.22	0.38	0.35
3A	0.57	0.52	0.25	0.73	0.94	0.76	0.27	0.54	0.40
4A	0.56	0.52	0.25	0.75	0.95	0.77	0.43	0.68	0.46

When winds blow from the PPV and P directions, the wave penetrating through the planned southern port gates at the first point (near the planned marina entrance channel) will be reduced by nearly half in the case of Alternatives 2A, 3A, and 4A. The diffraction coefficients for the aforementioned PŪV alternatives are similar regardless of wind direction. At the second point, located 200 m from the first point toward Kiaulės Nugaros Island, higher diffraction coefficients were observed for Alternatives 3A and 4A compared to Alternative 2A. Therefore, wave heights at Point 2 will also be more hazardous to navigation. At the third point, located 700 m from the first point toward Kiaulės Nugaros Island, the highest K values were observed for Alternative 4A. This is determined by the configuration of the landmass and the location where ships turn.

From a navigation perspective, in the northern part of the Curonian Lagoon, from the planned southern port entrance to Kiaulės Nugaros Island, the most unfavorable conditions in Alternatives 3A and 4A would occur during strong P-direction winds. In addition, for the aforementioned PŪV alternatives, higher waves are observed near the Curonian Spit coast (K varies from 0.2 to 0.3). Alternative 2A is the most favorable in terms of wave dispersion, as the incoming waves passing through the southern gate propagate more uniformly and subside more quickly than in the cases of Alternatives 3A and 4A.



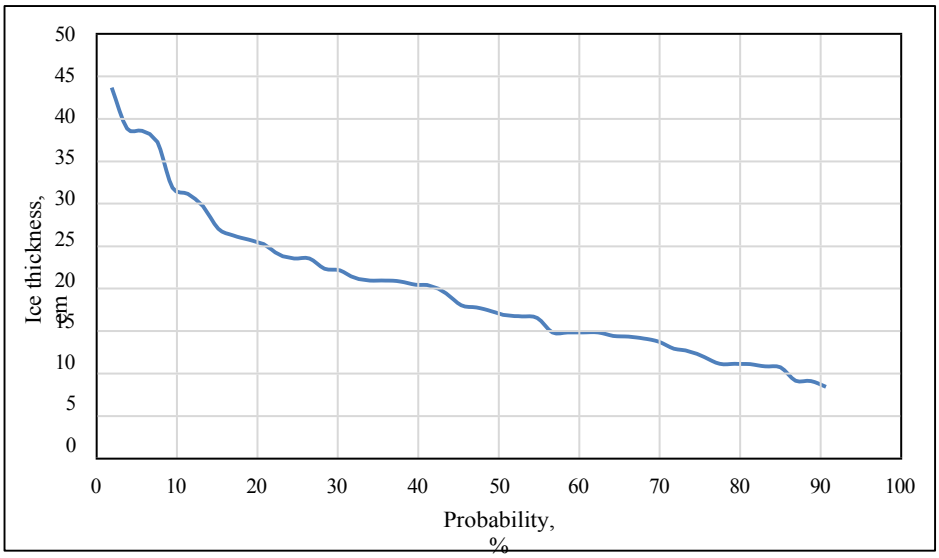
4.1.2.68 Fig. Distribution of wave diffraction coefficients in longitudinal profile 1–2 from the planned southern port gates to Kiaulės Nugaros Island (Fig. 4.1.2.61d): a) with a PPV wind, b) with a P wind, c) with a PPR wind

Conclusion: The highest waves in the northern part of the Curonian Lagoon, from the planned southern port entrance to Kiaulės Nugaros Island, would occur in Alternatives 3A and 4A when a strong P-direction wind is blowing. Higher waves would also be observed near the Curonian Spit coast in the cases of the aforementioned PŪV alternatives (the diffraction coefficient varies from 0.2 to 0.3). Alternative 2A would be the most favorable in terms of wave dispersion, as the incoming waves passing through the planned southern port gates would propagate more evenly and subside more quickly than in the case of Alternatives 3A and 4A.

The influence of ice cover on the flow regime in the northern part of the Curonian Lagoon

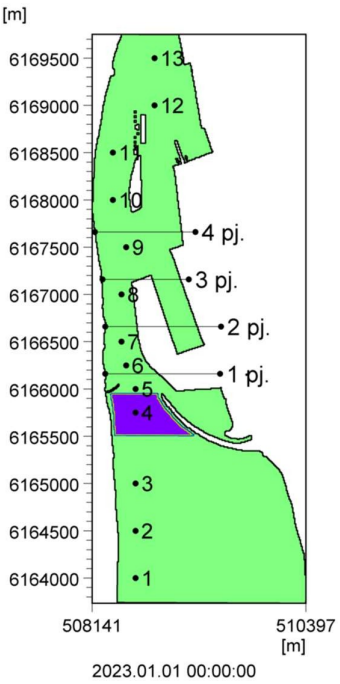
The influence of ice cover on the flow regime in the northern part of the Curonian Lagoon for different Alternatives was assessed using the MIKE 21 HD FM model with ice cover data. Initial ice cover data (ice cover thickness, m) were determined based on data from the Juodkrantė water gauging station for 1961–2011. A probabilistic ice cover thickness distribution was prepared (Fig. 4.1.2.69). The average ice thickness in the Curonian Lagoon near Juodkrantė is low (0.17 m). Climate change has also contributed to this. Therefore, to assess the impact of ice cover on the hydrodynamics of the northern part of the Curonian Lagoon, a 5
% probability (recurrence interval of once every 20 years) ice cover thickness of 0.38 m was selected. Such an ice cover thickness at the southern boundary of the port's water area is even less likely, as the ice cover thins due to changes in the flow regime in the water area toward the Klaipėda

Strait.



4.1.2.69 Fig. Probabilistic distribution of ice thickness in the Curonian Lagoon near Juodkrantė

To simulate the influence of the ice cover on the hydrodynamics of the northern part of the Curonian Lagoon, we modeled an ice sheet in front of the planned southern port entrance breakwaters. The ice bar extends approximately 500 m, and the ice cover is 0.38 m thick (Fig. 4.1.2.70). Hydrodynamic modeling was performed for all PŪV alternatives, both with and without ice cover, for three different discharge rates from the Curonian Lagoon to the Baltic Sea. Higher discharge rates were selected (1,300, 1,850, and 2·700 m³/s) because, when flows smaller than the average discharge pass through the strait, flow velocities in the northern part of the Curonian Lagoon will be low and will not affect ice accumulations.



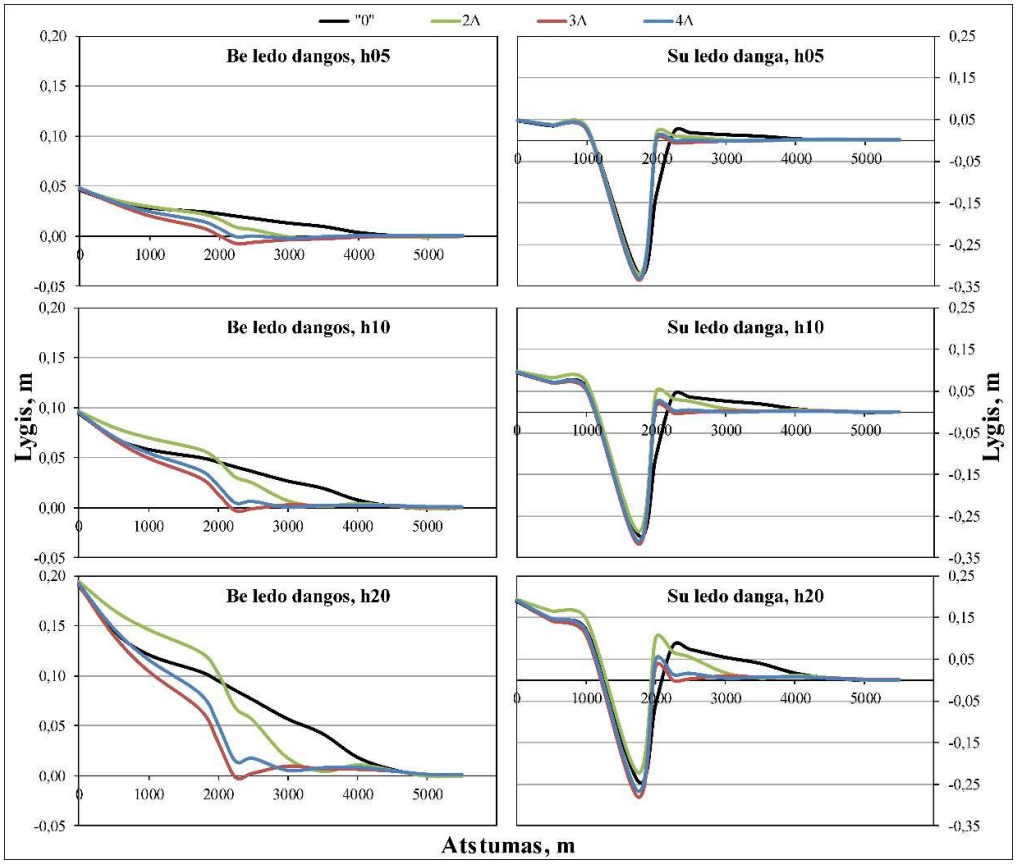
4.1.2.70 Fig. Position of the ice edge (purple) in the modeled port basin (points 1–13 mark

locations where water level differences (m) were calculated in the longitudinal section; points 1–4

sections, flow velocities were assessed for all PŪV alternatives)

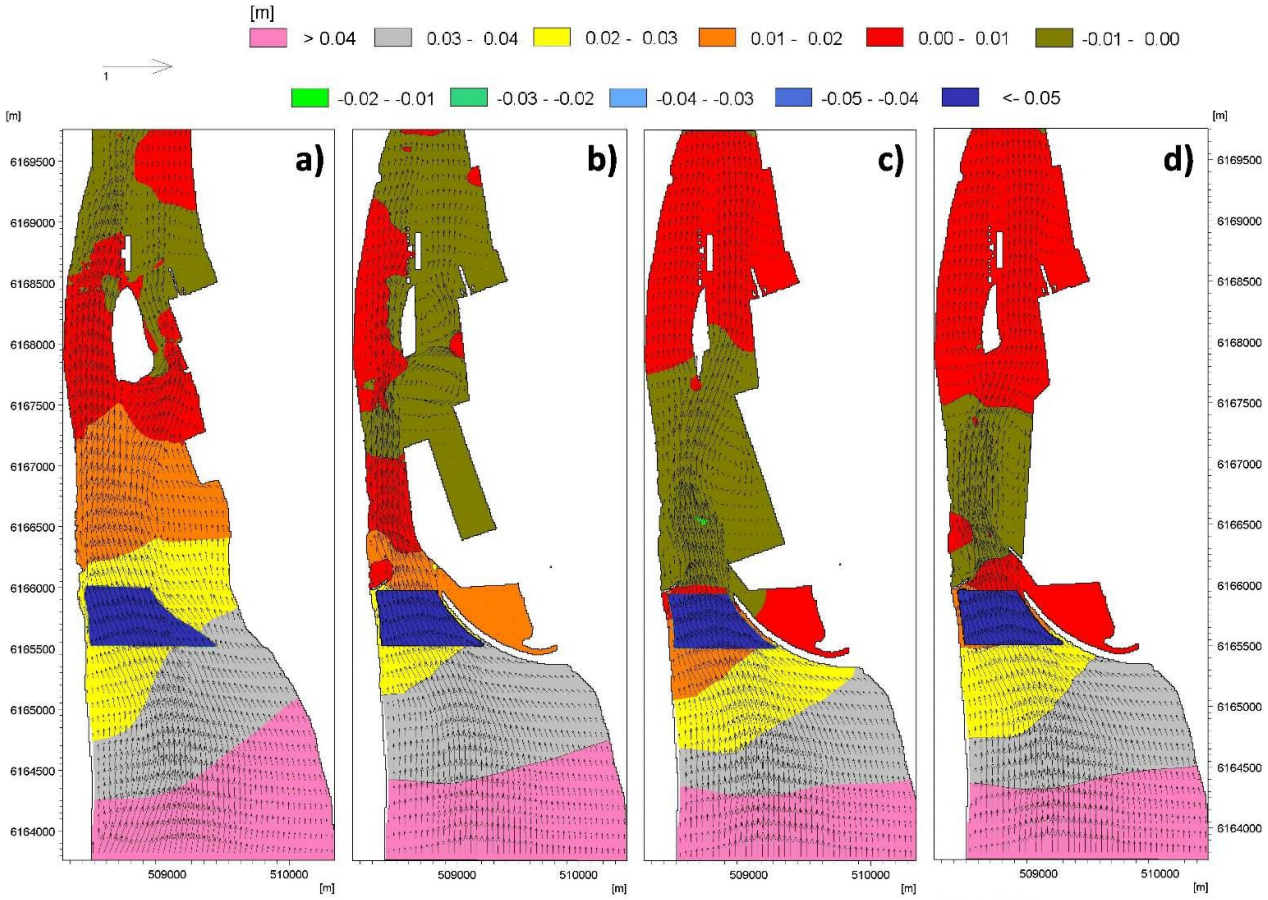
4.1.2.71 – Fig. 4.1.2.73 illustrates water level changes and flow velocity distributions at different discharge rates when an ice bank has formed near the planned southern port gates. Each PŪV alternative affects the hydrodynamic processes in the northern part of the Curonian Lagoon differently. Changes in flow velocities for different PŪV alternatives have been described in detail previously, when there is no ice cover in the water area. This section analyzes whether the formed ice cover will affect the distribution of water level differences and flow velocities compared to the hydrodynamic regime of the water area without ice cover.

Fig. 4.1.2.74 shows changes in water level differences in a longitudinal section of the water area (Fig. 4.1.2.70, from point 1 to point 13) without ice cover and with ice cover, for three water level differences between the boundary walls of the modeled water area (h05 = 0.05 m; h10 = 0.10 m; h20 = 0.20 m). These water level differences correspond to discharge rates of 1300, 1850, and 2700 m^3/s in the modeled water area.



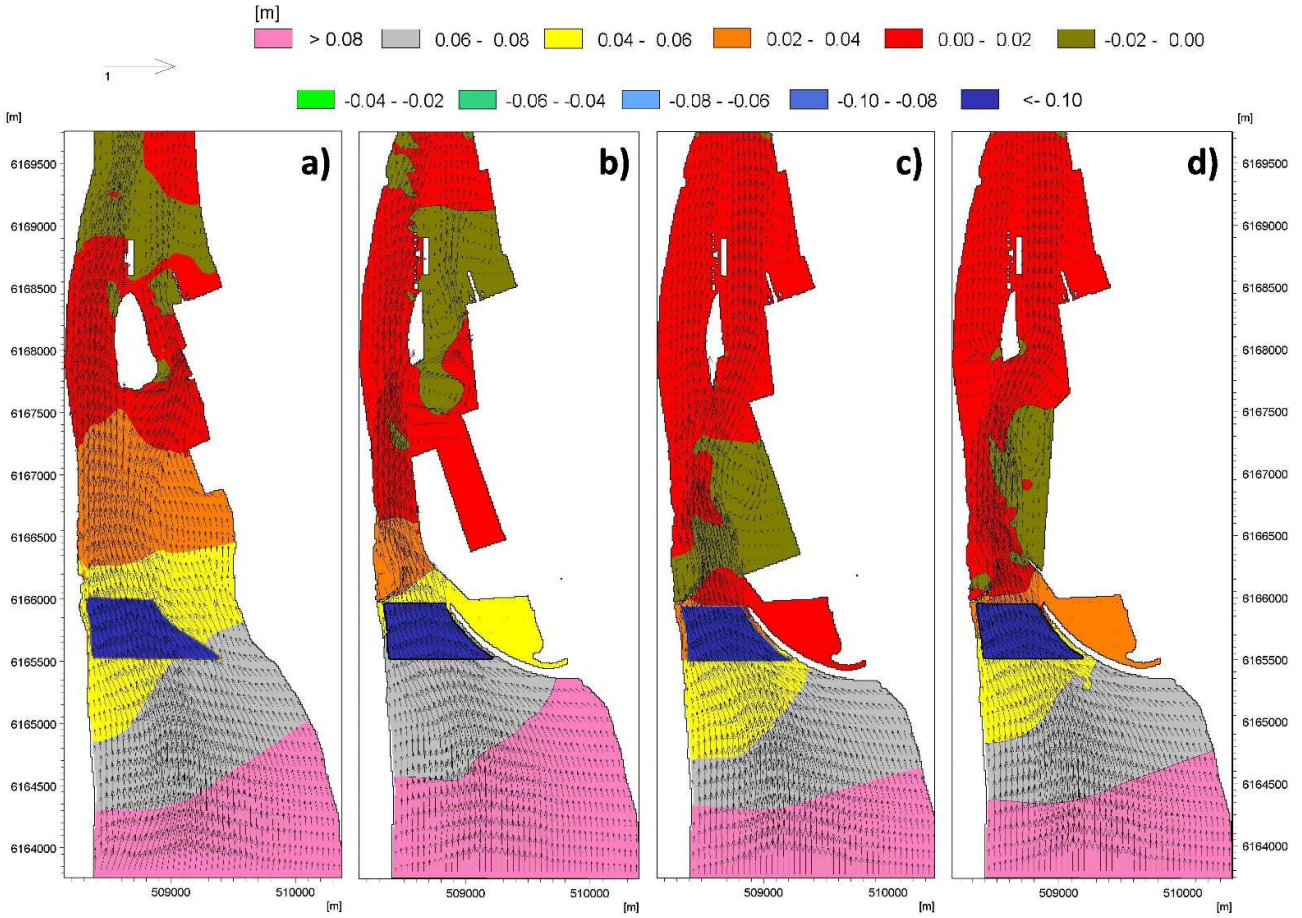
4.1.2.71 Fig. Changes in water level differences in the longitudinal section of the water area (Fig. 4.1.2.70, from points 1 to 13) without ice cover and with ice cover, for three water level differences between

the outer walls of the modeled water area (h05 = 0.05 m; h10 = 0.10 m; h20 = 0.20 m)



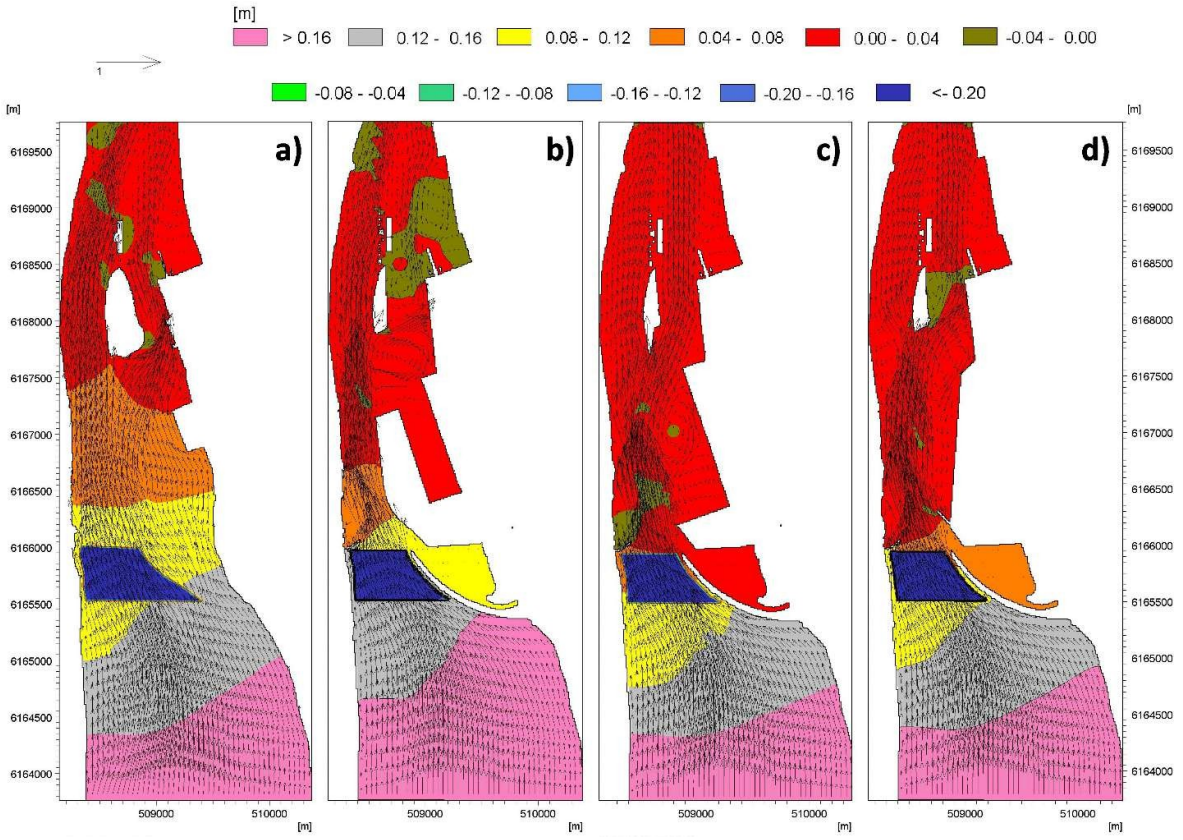
4.1.2.72 Fig. Distribution of water level differences and flow velocities for a 0.05 m water level difference in the water area with a flow rate of 1300 m³/s:

a) Alternative 0, b) 2A, c) 3A, and d) 4A



4.1.2.73 Fig. Distribution of water level differences and flow velocities with a 0.10 m water level difference in the water area at a flow rate of[1,850]m³/s:

a) Alternative 0, b) 2A, c) 3A, and d) 4A

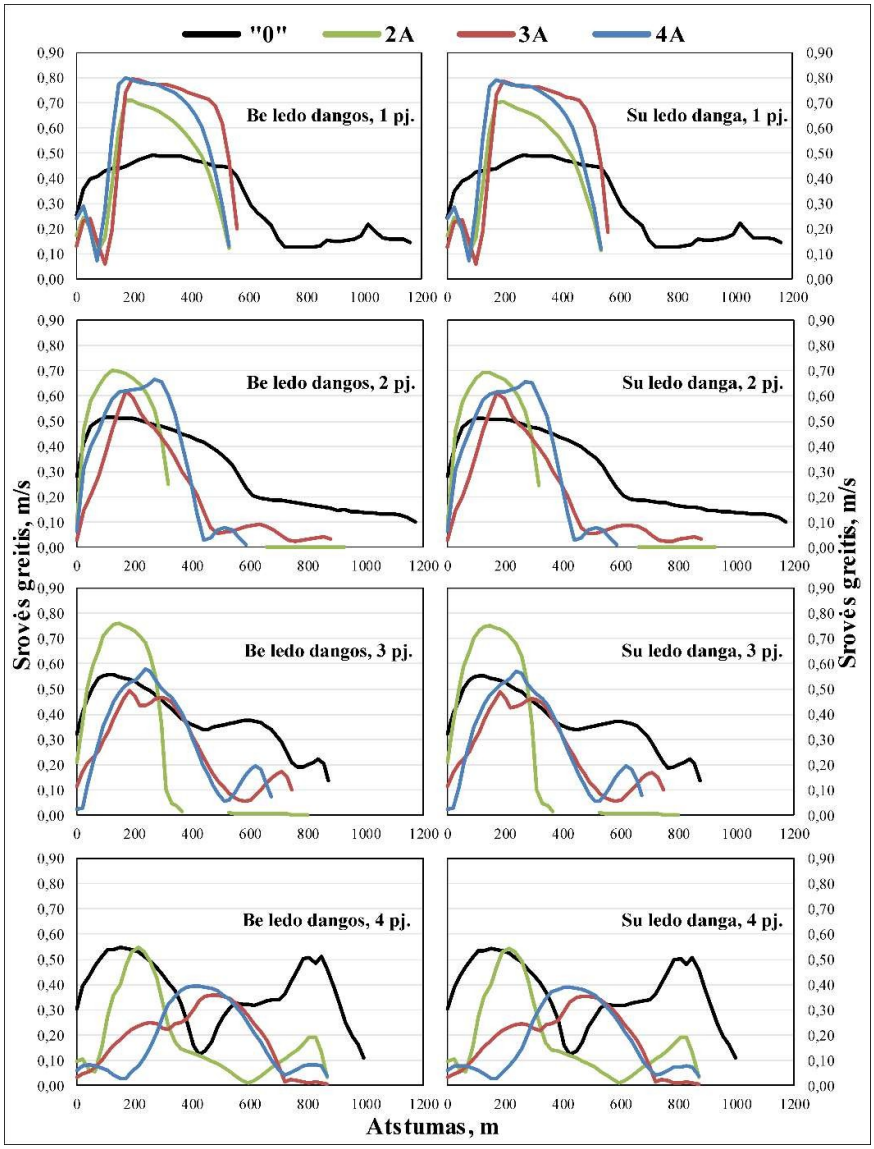


4.1.2.74 Fig. Distribution of water level differences and flow velocities with a 0.20 m water level difference in the water area at a flow rate of 2700 m³/s:

a) Alternative 0, b) 2A, c) 3A, and d) 4A

Water level differences decrease most gradually for the current situation alternative (Fig. 11.6, Alternative 0), when there is no ice cover in the modeled area. In the case of Alternatives 3A and 4A, a sharp drop in water level is observed in the water area beyond the planned southern port gates (Fig. 4.1.2.70, point 6), while in the outer water area toward Kiaulės Nugaros Island, the water level increases slightly (up to 1 cm) when the level difference is high (h20). Different changes in water level differences were observed when an ice cover formed in the water area (Fig. 4.1.2.74, right column). A significant decrease in water level (up to 0.34 m) was observed after ice formation (Fig. 4.1.2.70, point 4). This decrease depends more on the selected initial water level difference than on the selected port development alternative. A rise in water level is observed in the water area beyond the planned southern port gates—a water backwater will form. The maximum backwater height (m) was determined for Alternatives 2A and 0. The water backwater would be half as high in the case of ice cover for Alternatives 3A and 4A.

To assess the impact of ice cover on the hydrodynamics of the northern part of the Curonian Lagoon, the distribution of flow velocities (Fig. 4.1.2.75) was analyzed in four cross-sections of the water area (Fig. 4.1.2.70, sections 1–4) without ice cover and with ice cover, when the flow rate in the water area is $1^{,850\ m^3}$/s.



4.1.2.75 Fig. Flow velocity distributions in 4 cross-sections of the water area (Fig. 4.1.2.70, sections 1–4) without ice cover and with ice cover, with an initial water level difference of 0.10 m between

the outer walls of the modeled water area (at a flow rate of 1850 m^3/s)

When comparing changes in flow velocity between conditions with and without ice cover in the waterway, no significant differences were observed at any of the cross-sections studied (Fig. 4.1.2.75). Differences in flow velocities range from 0.01 to 0.02 m/s, which accounts for only up to 2% of the average flow velocities. Changes in flow at the cross-sections are determined by the selected PŪV alternative, not by the influence of ice cover.

After assessing the impact of the ice cover formed upstream of the planned southern port gates, on the hydrodynamics of the northern part of the Curonian Lagoon, it was determined that in the case of Alternatives 3A and 4A, a backwater with half the water level will form in the water area beyond the planned southern port gates toward Kiaulės Nugaros, than in Alternatives 0 and 2A (at a high flow rate of $2,700 m^3/s$, the backwater height is 0.05 m and 0.10 m, respectively).

Conclusion: Due to the formation of an ice cover in the planned southern port entrance water area, a water backwater would form in the water area beyond the planned southern port entrance toward Kiaulės Nugaros Island. In the case of Alternatives 3A and 4A, the water level backwater height would be half that of Alternatives 0 and 2A (at a flow rate of^{2,700}m³/s, the backwater height would be 0.05 m and 0.10 m, respectively).

Impact of the reduction in the area of the Curonian Lagoon

The total area of the lagoon is 1,584 km², but the part of the Curonian Lagoon belonging to the Republic of Lithuania covers 381.6 km². The Curonian Lagoon contains the sole island of Kiaulės Nugaros. According to the EIA solutions for individual EIA alternatives, it is planned to fill part of the lagoon's water area with soil (to form land) and to dredge part of the territory of Kiaulės Nugaros Island (to form a water area): In the case of Alternative 2A—approximately 106.6 ha and approximately 13.4 ha, respectively; in the case of Alternative 3A—approximately 77.6 ha and approximately 13.2 ha, respectively; in the case of Alternative 4A—approximately 101.4 ha and approximately 13.6 ha, respectively. Due to these PŪV solutions, the area of the lagoon water area would decrease by 93.2 ha in the case of Alternative 2A (or approximately 0.24% of the total area within the territory of the Republic of Lithuania), by 64.4 ha in the case of Alternative 3A (or approximately 0.17% of the total area within the territory of the Republic of Lithuania), and in the case of Alternative 4A—by 87.8 ha (or approximately 0.23% of the total area within the territory of the Republic of Lithuania).

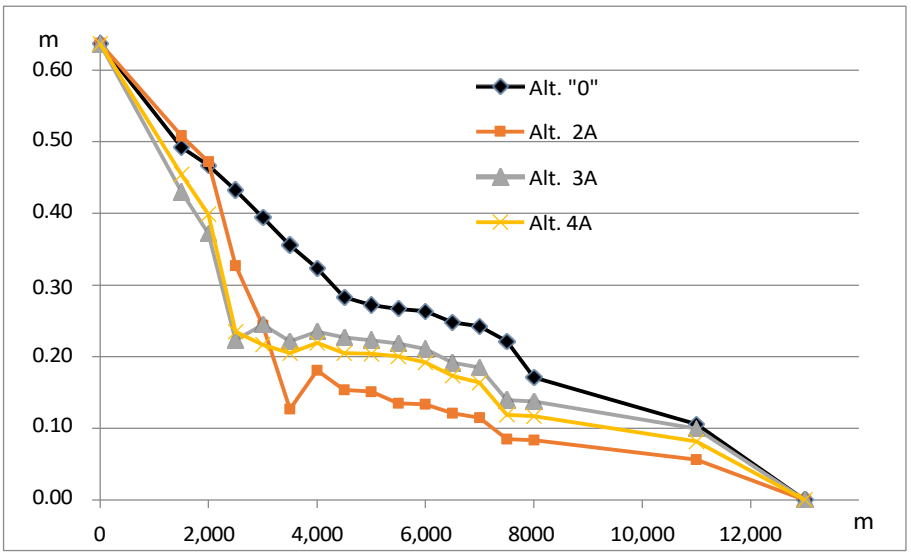
Conclusion: Due to these PŪV solutions, the area of the lagoon water body would decrease by 93.2 ha in the case of Alternative 2A (or approximately 0.24% of the total area of the Republic of Lithuania), by 64.4 ha in the case of Alternative 3A (or approximately 0.17% of the total area of the Republic of Lithuania), and by 87.8 ha (or approximately 0.23% of the total area within the territory of the Republic of Lithuania) in the case of Alternative 4A. In terms of increasing impact, the PŪV alternatives are ranked as follows: 3A < 4A < 2A

Impact due to the risk of flooding in the PŪV area

As described in Section 4.1.1, in the Klaipėda Strait, the instantaneous water level most often (in 95% of cases) fluctuates between 50 and -50 cm, while the observed extreme levels are +186 cm and -100 cm. The PŪV solutions for any PŪV alternative will affect areas falling within high- and medium-probability flood hazard and risk zones: Kiaulės Nugaros Island, the KVJU contaminated soil storage site, and the southwestern coast of the Smeltė Peninsula are planned to be raised. In the remaining (unreclaimed) part of Kiaulės Nugaros Island, a layer of soil approximately 0.5 m thick is planned to be deposited to create an area suitable for bird nesting sites. The surface of the newly formed land, including the KVJU contaminated soil storage site and the coast of the southwestern part of the Smeltė Peninsula, will be raised to a level of 3.0–3.5 m above the existing water surface in all PŪV alternatives, i.e., to the existing surface level on the Smeltė Peninsula near Kairių St. (solutions must be refined during the technical design phase). Upon implementation of the PŪV solutions for any PŪV alternative, the risk of flooding of the newly formed land area, taking climate change into account, would be unlikely.

To assess water level changes (potential backwater) in the Klaipėda Strait as water flows from the Baltic Sea into the Curonian Lagoon, additional calculations were performed. The calculated water level changes along a longitudinal section of the Curonian Lagoon and the Klaipėda Strait, the start of which coincides with the southern boundary of the Port of Klaipėda (point "0" on the "x" axis in Figs. 4.1.2.76 and 4.1.2.77), and the end of the section at the northern port gates.

4.1.2.76 Fig. shows water level changes in the longitudinal section when a flow rate of 4·210 m³/s flows through the strait from the Curonian Lagoon to the Baltic Sea. Upon implementation of the PŪV solutions, the strait's capacity would increase in the case of Alternatives 3A and 4A, therefore, the water flow passing through the planned southern port gates (Fig. 4.1.2.76, "2200 m" mark on the "x" axis) would flow more quickly into the Baltic Sea without causing a water level backwater in the Curonian Lagoon. The backwater height would increase very slightly in the Curonian Lagoon water area from the cross-section of the Klaipėda Port water area to the water area of the planned southern port gates in the case of Alternative 2A. This increase is not significant and would not pose a threat to the shores of the Curonian Spit.



4.1.2.77 Fig. Changes in water level differences in a longitudinal section of the water area (the "0 m" point on the x-axis is the southern boundary of the seaport, the "13,000 m" point is at the northern port gates), when a flow of

4·210 m³/s from the Curonian Lagoon to the Baltic Sea.

Fig. 4.1.2.77 illustrates water level changes for all evaluated PŪV alternatives when a flow rate of 3·200 m³/s flows through the strait from the sea into the lagoon. When comparing Alternatives 2A, 3A, and 4A with Alternative
"0," the water level in the Klaipėda Strait (Fig. 4.1.2.77, from 4,000 to 13,000 m on the "x" axis) would increase slightly due to the planned construction of the southern port gates. In the northern part of the Curonian Lagoon (from Kiaulės Nugaros Island to the planned southern port gates, from 4,000 to 2,200 m on the "x" axis in Fig. 4.1.2.77), a drop in water level to the level under Alternative "0" is observed, while in the section from the planned southern port gates to the southern expansion of the Port of Klaipėda, water level changes are similar across all evaluated PŪV alternatives. Hydrodynamic modeling results confirmed that, with a narrow flow from the Baltic Sea into the Curonian Lagoon, in the northern part of the lagoon, the PŪV Alternatives 2A, 3A, and 4A will not increase the risk of flooding for the shores of the Curonian Spit.

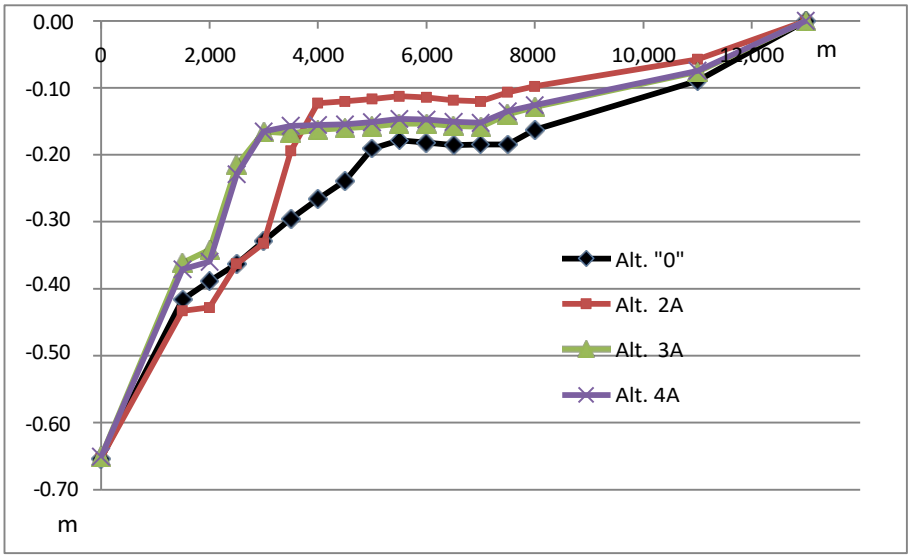


Fig. 4.1.2.77. Changes in water level differences in a longitudinal section of the water area (the “0 m” point on the x-axis is the southern boundary of the seaport, the “13,000 m” point is at the northern port entrance), when the flow rate through the strait is

a flow rate of 3,200 m³/s from the Baltic Sea into the Curonian Lagoon.

An analysis of water level changes (water levels) was conducted for very high flow rates both from the lagoon to the sea as well as from the sea into the lagoon, confirmed that the newly formed land areas and the dredging of the water area will not increase the risk of flooding for the Curonian Spit coastline or the newly formed land areas in any of the assessed project alternatives.

The need for surface water management due to new land areas

Upon implementation of the PŪV solutions under any PŪV alternative, a new area (both in the water and on land) will be formed in place of part of the Curonian Lagoon water area, with an area that, depending on the selected PŪV alternative, would be: Alternative 2A – approximately 106.6 ha, Alternative 3A – approximately 77.6 ha, and Alternative 4A – approximately 101.4 ha. It is assumed that the entire area will be covered with impermeable surfaces, resulting in a significant volume of surface runoff that will need to be collected and managed accordingly (treated and discharged into the Curonian Lagoon).

It is preliminarily estimated that in the case of Alternative 2A, approximately 681,281 m³/year would be generated, in the case of Alternative 3A – approximately 495,492 m³/year, and in the case of Alternative 4A – approximately 648,048 m³/year.

The exact volumes of wastewater, their pollution levels, and treatment solutions will be determined once the specific land uses and development plans for the area are known during the technical design phase. Surface runoff generated and collected within the PŪV territory must be managed in accordance with the requirements of the Surface Runoff Management Regulations [69],

Conclusion: the creation of additional port land areas will result in additional volumes of surface runoff, which will need to be collected and managed accordingly. It is preliminarily estimated that in the case of Alternative 2A, approximately 681,281 m³/year would be generated, in the case of Alternative 3A—approximately 495,492 m³/year, and in the case of Alternative 4A—approximately

648,048 m³/year. In terms of increasing impact, the PŪV alternatives are ranked as follows: 3A < 4A < 2A.

Summary conclusion: The PŪV solutions for port development plan to create new land and deepen the water area in the northern part of the Curonian Lagoon within the KVJU territory. In the case of Alternative 2A, this would amount to approximately 81.6 ha and 95.2 ha, in the case of Alternative 3A—approximately 60.5 ha and 114.8 ha, respectively, and in the case of Alternative 4A—approximately 83.4 ha and 96.4 ha, respectively. Due to these PŪV solutions, in the case of any PŪV alternative, surface water bodies would be subject to direct and indirect impacts during the construction of the facilities (due to increased water turbidity during dredging and soil deposition). The impact would be short-term (only during construction), interactive (may affect other environmental elements, e.g., ichthyofauna), and of minor negative significance. Once the solutions are implemented, the impact during facility operation would be long-term (throughout the entire operational period), interactive (may affect other environmental elements, e.g., biodiversity), ranging from minor to moderate negative (due to hydrodynamic processes, sediment transport, salinity and wave dispersion, changes in the reservoir area, the threat of flooding, and increased surface runoff). When comparing the PŪV alternatives, the least impact on the aquatic environment would be observed in the case of PŪV alternatives 4A and 3A. During the construction and operation of PŪV facilities, it is necessary to implement measures to prevent, mitigate, and/or compensate for the negative impacts of the PŪV.

4.1.3 Measures to prevent, reduce, and compensate for significant adverse environmental impacts:

Proposed measures to prevent and reduce impacts on surface water:

- As one of the economic entities capable of influencing the condition of the aforementioned surface water bodies, the Port of Klaipėda, in carrying out its activities and planning port development, must implement solutions and preventive measures that would prevent and minimize potential negative consequences and comply with both the requirements of the laws of the Republic of Lithuania and the provisions of the 1992
  Helsinki Convention on the Protection of the Marine Environment of the Baltic Sea Area [37] and the requirements set forth in its annexes;
- Responsible use of low-polluting equipment (dredgers, ships, vehicles, machinery, etc.) during and after the implementation of the solutions;
- Responsible and timely execution of dredging and disposal of sediments accumulated on the bottom of water bodies in accordance with established requirements;
- Implementation of sustainable solutions and technologies in the development and expansion of economic activities within the KVJU territory, enabling a reduction in water consumption and the volume of wastewater generated;
- Responsible management of generated wastewater, ensuring the necessary wastewater collection and treatment capacities, in accordance with the requirements of the Republic of Lithuania Water Law [70], the Wastewater Management Regulation [71], and the Surface Water Management Regulation [69];
- Monitoring of discharged wastewater and its impact on surface water during the use of the site (applicable in later stages of operation, once specific economic activities have commenced on the site).

4.2 Ambient Air

4.2.1 Description of the current situation

The background pollution of ambient air at the project site was determined in accordance with the "Recommendations for the Use of Background Ambient Air

to Assess the Impact of Economic Activities on Ambient Air Quality" [42]. There are no air quality monitoring stations within a 2 km radius of the project site. An indicative assessment of ambient air quality has been conducted near the project site—KLP11 (Minijos St. and Naikupės St.). Its results (annual averages):

- Nitrogen dioxide – 18.6 μg/m^3;
- Sulfur dioxide – 0.5 μg/m^3.

Based on information provided on the Environmental Protection Agency's website, the background ambient air pollution in the area under consideration, as determined by modeling for 2022, is:

- Carbon monoxide – 210–220 μg/m^3;
- Nitrogen dioxide – 9–12 μg/m^3;
- Particulate matter (PM_{10}) – 17–25 μg/m^3;
- Particulate matter ($PM_{2.5}$) – 7–11.9 μg/m^3;
- Sulfur dioxide – 6.9–7.8 μg/m^3;
- Volatile organic compounds – 32–49 μg/m^3 .

Background environmental pollution data should be used in the following order (in descending order of priority):

- data from indicative ambient air quality assessments;
- data on ambient air pollution determined by modeling.

4.2.2 Expected significant impact on ambient air

Correspondence of the abbreviations for ambient air pollutants used in this document to the names and codes specified in the Procedure for Accounting and Reporting on Emissions of Pollutants into the Ambient Air [73]:

Abbreviation of pollutant name in the document	Full name of the pollutant used in the procedure description	
	Name	Code
Carbon monoxide (B)	Carbon monoxide (B)	5917
Nitrogen oxides (B)	Nitrogen oxides (NO_x) (B)	5872
Particulate matter	Particulate matter from the combustion of solid, liquid, or gaseous fuels or waste (dust)	6486
LOJ	Volatile organic compounds, excluding methane, not differentiated by composition (individual compounds)	308
Sulfur dioxide (B)	Sulfur dioxide (SO_2) (B)	5897

Impact during the construction of the PŪV facilities

During the construction/implementation of the PŪV facilities, the ambient air will be polluted by pollutants emitted into the ambient air from vehicles (trucks, cranes, lifts, excavators, bulldozers, ships, barges, etc.) and equipment (backhoes and excavators, drilling rigs, pile drivers, generators, and other machinery). These emissions include combustion products (NO_x, CO, CH4, SO_x, LOJ) emitted into the ambient air during soil excavation, material transport, the development of areas with the necessary infrastructure, the construction of hydraulic structures and facilities, and the dismantling and demolition of structures. The majority of the work involves dredging the navigation channel and water areas, as well as the transportation of dredged soil, including its disposal (by transporting and forming new land areas, transporting and replenishing beaches, or dumping it in landfills).

Air pollutant emissions from ships' internal combustion engines depend on the ship type, tonnage, engine type, power, load, and operating mode, as well as the type of fuel burned. According to the EIA report on the reconstruction of the southern and northern breakwaters of the KVJU [19], a single 2·450 m³ dredger-barge

emits approximately 33.8 tons of air pollutants into the ambient air while transporting a nominal 1 million $m^3$of soil over a distance of 1 km.

The quantities of soil planned to be excavated, used for backfilling, and disposed of are specified in Section 3.3, Figure 3.3.11. For the formation of new areas, it is planned to use the soil excavated during the dredging of the water area, of which approximately 5.43 million $m^3$of soil will be required in the case of Alternative 2A, approximately 3.88 million m^3 of soil for Alternative[3A], and approximately 5.14 million m^3 of soil for Alternative 4A.

In the case of Alternative 2A, the approximate average distance over which the soil would be transported from the excavation site to the disposal site for the formation of new land would be approximately 1.1 km; in the case of Alternative 3A, approximately 1 km; and in the case of Alternative 4A, approximately 1.4 km.

It is estimated that approximately 6.54 million $m^3$of excess soil will be generated for Alternative 2A, approximately 8.42 million m^3 for Alternative 3A, and approximately 6.54 million m^3 for Alternative 4A. According to preliminary estimates, the majority of the excavated soil will be sand (approximately 55%), with the remainder consisting of various types of morainic loam and sandy loam (40%) and silt, etc. (up to 5%).

For the assessment of air pollution, it is assumed that excess soil and soil of pollution classes II–III, depending on lithological composition, will be disposed of at the existing Landfill Sites III and IV and/or at the planned new disposal site at a depth of 42 m on the western side of the Klaipėda Port roadstead (Fig. 3.9.1). The average distance from the PŪV territory to the soil disposal sites is approximately 25.7 km. It is proposed that the excavated sandy rock, after assessing its contamination level (if it meets Contamination Class I), be used for shoreline management purposes. The exact location and methods for the use or temporary storage of this excavated soil prior to use should be determined in subsequent planning and design stages.

When transporting the excavated soil to the sites of intended use and disposal (in the event that all excess soil is landfilled), it is estimated that approximately 1,177 t may be released into the ambient air in the case of PŪV alternative 2A, in the case of PŪV Alternative 3A – approximately 1,489 t, and in the case of PŪV Alternative 4A – approximately 1,185 t of air pollutants per year (construction work on the PŪV facilities is expected to last up to 5 years).

If necessary, some of these raw materials, such as sand and gravel, could be transported to the PŪV site by truck from the nearest quarry or quarries. The nearest quarries for the aforementioned mineral resources in the territory of Klaipėda District Municipality are located approximately 13.5–15 km from the project site.

Air pollutants will be generated during the construction of the facilities and other activities (e.g., installing quays, retaining walls, transporting and transshipping materials, and performing other construction works). The calculations for the aforementioned work groups (transporting soil by barge, transporting raw materials and other materials) are only approximate and are intended for a preliminary comparison of the potential impact on ambient air quality among the different project alternatives. Alternative 3A will have the largest scope of work and the greatest impact on ambient air, while Alternative 2A will have the smallest scope of work and the least impact on ambient air.

Some impact on ambient air is possible due to dust generated during earthworks and vehicle traffic. During these works, ambient air pollution with particulate matter is possible. The extent of

extent of ambient air pollution depends on the scope of the work being carried out, the sequence of work organization, the equipment used, meteorological conditions, etc., and is difficult to assess at this stage.

It should be noted that the implementation period for the project's solutions is relatively long (until 2034), and the implementation of specific solutions—and thus the associated anthropogenic load—would be distributed evenly over this period.

Assessment of the compliance of pollutant concentrations in ambient air emitted during construction work with ambient air quality limit values

The impact of the pollution sources generating the highest emissions on the immediate residential environment was assessed. For all three PŪV alternatives 2A, 3A, and 4A, the minimum distances from the PŪV solutions to the nearest residential buildings are specified in Section 4.12.2.

In the case of dredging works, the most polluting equipment is the dredger (ZSB) and the soil carrier (barge; BRZ) (Fig. 4.2.2.1).



4.2.2.1 Fig. A.t.š. during dredging works

In the case of site formation works, the most polluting equipment is the pile driver (PLK), dredge barge (BRZ), excavator (EKV), and floating crane (PKR) (Fig. 4.2.2.2).



4.2.2.2 Fig. A.t.š. During site preparation work The

fuel (diesel) consumption of the equipment is presented in Table 4.2.2.1.

4.2.2.1 Table. Fuel consumption of equipment

Equipment	Fuel consumption l/h	Fuel consumption, kg/h
Site excavation works		
Dredger	110	92.4
Dredger (barge)	45	37.8
Site development (construction work)		
Pile driving	30	25.2
Dredger (barge)	45	37.8
Excavator	30	25.2
Floating crane	10	8.4

In accordance with the Methodology for the Assessment of Pollutants Emitted into the Atmosphere from Machinery with Internal Combustion Engines [62], the instantaneous pollutant emission rates of the installations are calculated in Table 4.2.2.2.

4.2.2.2 Table. Instantaneous pollutant emissions from the facilities

Pollutant	Emission factor for a diesel engine, g/kg of fuel	Amount of fuel burned, kg/h	Coefficients			Amount of pollutant emitted, g/s
			K1	K2	K3	
Dredger						
Carbon monoxide (B)	130	92,400	1,364	1	0.95	4,324
LOJ	40.7		1.1	1	1.02	1.172
Nitrogen oxides (B)	31.3		0.984	1	0.39	0.308
Sulfur dioxide (B)	1		1	1	1	0.026
Particulate matter	4.3		0.8	1	1	0.088
Dredger (barge)						

Carbon monoxide (B)	130	37,800	1,364	1	0.95	1,769
LOJ	40.7		1.1	1	1.02	0.479
Nitrogen oxides (B)	31.3		0.984	1	0.39	0.126
Sulfur dioxide (B)	1		1	1	1	0.011
Particulate matter	4.3		0.8	1	1	0.036
Polyacrylate						
Carbon monoxide (B)	130	25,200	1,364	1	0.95	1,179
LOJ	40.7		1.1	1	1.02	0.320
Nitrogen oxides (B)	31.3		0.984	1	0.39	0.084
Sulfur dioxide (B)	1		1	1	1	0.007
Particulate matter	4.3		0.8	1	1	0.024
Excavator						
Carbon monoxide (B)	130	25,200	1,364	1	0.95	1,179
LOJ	40.7		1.1	1	1.02	0.320
Nitrogen oxides (B)	31.3		0.984	1	0.39	0.084
Sulfur dioxide (B)	1		1	1	1	0.007
Particulate matter	4.3		0.8	1	1	0.024
Floating crane						
Carbon monoxide (B)	130	8,400	1,364	1	0.95	0.393
LOJ	40.7		1.1	1	1.02	0.107
Nitrogen oxides (B)	31.3		0.984	1	0.39	0.028
Sulfur dioxide (B)	1		1	1	1	0.002
Particulate matter	4.3		0.8	1	1	0.008

Pollution Level Threshold Values

The limit values for pollutant concentrations emitted into the ambient air during the facility's operation are established in accordance with Order No. D1-329/V-469 of the Minister of the Environment and the Minister of Health of the Republic of Lithuania dated June 11, 2007 "On the Approval of the List of Pollutants Whose Concentrations in Ambient Air Are Limited in Accordance with European Union Criteria, the List of Pollutants Whose Concentrations in Ambient Air Are Limited in Accordance with National Criteria, and the Limit Values for Ambient Air Pollution" [63] and are presented in Table 4.2.2.3.

4.2.2.3 Table. Limit values for pollutants

Pollutant name	**Limit values for pollution levels, [µg/m³]**		
	½ hour	**Daily**	**Annual**
Carbon monoxide	-	10,000[1]	-
Nitrogen dioxide	200[2]	-	40
Nitrogen oxides	-	-	30[3]
Particulate matter ($_{PM10}$)	-	50[4]	40
Particulate matter ($_{PM2.5}$)	-	25[5]	10[6]
LOJ	5,000[7]	1,500[7]	-
Sulfur dioxide	350[8]	125[9]	20[3]

[1] The maximum 8-hour daily average is specified [64]

[2] The 1-hour average limit value, which must not be exceeded more than 18 times per calendar year [64], i.e., the 99.8th percentile applies.
[3] Critical pollution level established for the protection of vegetation [64]. In accordance with Section 3 of Annex 3 to the Procedure for the Assessment of Ambient Air Quality [65], the "<...> location of sampling points on a macroscale for the protection of vegetation and natural ecosystems:
3.1. Sampling sites shall be located no closer than 20 km from the boundaries of agglomerations or no closer than 5 km from other built-up areas, industrial facilities, highways, or major roads with daily traffic exceeding 50,000 vehicles, which means that samples must be taken at a location such that the air sample collected is representative of the air quality in the surrounding area covering at least 1,000 km^2 (2). <...>".
In this specific case, the limit value does not apply.
35. The specified limit value is a 24-hour average, which must not be exceeded more than 35 times per calendar year [64], i.e., the 90.4th percentile applies.
36. The specified 24-hour average limit value applies from 2025-01-01 and must not be exceeded more than 3 times per calendar year [64], i.e., the 99.18th percentile applies.
[6] The limit value applies from January 1, 2025.
[7] Limit value for gasoline (VOCs emitted from gasoline).
[8] – The specified 1-hour average limit value, which must not be exceeded more than 24 times per calendar year [64] i.e., the 99.7th percentile applies.
[9] – The specified limit value is a 24-hour average, which must not be exceeded more than 3 times per calendar year [64] i.e., the 99.2 percentile applies.

Ambient air pollution forecast

Pollutant dispersion modeling was performed using the "ISC-AERMOD View" software package, an AERMOD mathematical model designed to simulate the dispersion of pollutants emitted by industrial source complexes in the environment.

"Recommendations for the Selection of Pollutant Dispersion Calculation Models for Assessing the Impact of Economic Activities on Ambient Air," approved by Order No. AV-200 of the Director of the Environmental Protection Agency of the Republic of Lithuania on December 9, 2008 [66], the AERMOD model is recommended for modeling pollutant dispersion.

Data for modeling the dispersion of air pollutants

Input parameters for pollutant dispersion modeling. The input parameters for pollutant dispersion modeling are presented in Table 4.2.2.2.

Selection of the ambient air pollution model. The ISC-AERMOD View program allows for a choice between several models; specifically, the AERMOD model was selected for this work.

Averaging time interval for results. The averaging time interval for results is a particularly important parameter that significantly influences the final simulation results.

The averaging time interval is the time period during which fluctuations in pollutant concentrations are smoothed out by calculating a single average concentration value for a specific time interval.

When performing pollutant dispersion modeling for the object under study, the averaging time interval for a specific pollutant was selected to be the same as the averaging time interval of the established limit value.

Conversion of nitrogen oxides: $NO_x \rightarrow NO_2$. There are two possible methods for modeling nitrogen oxide conversion: the ozone limit method or the molar ratio in ambient air method. In this specific case, the molar ratio in ambient air method was selected. When selecting this method, the NO_x/NO_2 ratio at the pollution source, the NO_x/NO_2 equilibrium ratio in ambient air, and the background concentration of ozone (O_3) must be specified. The default NO_x/NO_2 ratio selected for the pollution source is 0.5. Based on measurement data from the air quality monitoring station (Klaipėda, Šilutės pl.) in 2022, the NO_x/NO_2 ratio is 0.64. This ratio is specified as the NO_x/NO_2 equilibrium ratio in ambient air.

The average ozone concentration measured at the air quality monitoring station (Klaipėda, Šilutės pl.) was 50.8 μg/m^3.

Particulate matter (PM_{10} and $PM_{2.5}$). The AERMOD model cannot directly calculate PM_{10} or $PM_{2.5}$ concentrations using the total amount of particulate matter emitted from pollution sources as input data. Based on point 8 of the "Recommendations on the Use of Background Ambient Air Pollution Data to Assess the Impact of Economic Activities on Ambient Air Quality" [42], a factor of 0.7 is used to convert particulate matter concentrations to PM_{10}, and a factor of 0.5 is used to convert PM_{10} concentrations to $PM_{2.5}$ concentrations.

Emission factors for pollution sources. Emission factors for pollution sources are coefficients that allow the model to assess the variability of pollutant emissions over time. This is a coefficient that is multiplied by the pollutant emissions from the specified source of ambient air pollution, thereby accounting for their variability. Emission factors can range from 0 to 1. When the emission factor is 0, emissions from a specific pollution source are also zero; when it is 0.5, the pollution source emits 50% of the specified emissions. When the emission factor is 1, the pollution source emits 100% of the specified emissions. For example, in cases where a pollution source operates only during working hours (i.e., 8 hours per day) and only on weekdays, it is illogical to allow the model to estimate these emissions as if they lasted 24 hours a day and 7 days a week. In such a case, it is appropriate to specify emission factors for each hour of the day (the emission factor for working hours is 1, and 0 for the remaining hours) and for each day (the emission factor for working days is 1, and 0 for the others).

When performing mathematical modeling of pollutant dispersion in the ambient air for the facility in question, it is specified that pollution sources operate on working days during working hours (Monday–Friday, 8 hours each).

Meteorological parameters. To ensure maximum accuracy of the AERMOD model, it requires highly detailed meteorological data: values for nine meteorological parameters for every hour of the year.

When performing mathematical modeling of pollutant dispersion using the AERMOD model in this specific case, the 2018–2022 meteorological data package provided by the Lithuanian Hydrometeorological Service is used (Textual Appendix 10). The package includes hourly values of the following meteorological parameters: ambient temperature, air humidity, atmospheric pressure, wind speed and direction, precipitation, cloud cover, cloud base height, and the sum of solar radiation on a horizontal surface.

Receptor network. Ground-level concentrations are calculated in mathematical models at specific, predefined points. These points are called receptors. Typically, receptors are defined by forming a set (network) of points spaced at a certain distance from one another. The closer the points are to each other, the more accurate the calculations become (the interpolation intervals for calculating intermediate concentrations between adjacent points decrease), but the duration of the calculation (modeling) increases; therefore, when modeling, an optimal solution is sought for selecting the distance between adjacent points so that the accuracy and reliability of the results are affected as little as possible, while minimizing the modeling duration.

In this specific case, a polar receptor network was established. The coordinates of the network center in the LKS'94 coordinate system are: X = 320222.06; Y = 6173463.37. The network radii are spaced at 10° intervals, for a total of 36 radii; the rings of the sensor network are spaced every 25 m from the network center up to 400 m, every 50 m from 400 m to 600 m, every 100 m from 600 m to 800 m, and every 300 m from 800 m to 2000 m. In total, the receptor network consists of 26 rings, 936 receptors, with a receptor network radius of 2 km. Additionally, point receptors are placed near the nearest residential area.

Pollutant concentrations are calculated at a height of 1.5 m during modeling—this is considered the height at which a person of average height breathes.

Terrain and buildings. The AERMOD model, where possible, allows for the assessment of the influence of terrain and buildings on pollutant dispersion. The AERMAP subprogram is used for terrain assessment, which characterizes the terrain and determines the altitudes of receptors or receptor grids for the dispersion model. In this specific case, SRTM1 (*Shuttle Radar Topography Mission*) digital terrain data is used; this is global (covering the entire Earth) terrain data. The data resolution is ~30 m.

No assessment of structures is performed in this specific case.

Anemometer height. Based on a report provided by the Lithuanian Hydrometeorological Service, wind directions and speeds are determined at a height of 10 m above the Earth's surface.

Percentile. The purpose of the percentile is to reject statistically unreliable modeling results. Percentiles vary widely and indicate the percentage of results considered statistically reliable. The remaining results are rejected to avoid statistically unreliable "outliers" in concentrations that could distort the overall picture.

The following percentiles were used to determine the threshold pollutant concentrations in the mathematical modeling of pollutant dispersion:

- the 100th percentile is used for the 8-hour concentration of carbon monoxide;
- the 99.8th percentile is used for the 1-hour concentration of nitrogen oxides;
- the 90.4th percentile for the 24-hour concentration of particulate matter (PM_{10});
- the 99.18th percentile is used for the 24-hour concentration of particulate matter ($PM_{2.5}$);
- the 100th percentile is used for 24-hour concentrations of pollutants on the "national" list;
- the 100th percentile is used for pollutants for which annual concentrations are calculated.

Based on the "Recommendations for the Selection of Pollutant Dispersion Calculation Models for Assessing the Impact of Economic Activities on Ambient Air Quality," approved by Order No. AV-200 of the Director of the Environmental Protection Agency of the Republic of Lithuania on December 9, 2008 "Recommendations for the Selection of Pollutant Dispersion Calculation Models for Assessing the Impact of Economic Activities on Ambient Air," if the model is unable to calculate a half-hourly concentration, the 98.5th percentile of the hourly values may be calculated and compared with the half-hourly limit value. In this specific case, this method was applied to the 1-hour concentration of volatile organic compounds.

Results of pollutant dispersion modeling

4.2.2.4 Table. Results of pollutant dispersion modeling

Pollutant name	Threshold value		Excluding background pollution		Taking background pollution into account	
			Cmax	Cmax/threshold value	Cmax	Cmax./ threshold value
	average	[µg/m³]	[µg/m³]	[units/dl]	[µg/m³]	[units/dl]
1	2	3	4	5	6	7
Site excavation work						
Carbon monoxide	8 hours	10,000	1,883.80	0.19	2,098.80	0.21
Nitrogen dioxide	1 hour	200	87.93	0.44	106.53	0.53
	years	40	5.74	0.14	24.34	0.61
Particulate matter (PM_{10})	24-hour	50	3.85	0.08	24.85	0.50
	years	40	1.79	0.04	22.79	0.57
Particulate matter ($PM_{2.5}$)	24-hour	25	3.17	0.13	12.62	0.50
	years	10	0.90	0.09	10.35	1.03
LOJ	½ hour	5,000	313.41	0.06	353.91	0.07
	24 hours	1,500	214.34	0.14	254.84	0.17
Sulfur dioxide	1 hour	350	10.83	0.03	18.18	0.05
	24 hours	125	2.69	0.02	10.04	0.08
Site development (construction work)						
Carbon monoxide	8 hours	10,000	1,069.91	0.11	1,284.91	0.13
Nitrogen dioxide	1 hour	200	56.75	0.28	75.35	0.38
	years	40	3.87	0.10	22.47	0.56
Particulate matter (PM_{10})	24-hour	50	2.23	0.04	23.23	0.46
	years	40	1.21	0.03	22.21	0.56
Particulate matter ($PM_{2.5}$)	24-hour	25	1.93	0.08	11.38	0.46
	years	10	0.60	0.06	10.05	1.01
LOJ	½ hour	5,000	177.51	0.04	218.01	0.04
	24 hours	1,500	131.73	0.09	172.23	0.11
Sulfur dioxide	1 hour	350	7.01	0.02	14.36	0.04
	24 hours	125	1.65	0.01	9.00	0.07

After performing mathematical modeling of the dispersion of pollutants emitted during the deepening works in the ambient air without considering background pollution, the maximum 1-hour average concentration of nitrogen dioxide was found to be 44%, and the 8-hour concentration of carbon monoxide was 19% of the ambient air pollution limit values. The maximum calculated concentrations of other pollutants were lower, ranging from 2% to 14% of the ambient air pollution limit values. When assessing and modeling background pollution, the highest concentration of particulate matter ($PM_{2.5}$) was found to be 103% of the ambient air pollution limit value, which will take effect on January 1, 2025. Concentrations of pollutants higher than the limit value would occur up to 55 m from the pollution source and would not reach residential areas (Table 4.2.2.5). The annual concentration of nitrogen dioxide would be 61%, and the annual concentration of particulate matter (PM_{10}) would be 57% of the ambient air pollution limit values. The maximum concentrations of other pollutants were lower, ranging from 5% to 53% of the ambient air pollution limit values.

During the site development works, without accounting for background pollution, the maximum 1-hour average concentration of nitrogen dioxide was 28%, and the 8-hour concentration of carbon monoxide was 11% of the ambient air pollution limit values. The maximum calculated concentrations of other pollutants were lower, ranging from 1% to 10% of ambient air pollution limit values. When background pollution was also taken into account, the maximum concentration of particulate matter

($PM_{2.5}$) was found to be 101% of the

air pollution limit values, which will come into effect on January 1, 2025. Pollutant concentrations higher than the limit value would occur up to 35 m from the pollution source and would not reach the residential environment (Table 4.2.2.5). The annual concentrations of nitrogen dioxide and particulate matter (PM_{10}) each accounted for 56% of the ambient air pollution limit value. The maximum concentrations of other pollutants were lower, ranging from 4% to 46% of the ambient air pollution limit values.

Ambient air pollutant concentrations near the nearest residential area are presented in Table 4.2.2.5.

4.2.2.5 Table. Ambient air pollutant concentrations near the nearest residential area

Pollutant name	Limit value		When assessing background pollution	
			C_{max}	C_{max}./limit value
	Average	[µg/m³]	[µg/m³]	[units/dl]
1	2	3	6	7
175 Nemuno St., Klaipėda				
Site excavation work				
Carbon monoxide	8 hours	10,000	395.47	0.04
Nitrogen dioxide	1 hour	200	20.64	0.10
	years	40	18.69	0.47
Particulate matter (PM_{10})	24-hour	50	21.07	0.42
	years	40	21.03	0.53
Particulate matter ($PM_{2.5}$)	24-hour	25	9.57	0.38
	year	10	9.46	0.95
LOJ	½ hour	5,000	46.44	0.01
	24 hours	1,500	65.43	0.04
Sulfur dioxide	1 hour	350	7.57	0.02
	24 hours	125	7.46	0.06
Site development (construction work)				
Carbon monoxide	8 hours	10,000	285.76	0.03
Nitrogen dioxide	1 hour	200	19.36	0.10
	years	40	18.63	0.47
Particulate matter (PM_{10})	24-hour	50	21.02	0.42
	years	40	21.01	0.53
Particulate matter ($PM_{2.5}$)	24-hour	25	9.51	0.38
	year	10	9.45	0.95
LOJ	½ hour	5,000	42.59	0.01
	24 hours	1,500	48.61	0.03
Sulfur dioxide	1 hour	350	7.44	0.02
	24 hours	125	7.40	0.06
1 Senoji Smiltelės St., Klaipėda				
Site excavation work				
Carbon monoxide	8 hours	10,000	367.58	0.04
Nitrogen dioxide	1 hour	200	20.41	0.10
	years	40	18.67	0.47
Particulate matter (PM_{10})	24 hours	50	21.06	0.42
	years	40	21.02	0.53
Particulate matter ($PM_{2.5}$)	24-hour	25	9.55	0.38
	year	10	9.46	0.95
LOJ	½ hour	5,000	45.54	0.01
	24 hours	1,500	63.20	0.04
Sulfur dioxide	1 hour	350	7.55	0.02
	24 hours	125	7.43	0.06
Site development (construction work)				
Carbon monoxide	8 hours	10,000	279.32	0.03

Nitrogen dioxide	1 hour	200	19.29	0.10
	years	40	18.63	0.47
Particulate matter (PM_{10})	24-hour	50	21.02	0.42
	years	40	21.01	0.53
Particulate matter ($PM_{2.5}$)	24-hour	25	9.50	0.38
	years	10	9.45	0.95
LOJ	½ hour	5,000	42.04	0.01
	24 hours	1,500	47.92	0.03
Sulfur dioxide	1 hour	350	7.43	0.02
	24 hours	125	7.40	0.06
3 Senoji Smiltelės St., Klaipėda				
Site excavation work				
Carbon monoxide	8 hours	10,000	342.82	0.03
Nitrogen dioxide	1 hour	200	20.02	0.10
	years	40	18.66	0.47
Particulate matter (PM_{10})	24 hours	50	21.05	0.42
	years	40	22.79	0.57
Particulate matter ($PM_{2.5}$)	24-hour	25	9.53	0.38
	years	10	9.46	0.95
LOJ	½ hour	5,000	44.83	0.01
	24 hours	1,500	59.76	0.04
Sulfur dioxide	1 hour	350	7.52	0.02
	24 hours	125	7.42	0.06
Site preparation (construction work)				
Carbon monoxide	8 hours	10,000	269.94	0.03
Nitrogen dioxide	1 hour	200	19.25	0.10
	years	40	18.63	0.47
Particulate matter (PM_{10})	24-hour	50	21.02	0.42
	years	40	21.01	0.53
Particulate matter ($PM_{2.5}$)	24-hour	25	9.50	0.38
	years	10	9.45	0.95
LOJ	½ hour	5,000	42.24	0.01
	24 hours	1,500	46.99	0.03
Sulfur dioxide	1 hour	350	7.43	0.02
	24 hours	125	7.39	0.06
Old Smiltelės St. 4A, Klaipėda				
Site excavation work				
Carbon monoxide	8 hours	10,000	287.10	0.03
Nitrogen dioxide	1 hour	200	19.36	0.10
	years	40	18.63	0.47
Particulate matter (PM_{10})	24-hour	50	21.02	0.42
	years	40	22.79	0.57
Particulate matter ($PM_{2.5}$)	24-hour	25	9.50	0.38
	years	10	9.46	0.95
LOJ	½ hour	5,000	42.72	0.01
	24 hours	1,500	51.45	0.03
Sulfur dioxide	1 hour	350	7.44	0.02
	24 hours	125	7.39	0.06
Site development (construction work)				
Carbon monoxide	8 hours	10,000	250.09	0.03
Nitrogen dioxide	1 hour	200	19.03	0.10
	years	40	18.62	0.47
Particulate matter (PM_{10})	24 hours	50	21.01	0.42
	years	40	21.01	0.53
Particulate matter ($PM_{2.5}$)	24-hour	25	9.48	0.38
	year	10	9.45	0.95

LOJ	½ hour	5,000	41.61	0.01
	24 hours	1,500	44.11	0.03
Sulfur dioxide	1 hour	350	7.40	0.02
	24 hours	125	7.38	0.06
1 Marių St., Klaipėda				
Site excavation work				
Carbon monoxide	8 hours	10,000	392.41	0.04
Nitrogen dioxide	1 hour	200	19.89	0.10
	years	40	18.66	0.47
Particulate matter (PM_{10})	24-hour	50	21.04	0.42
	years	40	22.79	0.57
Particulate matter ($PM_{2.5}$)	24-hour	25	9.53	0.38
	years	10	9.46	0.95
LOJ	½ hour	5,000	44.39	0.01
	24 hours	1,500	56.61	0.04
Sulfur dioxide	1 hour	350	7.49	0.02
	24 hours	125	7.42	0.06
Site Development (Construction Work)				
Carbon monoxide	8 hours	10,000	283.16	0.03
Nitrogen dioxide	1 hour	200	19.33	0.10
	years	40	18.63	0.47
Particulate matter (PM_{10})	24-hour	50	21.02	0.42
	years	40	21.01	0.53
Particulate matter ($PM_{2.5}$)	24-hour	25	9.51	0.38
	years	10	9.46	0.95
LOJ	½ hour	5,000	42.53	0.01
	24 hours	1,500	46.98	0.03
Sulfur dioxide	1 hour	350	7.44	0.02
	24 hours	125	7.40	0.06
3 Marių St., Klaipėda				
Site excavation work				
Carbon monoxide	8 hours	10,000	388.51	0.04
Nitrogen dioxide	1 hour	200	19.87	0.10
	years	40	18.66	0.47
Particulate matter (PM_{10})	24 hours	50	21.04	0.42
	years	40	22.79	0.57
Particulate matter ($PM_{2.5}$)	24-hour	25	9.52	0.38
	years	10	9.46	0.95
LOJ	½ hour	5,000	44.31	0.01
	24 hours	1,500	56.26	0.04
Sulfur dioxide	1 hour	350	7.49	0.02
	24 hours	125	7.41	0.06
Land development (construction work)				
Carbon monoxide	8 hours	10,000	284.93	0.03
Nitrogen dioxide	1 hour	200	19.33	0.10
	years	40	18.63	0.47
Particulate matter (PM_{10})	24-hour	50	21.02	0.42
	years	40	21.01	0.53
Particulate matter ($PM_{2.5}$)	24-hour	25	9.51	0.38
	years	10	9.46	0.95
LOJ	½ hour	5,000	42.53	0.01
	24 hours	1,500	47.44	0.03
Sulfur dioxide	1 hour	350	7.44	0.02
	24 hours	125	7.40	0.06
5 Marių St., Klaipėda				
Site excavation work				

Carbon monoxide	8 hours	10,000	378.89	0.04
Nitrogen dioxide	1 hour	200	19.84	0.10
	years	40	18.65	0.47
Particulate matter (PM_{10})	24-hour	50	21.04	0.42
	years	40	22.79	0.57
Particulate matter ($PM_{2.5}$)	24-hour	25	9.52	0.38
	years	10	9.46	0.95
LOJ	½ hour	5,000	44.13	0.01
	24 hours	1,500	55.38	0.04
Sulfur dioxide	1 hour	350	7.49	0.02
	24 hours	125	7.41	0.06
Site development (construction work)				
Carbon monoxide	8 hours	10,000	284.81	0.03
Nitrogen dioxide	1 hour	200	19.33	0.10
	years	40	18.63	0.47
Particulate matter (PM_{10})	24 hours	50	21.02	0.42
	years	40	21.01	0.53
Particulate matter ($PM_{2.5}$)	24-hour	25	9.51	0.38
	year	10	9.45	0.95
LOJ	½ hour	5,000	42.50	0.01
	24 hours	1,500	48.17	0.03
Sulfur dioxide	1 hour	350	7.43	0.02
	24 hours	125	7.40	0.06
7 Marių St., Klaipėda				
Site excavation work				
Carbon monoxide	8 hours	10,000	367.72	0.04
Nitrogen dioxide	1 hour	200	19.80	0.10
	years	40	18.65	0.47
Particulate matter (PM_{10})	24-hour	50	21.04	0.42
	years	40	22.79	0.57
Particulate matter ($PM_{2.5}$)	24-hour	25	9.52	0.38
	years	10	9.46	0.95
LOJ	½ hour	5,000	44.09	0.01
	24 hours	1,500	54.37	0.04
Sulfur dioxide	1 hour	350	7.48	0.02
	24 hours	125	7.41	0.06
Site development (construction work)				
Carbon monoxide	8 hours	10,000	283.31	0.03
Nitrogen dioxide	1 hour	200	19.33	0.10
	years	40	18.63	0.47
Particulate matter (PM_{10})	24-hour	50	21.02	0.42
	years	40	22.21	0.56
Particulate matter ($PM_{2.5}$)	24-hour	25	9.51	0.38
	years	10	9.46	0.95
LOJ	½ hour	5,000	42.53	0.01
	24 hours	1,500	48.92	0.03
Sulfur dioxide	1 hour	350	7.43	0.02
	24 hours	125	7.40	0.06
9 Marių St., Klaipėda				
Site excavation work				
Carbon monoxide	8 hours	10,000	354.84	0.04
Nitrogen dioxide	1 hour	200	19.77	0.10
	years	40	18.65	0.47
Particulate matter (PM_{10})	24-hour	50	21.04	0.42
	years	40	22.79	0.57
Particulate matter ($PM_{2.5}$)	24-hour	25	9.52	0.38

	years	10	9.46	0.95
LOJ	½ hour	5,000	43.93	0.01
	24 hours	1,500	53.20	0.04
Sulfur dioxide	1 hour	350	7.48	0.02
	24 hours	125	7.41	0.06
Site development (construction work)				
Carbon monoxide	8 hours	10,000	283.36	0.03
Nitrogen dioxide	1 hour	200	19.31	0.10
	years	40	18.63	0.47
Particulate matter (PM_{10})	24-hour	50	21.02	0.42
	years	40	21.01	0.53
Particulate matter ($PM_{2.5}$)	24-hour	25	9.51	0.38
	years	10	9.45	0.95
LOJ	½ hour	5,000	42.51	0.01
	24 hours	1,500	49.33	0.03
Sulfur dioxide	1 hour	350	7.43	0.02
	24 hours	125	7.40	0.06
11 Marių St., Klaipėda				
Site excavation work				
Carbon monoxide	8 hours	10,000	340.39	0.03
Nitrogen dioxide	1 hour	200	19.73	0.10
	years	40	18.65	0.47
Particulate matter (PM_{10})	24-hour	50	21.04	0.42
	years	40	22.79	0.57
Particulate matter ($PM_{2.5}$)	24-hour	25	9.51	0.38
	years	10	9.46	0.95
LOJ	½ hour	5,000	43.82	0.01
	24 hours	1,500	51.89	0.03
Sulfur dioxide	1 hour	350	7.47	0.02
	24 hours	125	7.40	0.06
Site development (construction work)				
Carbon monoxide	8 hours	10,000	283.96	0.03
Nitrogen dioxide	1 hour	200	7:30 PM	0.10
	years	40	18.63	0.47
Particulate matter (PM_{10})	24-hour	50	21.02	0.42
	years	40	21.01	0.53
Particulate matter ($PM_{2.5}$)	24-hour	25	9.51	0.38
	years	10	9.45	0.95
LOJ	½ hour	5,000	42.50	0.01
	24 hours	1,500	49.68	0.03
Sulfur dioxide	1 hour	350	7.43	0.02
	24 hours	125	7.40	0.06
13 Marių St., Klaipėda				
Site excavation work				
Carbon monoxide	8 hours	10,000	326.75	0.03
Nitrogen dioxide	1 hour	200	19.72	0.10
	years	40	18.64	0.47
Particulate matter (PM_{10})	24-hour	50	21.04	0.42
	years	40	22.79	0.57
Particulate matter ($PM_{2.5}$)	24-hour	25	9.51	0.38
	years	10	9.46	0.95
LOJ	½ hour	5,000	43.69	0.01
	24 hours	1,500	50.80	0.03
Sulfur dioxide	1 hour	350	7.47	0.02
	24 hours	125	7.40	0.06
Site development (construction work)				

Carbon monoxide	8 hours	10,000	283.15	0.03
Nitrogen dioxide	1 hour	200	19.29	0.10
	years	40	18.63	0.47
Particulate matter (PM_{10})	24-hour	50	21.02	0.42
	years	40	21.01	0.53
Particulate matter ($PM_{2.5}$)	24-hour	25	9.51	0.38
	years	10	9.45	0.95
LOJ	½ hour	5,000	42.48	0.01
	24 hours	1,500	49.84	0.03
Sulfur dioxide	1 hour	350	7.43	0.02
	24 hours	125	7.40	0.06
15 Marių St., Klaipėda				
Site excavation work				
Carbon monoxide	8 hours	10,000	312.07	0.03
Nitrogen dioxide	1 hour	200	19.65	0.10
	years	40	18.64	0.47
Particulate matter (PM_{10})	24 hours	50	21.04	0.42
	years	40	22.79	0.57
Particulate matter ($PM_{2.5}$)	24-hour	25	9.51	0.38
	years	10	9.46	0.95
LOJ	½ hour	5,000	43.56	0.01
	24 hours	1,500	49.42	0.03
Sulfur dioxide	1 hour	350	7.46	0.02
	24 hours	125	7.40	0.06
Site development (construction work)				
Carbon monoxide	8 hours	10,000	278.89	0.03
Nitrogen dioxide	1 hour	200	19.27	0.10
	years	40	18.63	0.47
Particulate matter (PM_{10})	24-hour	50	21.02	0.42
	years	40	21.01	0.53
Particulate matter ($PM_{2.5}$)	24-hour	25	9.50	0.38
	years	10	9.45	0.95
LOJ	½ hour	5,000	42.46	0.01
	24 hours	1,500	49.62	0.03
Sulfur dioxide	1 hour	350	7.43	0.02
	24 hours	125	7.40	0.06
Marių St. 17; 19; 21; 23; 25; 27; 29; 31; 33; 35, Klaipėda				
Site excavation work				
Carbon monoxide	8 hours	10,000	300.82	0.03
Nitrogen dioxide	1 hour	200	19.57	0.10
	years	40	18.64	0.47
Particulate matter (PM_{10})	24-hour	50	21.03	0.42
	years	40	22.79	0.57
Particulate matter ($PM_{2.5}$)	24-hour	25	9.51	0.38
	years	10	9.46	0.95
LOJ	½ hour	5,000	43.39	0.01
	24 hours	1,500	48.31	0.03
Sulfur dioxide	1 hour	350	7.46	0.02
	24 hours	125	7.40	0.06
Site development (construction work)				
Carbon monoxide	8 hours	10,000	272.28	0.03
Nitrogen dioxide	1 hour	200	19.28	0.10
	years	40	18.63	0.47
Particulate matter (PM_{10})	24-hour	50	21.02	0.42
	years	40	21.01	0.53
Particulate matter ($PM_{2.5}$)	24-hour	25	9.50	0.38

	years	10	9.45	0.95
LOJ	½ hour	5,000	42.45	0.01
	24 hours	1,500	49.03	0.03
Sulfur dioxide	1 hour	350	7.43	0.02
	24 hours	125	7.39	0.06
20 Žūklės St., Klaipėda				
Site excavation work				
Carbon monoxide	8 hours	10,000	284.15	0.03
Nitrogen dioxide	1 hour	200	19.38	0.10
	years	40	18.63	0.47
Particulate matter (PM_{10})	24-hour	50	21.03	0.42
	years	40	22.79	0.57
Particulate matter ($PM_{2.5}$)	24-hour	25	9.50	0.38
	years	10	9.46	0.95
LOJ	½ hour	5,000	42.82	0.01
	24 hours	1,500	46.81	0.03
Sulfur dioxide	1 hour	350	7.44	0.02
	24 hours	125	7.40	0.06
Site development (construction work)				
Carbon monoxide	8 hours	10,000	270.20	0.03
Nitrogen dioxide	1 hour	200	19.20	0.10
	years	40	18.63	0.47
Particulate matter (PM_{10})	24 hours	50	21.02	0.42
	years	40	21.01	0.53
Particulate matter ($PM_{2.5}$)	24-hour	25	9.50	0.38
	years	10	9.51	0.95
LOJ	½ hour	5,000	42.22	0.01
	24 hours	1,500	46.74	0.03
Sulfur dioxide	1 hour	350	7.42	0.02
	24 hours	125	7.39	0.06
22 Žūklės St., Klaipėda				
Site excavation work				
Carbon monoxide	8 hours	10,000	274.28	0.03
Nitrogen dioxide	1 hour	200	19.38	0.10
	years	40	18.63	0.47
Particulate matter (PM_{10})	24-hour	50	21.03	0.42
	years	40	22.79	0.57
Particulate matter ($PM_{2.5}$)	24-hour	25	9.50	0.38
	years	10	9.46	0.95
LOJ	½ hour	5,000	42.77	0.01
	24 hours	1,500	45.91	0.03
Sulfur dioxide	1 hour	350	7.44	0.02
	24 hours	125	7.39	0.06
Site development (construction work)				
Carbon monoxide	8 hours	10,000	270.55	0.03
Nitrogen dioxide	1 hour	200	19.20	0.10
	years	40	18.63	0.47
Particulate matter (PM_{10})	24 hours	50	23.23	0.46
	years	40	21.01	0.53
Particulate matter ($PM_{2.5}$)	24-hour	25	9.50	0.38
	years	10	9.45	0.95
Volatile organic compounds	½ hour	5,000	42.22	0.01
	24 hours	1,500	46.21	0.03
Sulfur dioxide	1 hour	350	7.41	0.02
	24 hours	125	7.39	0.06

The graphical results of the mathematical modeling of pollutant dispersion are presented in Appendix 5.

Impact during the operation of the PŪV facilities

The impact of the PŪV on ambient air during the operation of PŪV facilities is associated with the maintenance of the port navigation channel and water area by dredging accumulated sediments to maintain the design depth. The projected annual quantities of sediment that has settled and accumulated in the PŪV water area and will need to be removed are indicated in
Table 3.9.1. Sediments dredged/pumped out during maintenance of the KVJU water area would be transported for disposal at sea, depending on their pollution class.

Similarly to the assessment of pollutant emissions during the construction/implementation of the PŪV, the amount of pollutants that would be released into the ambient air during the dredging/suction and transportation of sediment to potential disposal sites was calculated based on the estimated volume of soil/sludge to be dredged/suctioned (Table 4.2.2.1).

Table 4.2.2.1. Amounts of pollutants emitted into the ambient air during maintenance of the PŪV water area (while transporting dredged sediments), t/year

Water content	Alternative			
	0	2A	3A	4A
	pollutant content, t			
Year with average water availability Q = 1080 m^3/s	110.6	109.7	169.2	142.8
Wet year Q= 1343 m^3/s	189.4	174.4	340.2	285.6

During maintenance of the PŪV water area (dredging/pumping and transporting the dredged/excavated sediment), the highest amounts of pollutants would be emitted in the case of PŪV Alternative 3A, and the lowest in the case of Alternative 2A. As with the implementation of the PŪV solutions, an impact on ambient air is expected during water area maintenance works, i.e., it will be local and short-term. During maintenance of the PŪV water area, the same equipment will be used as during dredging works in the construction phase—a dredger and a soil carrier (barge). The work zone closest to the residential environment is also analogous. Therefore, the impact on the immediate residential environment during the maintenance of the PŪV water area will not be greater than that assessed during construction.

Conclusion: During the construction/implementation of the PŪV facilities and during the maintenance of the PŪV water area, pollutants emitted from sources of ambient air pollution will not cause significant changes in ambient air quality. In the event of the implementation of alternative solutions for the PŪV, there would be a direct impact on ambient air during the construction of the facilities (due to pollutant emissions). The impact would be short-term, temporary (only during construction), interactive (may affect other environmental elements, e.g., the climate), and of minor negative significance. Once the solutions are implemented, the impact during the operation of the facilities would be long-term, intermittent (only during water area maintenance work), interactive (may affect other environmental elements, e.g., the climate), and of minor negative significance. In terms of increasing impact, the PŪV alternatives are ranked as follows: 2A < 4A < 3A. During the construction and operation of the PŪV facilities, it is necessary to apply measures to prevent, reduce, and/or compensate for the negative impacts of the PŪV.

4.2.3 Measures to prevent, reduce, and compensate for significant negative environmental impacts

Measures to prevent and mitigate impacts on ambient air during the planned construction and operation of the facilities:

- use of low-emission vehicles and machinery (ships, vehicles, machinery, etc.) during construction work;
- optimal organization of transportation, construction, and loading operations (e.g., use of larger-capacity vessels for transporting soil).
- During the construction and operation of PŪV facilities, when transporting, storing, and loading bulk materials, it is necessary to comply with the requirements of Order No. 23677 of the Minister of the Environment of the Republic of Lithuania dated November 11, 2020, "On the Approval of Minimum Requirements for Reducing Dust Emissions During the Storage, Loading, and Transport of Bulk Solid Materials" [72].

4.3 Climate

4.3.1 Description of the current situation

Meteorological conditions of the

territory

The territory of Lithuania is located in the mid-latitude climate zone and, according to B. Alisov's climate classification, belongs to the southwestern subregion of the Atlantic-Continental Forest climate zone. Only the Baltic coastal climate region is closer to the climate of Western Europe and can be classified as a separate Southern Baltic climate subregion.

4.3.1.1 Table. Characteristics of the coastal climate region and subregions (data for 1981–2010)

Region		**Coastal**		
	Subregions	**Curonian Spit**	**Seaside**	**Coastal Lowlands**
Air temperature (°C)	Average annual	8.0	7.8	7.4
	Warmest month and its average temperature	July, August 18.4	August 17.8	July 17.8
	Coldest month and its average temperature	February -1.5	February -1.4	January -1.9
	Absolute lows	-29.0	-27.8	-32.2
	Absolute maximums	34.3	33.6	35.8
Annual precipitation (mm)		~ 770	~ 770	~ 800
Duration of snow cover (days)		~ 60	~ 60	~ 65–70
Duration of sunshine (hours)		~1990	~ 1950	~ 1950
Key factors and processes determining climate characteristics		Transport of maritime air to the continent Coastal breeze circulation High groundwater levels, marshy soils, sandy soils on the Curonian Spit		

The climate of the PŪV territory, as well as that of the city of Klaipėda and the region, is largely determined not by the most important climate-determining factor—the amount of heat received from the sun—but by its geographical location: the proximity to the Baltic Sea, which results in the year-round transport of moist Atlantic air masses. The climate here can be described as moderately warm and humid, with relatively mild, snow-poor winters featuring frequent thaws, cooler springs and summers, and a warm autumn. Due to active cyclonic activity, especially during the cold season, this region is characterized by sudden changes in weather.

A more detailed overview of meteorological indicators (air temperature, precipitation, fog, wind speed, and direction) is provided in Tables 4.3.1.2–4.3.1.6 and Figure 4.3.1.1. (Observation data from the Klaipėda Marine Meteorological Station and the Lithuanian Hydrometeorological Service).

4.3.1.2 Table. Average long-term air temperature in Klaipėda

Month temp. °C	Months												Year
	01	02	03	04	05	06	07	08	09	10	11	12	
Avg.	-2.0	-2.7	1.0	6.2	11.0	14.9	18.1	17.7	13.9	8.7	45	-0.2	7.6
Max.	8.7	15.4	18.6	27.0	30.4	34.0	34.0	34.0	30.4	22.2	15.4	10.3	34.0
Min.	-33.0	-33.4	-20.8	-12.8	-4.0	-0.7	4.9	2.9	-4.9	-9.1	-14.4	-24.2	-33.4

The Baltic Sea moderates the amplitude of air temperature fluctuations—maritime air masses moving in from the west bring wetter and warmer weather. The average long-term temperature during the coldest months (January and February) is -2 to 2.7^{0}°C (in northeastern Lithuania -6^{0}°C), while the warmest is around 18^{0}°C. Springs and summers are cooler than in central and eastern Lithuania. In autumn and winter, temperatures are $2–3^{0}$°C higher than in the eastern part of the country.

4.3.1.3 Table. Average long-term precipitation distribution in Klaipėda

Precipitation, mm	Months												Year
	01	02	03	04	05	06	07	08	09	10	11	12	
Average amount	55	37	40	35	40	57	68	81	83	84	87	68	735
Maximum amount per day	26.9	14.6	19.9	28.4	24.4	54.0	73.9	47.6	349	42.4	32.8	21.2	73.9

Klaipėda experiences the influence of moist Atlantic air masses throughout the year, with average precipitation ranging from 650 mm to 700 mm. The highest precipitation occurs during the warm season and in the fall, while the lowest is recorded from February to April. In some years, there may be significant deviations from the long-term average precipitation distribution. Fog and wind are very important meteorological phenomena that affect shipping and cargo handling operations in the port. A significant reduction in visibility during fog is a hazardous meteorological phenomenon. Due to active condensation of water vapor during fog, visibility is less than 1 km. The Klaipėda coastal region is characterized by advection-induced fog during the cold season and specific coastal (frontal) fogs that form in late summer, autumn, and winter. Fog is distributed almost evenly throughout the year along the Baltic coast. Even during the summer months, when fog generally occurs quite rarely, it is present in Klaipėda.

4.3.1.4 Table. Characteristics of fogs in Klaipėda

Parameter	Months												Year
	01	02	03	04	05	06	07	08	09	10	11	12	
Average number of days with fog 4.5	4.5	6.0	6.8	6.6	6.4	3.8	3.1	2.0	3.2	3.8	4.0	4.8	55.0
Average duration, hours	24	27	41	44	33	20	9	6	10	19	20	31	284
Longest duration, hours	126	120	194	115	112	74	52	42	26	74	102	102	682

4.3.1.5 Table. Average long-term wind direction and maximum wind speed in Klaipėda (at a height of 10 m)

Parameter	Months												Year
	01	02	03	04	05	06	07	08	09	10	11	12	
Dominant trend	R	R	R	NW	NW	SV	V	P	V	R	R	R	R
Maximum speed, m/s	34	30	28	26	24	25	34	32	30	40	36	38	40

Wind direction and speed are highly dependent on the seasonal activity of cyclones and anticyclones, which is very active in the coastal region (cyclonic circulation is observed here for about 200 days a year). Wind strength exhibits seasonal patterns—the strongest winds are observed during the cold season (October–January); furthermore, it has been established that the average wind speed along the coast is approximately 1.5 times higher than in central Lithuania throughout the year.

Winds with a speed of at least 15 m/s are considered storm-force winds. On the Baltic coast, there are an average of 28 to 38 days per year with storm-force winds. The highest wind speed in Klaipėda was recorded in 1999 during Hurricane Anatolijus, when the maximum wind speed reached up to 40 m/s. On January 14–15, 2007, during Hurricane “Pero,” wind gusts reached 29 m/s, and during Hurricane “Kirilo” (January 21) – 21 m/s. According to long-term observation data, winds stronger than 14 m/s are observed on average 88 days per year on the Klaipėda coast, and winds stronger than 20 m/s on 17 days. The year 1990 was exceptional, with winds exceeding 14 m/s observed on 115 days, and on 31 days the wind speed exceeded 20 m/s. During storms, not only hurricane-force winds (>30 m/s) are observed, but also relatively long periods (24–96 hours) during which high and moderate wind speeds (8–18 m/s) prevail. There are no clear trends in the long-term variation of days with strong winds.

In late autumn and winter, southeasterly winds prevail. In late spring, northwesterly and westerly winds begin to blow more frequently. They also blow in summer. This time of year sees mostly calm weather. Northerly winds are the rarest.

4.3.1.6 Table. Average long-term wind direction and maximum speed in Klaipėda (at a height of 10 m)

Parameter	Months												Year
	01	02	03	04	05	06	07	08	09	10	11	12	
Dominant trend	R	R	R	NW	NW	SV	V	P	V	R	R	R	R
Maximum speed, m/s	34	30	28	26	24	25	34	32	30	40	36	38	40

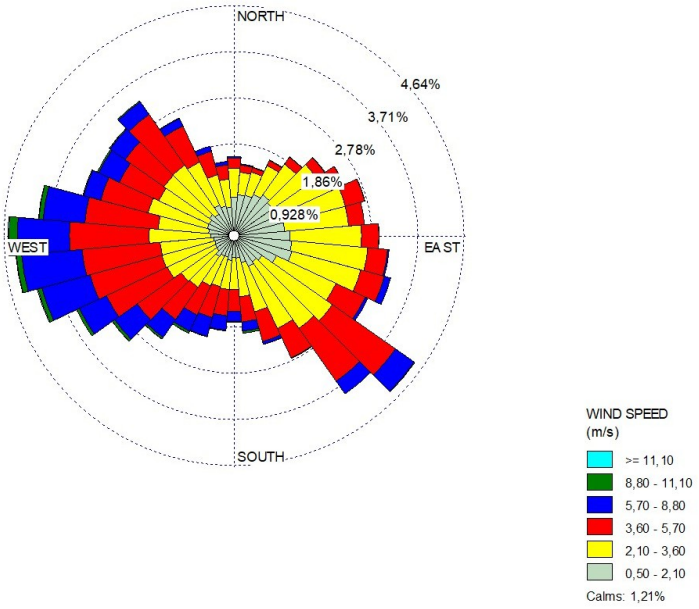


Fig. 4.3.1.1. Wind rose based on data from the Klaipėda meteorological station for 2016–2020

During the EIA for this project, LEI specialists analyzed observation data from the Klaipėda and Nida meteorological stations for the period 1961–2020 and compared temperature changes between the periods 1961–1990 and 1991–2020. The conclusions of this comparison stated that the following changes have occurred: the air temperature is 1.3 °C higher, precipitation has increased by 55 mm, wind speed has decreased by 1.0 m/s, the annual water temperature and salinity of the Curonian Lagoon (near Juodkrante) have increased by 0.9 °C and 0.43 ‰, respectively, the water level has risen by 8 cm, the duration of ice cover decreased by 27 days, and the ice is 5 cm thinner. These changes occurred due to both natural and anthropogenic factors (Textual Appendix 3).

4.3.2 Significant impact is anticipated

The Law on Financial Instruments for Climate Change Management of the Republic of Lithuania does not directly regulate port activities or ship emissions from a climate protection perspective. During the implementation of the KVJU PŪV solutions, greenhouse gases (GHGs), i.e., CO_2.

Project Alternative 3A would be characterized by the largest scope of work and the greatest impact on the climate, while the smallest scope of work and the least impact on the climate would be associated with Project Alternative 2A; however, no significant impact of the project on the climate is anticipated.

Conclusion: If the proposed alternatives are implemented, there would be an indirect impact on the climate during the construction of the facilities (due to emissions). The impact would be short-term, temporary (only during construction), interactive (may affect other environmental elements, e.g., ambient air), and insignificant. Upon implementation of the solutions during the operation of the facilities, the impact would be long-term, intermittent (only during water area maintenance work), interactive (may affect other environmental elements, e.g., ambient air), and insignificant. In terms of increasing impact, the PŪV alternatives are ranked as follows: 2A < 4A < 3A. During the construction and operation of the PŪV facilities, it is necessary to apply measures to prevent, reduce, and/or compensate for the negative impacts of the PŪV.

4.3.3 Measures to prevent, reduce, and compensate for significant adverse environmental impacts

No significant adverse impact on the climate is anticipated (see Section 4.3.2). Possible measures to prevent impacts on the climate would be analogous to the proposed measures to prevent or reduce ambient air pollution.

Conclusion: No significant adverse climate impacts are anticipated from the project solutions in the event of the implementation of any project alternative or the operation of the facilities.

4.4 Soil

4.4.1 Description of the current situation

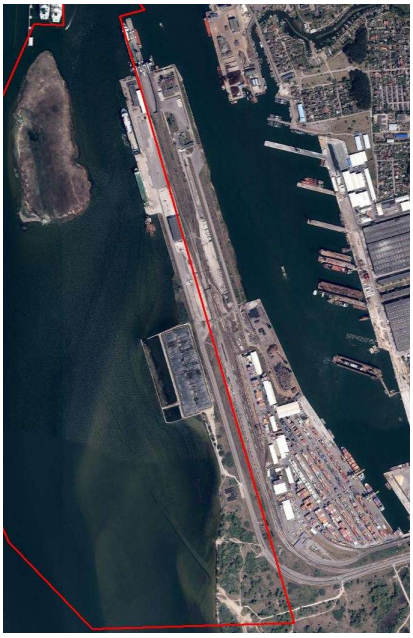
The PŪV solutions are planned to be implemented in the southern part of the KVJU. The impact on soil is relevant only in the port's land areas and where there is a soil layer.

Land areas or parts thereof within the PŪV territory:

- approximately 12.0 ha of the western part of the Smeltė Peninsula;
- Kiaulės Nugaros Island (approximately 18.0 ha);
- The area on the Curonian Spit where the existing 110 kV EEPOL power line is planned to be dismantled and a new underground power cable laid (approximately 3.5 ha).

Approximately 12 ha of the western part of the Smeltė Peninsula

The majority of the Smeltė Peninsula area within the project site is covered with artificial surfaces, built-up with structures and facilities, and has no remaining soil layer. Only the southwestern part of the Smeltė Peninsula, covering an area of about 11.0 ha (between Kairių St. and the lagoon), is currently not used for port purposes and is partially overgrown with grass, reeds, and areas of shrubs and scattered trees (Figs. 4.4.1.1–4.4.1.2).



Smeltė Peninsula



Southwestern part of the Smeltė Peninsula

4.4.1.1 Fig. PŪV territory on the Smeltė Peninsula

The average absolute elevations of the territory's surface are 2–3 m above sea level in the southern part and 3–4 m in the northern part, sloping down toward the Curonian Lagoon. In the central part of the territory, there is a separate fenced-off plot with unused and abandoned buildings—the former boat dock area (Fig. 4.4.1.2). The soil layer in the area is thin, only a few centimeters deep (about 5–15 cm), and in some places damaged and eroded.







4.4.1.2 Fig. Views of the PŪV territory in the southwestern part of the Smeltė Peninsula

Kiaulės Nugaros Island

Currently, the surface of Kiaulės Nugaros Island, which covers an area of about 18 ha, rises only a few to several dozen centimeters above the water surface and is overgrown with grass and reeds (Fig. 4.4.1.3). Almost the entire island is covered by a layer of soil approximately 0.1–0.2 m thick, formed from silt and other organic materials.



4.4.1.3 Fig. Orthophoto of Kiaulės Nugaros Island and view of Kiaulės Nugaros Island from the Curonian Spit (photo by L. Stumbrienė)

An area of approximately 3.5 ha in the Curonian Spit within the zone of dismantling the existing 110 kV power line section and laying a new 110 kV underground power cable

The soil layer in the section of the existing 110 kV EEPOL line (approximately 4 km long) planned for dismantling and in the section of the new 110 kV underground power cable (approximately 1.93 km long) planned for installation is thin, up to a few centimeters thick, damaged in many places, and in some places is completely absent (Fig. 4.4.1.4).



110 kV EEPOL support No. 20 on the Curonian Spit



110 kV EEPOL in the Curonian Spit





4.4.1.4 Fig. Existing soil in the 110 kV EEPOL section on the Curonian Spit (photo by L. Stumbrienė)

4.4.2 Significant impact anticipated

Impact during construction of the project facilities

Approximately 12 ha plot in the KVJU territory in the southwestern part of the Smeltė Peninsula

In this area, depending on the selected project alternative, an area of approximately 17.8–18.9 ha is planned to be filled with soil to form the landmass envisaged in the project solutions. Filling the area with soil would destroy (bury) the soil layer currently covering part of the territory; therefore, prior to implementing the solutions during the preparation of the PŪV area, the soil layer would be excavated/removed and transported to a temporary storage site(s) and later used for the reclamation of the area's access roads or for maintenance work within the port area. According to a preliminary assessment, if the PŪV solutions were implemented across the entire assessed area, the topsoil layer would be disturbed (excavated) over an area of approximately 9.97 ha in the case of Alternative 2A, approximately 8.86 ha in the case of Alternative 3A, and approximately 8.94 ha in the case of Alternative 4A. The volume of fertile soil to be removed to a temporary storage site may amount to approximately 8,950–9,970 m^3.

Currently, other ongoing projects [43] and the EIA screening prepared by other EIA document drafters [44], it is planned to establish temporary storage sites in this area for soil that will be excavated during the construction of the Port's southern gates and the water area of the marina for small and recreational vessels. The planned volume of soil to be stored is 390,000 m^3. The EIA screening report stipulates that, prior to the construction of the soil storage site, the fertile soil layer will be removed and/or transported to a temporary storage site on an area of approximately 5.0 ha [44].

Thus, if the solutions outlined in the aforementioned documents [43, 44] are implemented prior to the solutions for the PŪV assessed in this EIA, the topsoil layer in part of this area may already have been removed.

Kiaulės Nugaros Island

In implementing the PŪV solutions, in the case of Alternative 2A, it is planned to excavate approximately 13.4 ha of the island's territory (about 78% of the total area), in Alternative 3A—approximately 13.2 ha of the island's territory (about 76.7% of the total area), and in Alternative 4A—approximately 13.6 ha of the island's territory (about 79% of the total area) (Figs. 3.2.5–3.2.6). In the remaining part of the island, the surface would be managed in accordance with ornithologists' recommendations, and the existing surface would be covered with a layer of soil approximately 0.5 m thick (see Section 4.9). The existing soil layer, formed from silt and other organic materials, will not be preserved and will be removed along with the excavated soil.

An area of approximately 3.5 ha in the Curonian Spit within the zone of dismantling the existing 110 kV EEPOL line and laying a new 110 kV underground power cable

The 110 kV underground cable in the Curonian Spit area would be laid in reinforced concrete ducts buried at a depth of 1.5–2 m, which are installed by digging a 2 m wide trench. The two lines of the underground cable would "emerge" from beneath the Curonian Lagoon at Alksnių Ragas and be laid up to the road to Juodkrantė (over a 115-meter section), then a single line would run along the road to the Alksnynė farmstead (approx. 480 m) and, after drilling through the road at that point, would be laid through the existing right-of-way adjacent to the existing NordBalt cable line up to the existing 110 kV EEPOL tower No. 43 (approx. 1,335 m) (Fig. 3.3.11). In this section, the existing soil layer could be disturbed over an area of approximately 1.1 ha (the thin soil layer, only a few centimeters deep, does not cover the entire planned work area, assuming a disturbance width of 6 m). Additionally, during the dismantling and removal of the existing 110 kV power line towers from No. 20 to No. 43 (a total of approximately 4 km of power line and 23 towers would be dismantled on the Curonian Spit), heavy equipment (cranes, trucks, specialized transport), which would also damage the existing soil layer in the work area (where it has formed). The work would be carried out along the existing EEPOL route and its right-of-way. The area of potential soil disturbance is approximately 2.4 ha.

Upon completion of the works, restoration measures are necessary depending on the future use of this area; leaving areas unmanaged poses a risk of the formation and spread of erosion hotspots.

Impact during the operation of the PŪV facilities

If the impact mitigation measures planned for the construction phases are implemented, negative impacts on the soil during the operation of the PŪV facilities are unlikely.

Conclusion: When implementing the PŪV solutions in different parts of the PŪV area, the soil layer may be disturbed over an area of approximately 3.5 ha (on the Curonian Spit, during the dismantling of the existing 110 kV EEPOL section and the laying of a new 110 kV underground power cable section), destroyed on Kiaulės Nugaros Island (approximately 13.2–13.6 ha), and excavated over an area of approximately 8.86–9.97 ha in the southwestern part of the Smeltė Peninsula. The impact on the soil during the implementation of the solutions should be treated as direct and negative, with synergistic effects (it may also affect other environmental elements, e.g., biodiversity), on the Curonian Spit – of medium duration and minor significance, on Kiaulės Nugaros Island – long-term and irreversible (the soil layer is destroyed), on the Smeltė Peninsula – long-term and irreversible, but of minor significance (the excavated soil layer is preserved and reused elsewhere). Negative impacts on soil during the operation of the PŪV facilities are unlikely. In terms of increasing impact, the PŪV alternatives are ranked as follows: 3A < 4A < 2A. During the construction and operation of the PŪV facilities, it is necessary to implement measures to prevent, reduce, and/or compensate for the negative impacts of the PŪV.

4.4.3 Measures to prevent, mitigate, and compensate for significant adverse environmental impacts

Proposed measures to prevent and mitigate impacts on soil:

- Sustainable design solutions (optimizing design solutions and planning areas to minimize the size of potentially affected areas).
- Efficient organization of work, selecting the most optimal areas for construction and service zones, as well as transportation routes, to minimize the size of the potentially affected area.
- Temporary storage and reuse of the removed fertile soil layer. Upon completion of construction work, part of the stored soil would be used for landscaping the site and, where possible, for the reclamation of areas directly affected during the implementation of the project's solutions and adjacent areas.
- Use of excess soil for the reclamation/restoration of other damaged areas (outside the project area).
- Strict and timely compliance with environmental protection requirements during the construction and operation of facilities to prevent chemical pollution (emergencies) from mobile vehicles and technological equipment.

4.5 Subsurface

4.5.1 Description of the current state

Geological structure of the KVJU territory

The geological structure and engineering geological conditions of the KVJU territory are described based on the results of long-term studies conducted by UAB
"Geoprojektas" ir Ko [45], the results of engineering geological mapping of the southern part of the KVJU conducted by the Lithuanian Geological Survey in 2009 [44], and other publicly available information [46].

The sequence of Quaternary deposits, and especially its upper part, is highly heterogeneous throughout the KVJU territory; in the Upper Pleistocene moraine, fragments of much older deposits, glacial till, and fine-grained intercalations (i.e., glacial dislocations) are found. The geological structure of the KVJU water areas and the studied shores

structure of the KVJU water area and the studied shores consists of the following Quaternary sedimentary complexes, classified by age into four major strata from bottom to top:

- The Middle Pleistocene Medininkai, Samogitia, and Dainava sub-basin deformational moraine deposit stratum ($_{gd}$ II $_{md}$, $_{gd}$ II žm, $_{gd}$ II dn);
- The Upper Pleistocene Middle Nemunas Formation limnic and deformational moraine sediment sequence (lg III B, $_{gd}$ III $_{nm2}$);
- Late Glacial. Limnoglacial deposits of the Baltic glacial lake – lg III B;
- Holocene deposits (technogenic deposits, eolian deposits, alluvial deposits, limnic deposits, biogenic (marsh) deposits, and marine deposits) (t IV, v IV, a IV, l IV, b IV, and m IV).

Middle Pleistocene. Deformation moraine deposits of the Medininkai ($_{gd}$ II md), Samogitian ($_{gd}$ II žm), and Dainava ($_{gd}$ II dn) suites

The deformational moraine deposits of the Medininkai Formation ($_{gd}$ II md) consist of gray morainic silt and loam with abundant gravel, ranging from greenish-dark gray to brown dense plastic clay with isolated layers of fine sand and sandy silt and isolated gravel, deposits of greenish-gray silt and various types of sand. At the base of this layer, accumulations of gravel, cobbles, and water-saturated sand up to 1.0 m thick are found. The layer lies at a depth of 25.7–37.8 m, and its average thickness is 8.5 m.

Deformation moraine deposits of the Samogitian Suite ($_{gd}$ II) are found throughout nearly the entire study area. They consist of morainic sand mixed with gravel and cobbles, with accumulations of water-bearing cobbles and boulders throughout the layer. The average thickness of the layer is 6.5 m, and the layer lies at a depth of 33.4–43.4 m.

The top of the Dainava Formation's deformational moraine deposits ($_{gd}$ II dn) lies 39.5–44.3 m below sea level. They consist of coarse, compacted, hard morainic gravel with a grayish-green tint and a massive texture, mixed with gravel and pebbles 2.0–30.0 mm in diameter, with boulder accumulations distributed in the cracks and, in some places, with lenses of coarse sand.

Upper Pleistocene. Limnic (lg III B) and deformational moraine ($_{gd}$ III $_{nm2}$) deposits of the Middle Nemunas Formation

Deformation moraine deposits ($_{gd}$ III $_{nm2}$) of the Middle Nemunas Formation are widespread throughout the study area and lie beneath a complex of Holocene deposits (technogenic formations and marine sediments). The deposits consist of compact, gray or grayish-brown, coarse-grained, densely consolidated, hard morainic sand with an admixture of gravel and cobbles 2.0–30.0 mm in diameter, with boulder-rich intercalations, in which the majority of the deposits consists of gravel, cobbles, and boulders. The deformational moraine deposits contain a particularly large number of Quaternary-age sedimentary layers, lenses, or inclusions of various lithological compositions, which constitute the majority of this stratum, with their thickness ranging from several tens of centimeters to several dozen meters. The entire sedimentary sequence has a clearly expressed fissured structure, evident in numerous micro-fissures and micro-cracks.

The limnic sediments of the Middle Nemunas Formation (lg III B) consist of gray-brown and greenish-gray sandy aleurite, locally transitioning to yellow-brown fine-grained aleuritic sand of dense, massive texture with scattered fine gravel, with layers of fine sand and layers and intercalations of sand richly saturated with organic matter. These sediments are widespread throughout almost the entire study area. This layer lies at a depth of 8.2–14.0 m, and its average thickness is 1.3 m.

In the outcrops of the deformational moraine of the Middle Nemunas Suite ($_{gd}$ III $_{nm2}$), the majority of the glacial dislocations consist of the disrupted-textured limnic sediments of the Lower Nemunas Suite—a layered sequence of silt, clay, and sand. The morainic gravel of these deposits is brownish-gray, gradually transitioning to gray, fine-grained, compacted, and massive in texture, with admixtures of gravel and cobbles, cobble accumulations, and aleurite lenses. The moraine is rich in gravelly and coarse clayey dark brown to black-brown sand lenses, and in the lower part of the layer, there are accumulations of gravel and cobbles. The average thickness of the layer is 14.3 m, and the layer lies at depths ranging from 10.5 to 29.3 m. These deposits have been fairly extensively studied throughout the port area. In the port basin, these deposits are exposed on the seabed surface, but in some places—on the eastern edge of Malkų Bay, between the Smeltė Peninsula and the Curonian Spit, and along the coast of the Curonian Spit—they are covered by a layer of marine and Holocene limnic sediments ranging from several tens of centimeters to 12.0 m in thickness. In a significant part of the water area, the morainic deposits are covered by a layer of modern silt ranging from 0.3 m to 4.2 m in thickness. The crest of the naturally subsiding morainic deposits, ranging from -1.0 to -2.0 m in the eastern part of the port area, descends to 8.2–12.1 m below sea level beneath the Curonian Spit.

Late Glacial Period. Limnoglacial (LG III B) sediments of the Baltic Glacial Lake

These deposits lie beneath Holocene sediments. They are most commonly found in the landward part of the port area and on the Curonian Spit peninsula, while in the Klaipėda Strait, where the port basin is being deepened, they have already been completely excavated in many places. On the eastern edge of the Curonian Spit, the top of these sediments ranges from 7.3 m to 10.2 m; in the port basin, from 9.6 m to 11.0 m; on the Smeltė Peninsula—from 5.4 m to 9.1 m, and on the mainland port territory—from 1.7 m to 6.9 m below sea level. The base of the sediments, deposited on the deformational moraine deposits of the Middle Nemunas Formation, lies below the current sea level by 8.2 m to 11.2 m on the Curonian Spit, from 9.8 m to 12.5 m in the port basin, from 7.4 m to 11.0 m on the Smeltė Peninsula, and from 1.9 m to 8.5 m in the mainland part of the port territory. The thickness of the sediment layer varies from 0.8 m to 2.2 m and only in the southern part of the Smeltė Peninsula and the eastern part of the port territory does it increase to 5.6 m. The lithological composition of the sediments is very diverse—ranging from fine sand to gravel and cobble deposits. The predominant sediments are gray, varied, predominantly medium-grained, gravelly, carbonate-feldspar-quartz sand with admixtures of gravel and cobbles.

Holocene deposits. Marine sediments (m IV), eolian deposits (e IV), alluvial deposits (a IV), limnic sediments (l IV), biogenic (marsh) sediments (b IV), and technogenic deposits (t IV)

Marine sediments (m IV) are found on land within the port area. In the water area, with the exception of the Kiaulės Nugaros shoal and the western edge of the port water area along the coast of the Curonian Spit, they were excavated during the dredging of the port. The absolute height of the sediment crest varies from 3.8 m above sea level (Smeltė Peninsula, Curonian Spit) to 7.8 m below sea level, while the absolute height of their base ranges from 0.6 m above sea level to 8.1 m below sea

level. The thickness of the sediment layers ranges from several tens of centimeters to 4.6 m. The predominant sediments range from yellowish-gray carbonate-feldspar-quartz sand of varying coarseness with gravel admixtures to fine brown, gray-green or dark gray feldspar-quartz sand mixed with dark minerals, mica, and finely dispersed organic matter.

Holocene eolian formations (v IV) are found only in small patches in the mainland part of the port area and have survived on the easternmost edge of the port territory, where dunes of 2.5–3.0 m relative height remain, composed of fine, yellowish-gray, well-sorted sand. Meanwhile, on the Curonian Spit, where marine sediments have been covered by eolian formations, the thickness of the eolian formation layer ranges from 1.6 m (on the coast of the Curonian Lagoon) to 10.6 m. Aeolian deposits consist of fine, grayish-yellow, feldspar-quartz, well-sorted sand.

Alluvial deposits (a IV) have been found only in the riverbeds of the Smeltalė and Danė rivers. The thickness of this layer of yellow-brown and brown carbonate-feldspar-quartz sand of varying coarseness, often mixed with gravel and pebbles and contaminated with organic matter, ranges from several tens of centimeters to 2.0 meters.

On the Curonian Spit, the top of the limnic sediment (l–IV) lies 5.3 m below sea level, while the base is 9.4 m below sea level; On the Smeltė Peninsula, the crest is 5.9 m and the base 7.6 m below current sea level, and the layer thickness varies from 1.7 m to 3.1 m. The sediments consist of sandy, dark brown, coarse-grained, compacted sapropelite with a massive texture, mixed with mica and plant remains.

Biogenic (marsh) deposits (b IV) are not widely distributed. In the Curonian Spit, marsh deposits separate the Postlitorina and Litorina marine sediment layers, while on the Smeltė Peninsula, they separate two lagoon sediment layers of different ages from the Litorina Sea and two lake sediment layers of different ages. On the Smeltė Peninsula (in the southern area), they lie approximately 7.7 m below the current sea level between two layers of lacustrine sediments of different ages, consisting of brown, moderately compacted, and in places well-decomposed peat containing pieces of wood. Several layers of these deposits are found on the Curonian Spit.

The entire KVJU territory and a large part of the water area are covered by technogenic deposits (t IV). The thickness of the deposits, as well as the absolute elevation of this layer's base, varies greatly. Based solely on data from boreholes drilled within the port area, the thickness of boulders, rubble, gravel, gravel, sand of various grain sizes, morainic silt and loam, construction waste, concrete, reinforced concrete, and asphalt varies from several tens of centimeters to 6.0–8.0 m, and in some places up to 10.0–12.0 m. The thinnest average thickness of anthropogenic deposits, usually not exceeding 2.0 meters, is found in the eastern part of the port area. The thickest anthropogenic deposits are found in the northern part of the Smeltė Peninsula, in the Kiaulės Nugaros shoal, and along the eastern edge of the water area. Here, in some places, the thickness of the technogenic deposits reaches 6.0–12.0 meters, and the bottom of the layer descends to 8.8 meters below sea level. In the port basin, the layer of technogenic deposits—black, fine, liquid, loose, or dense sludge mixed with fine to very fine sand, containing pieces of morainic gravel, and in some places contaminated with petroleum products—reaches a thickness of up to 4.0 meters in places.

Physical and mechanical properties of the port area's soils

The geological section of the Smiltynė section of the underwater slopes of the Klaipėda Strait is dominated by a morainic deposit of highly heterogeneous composition and structural arrangement, but recent geological

, it is identified as a single stratigraphic taxonomic unit. The morainic deposit forming the slopes is now, according to the engineering geological mapping data of the Port of Klaipėda, considered a deformation product of the mid-Nemunas phase advance of the continental glacier during the last glacial period. The upper part of this morainic deposit consists of morainic loam, while the lower part consists of morainic sandy loam with numerous irregularly shaped intramorenic morainic aleurite (sandy) fragments, bounded by surfaces and inserted into the deposit during the processes of glacial exaration and deglaciation. The formation of this morainic deposit and the characteristics of postglacial cryogenic processes are associated with the presence of numerous intramorenic sand lenses and a concentration of very large erratic boulders in the section of the port navigation channel where dredging works are being carried out.

In the stratum forming the soil mass of the underwater slope of the Smiltynė section, three engineering geological layers (EGL) are distinguished, whose dip is highly uneven and variable, resulting in a complex arrangement of geological sections. The upper part of the stratum's geological section consists of morainic loam. It is characterized by a massive texture with traces of glacial dislocations, sand lens inclusions, and a content of rounded gravel and cobble particles not exceeding 5–7%. The specific gravity of the morainic loam ranges from 21.97 to 22.66 $^{Mg/m^3}$, while its density varies from 2.63 to 2.70 $Mg^{/m^3}$. The material is saturated with water; the degree of water saturation typically reaches 0.98–1.0, and the natural moisture content ranges from 0.11 to 0.14. The granulometric composition is close to that of optimal mixtures, and the porosity coefficient ranges from 0.295 to 0.376. The physical condition is characterized by moderate plasticity and a semi-solid to stiff consistency. The consistency index ranges from 0.89 to 1.48.

In the lower part of the geological section, there is a morainic loam with morainic dust xenoliths—flakes containing a higher proportion of rounded gravel and pebbles, along with large erratic boulders, and a lower proportion of clay particles in the overall granulometric composition of the soil. The texture of the morainic layer is massive, fissured, and porphyritic. The matrix structure of the massive fill is psamopelitic, while that of the silty fragments is aleuritic.

The morainic sandy loam is very compact, well-structured, and carbonated, with a grain size distribution similar to that of morainic loam. The gravel fraction accounts for 4.8–6.8%, the silt fraction for 27.2–53.0%, and the clay fraction for 11.4–22.3%. The natural density of morainic sandy loam is 2.24–2.33 $^{Mg/m^3}$, and the porosity coefficient is 0.288–0.331. Soil consistency is characterized by values of the consistency index I_C (0.98–1.67). These are semi-coarse and coarse soils with a friable texture, characteristic of morainic loams previously classified as having a hard physical condition.

In the granulometric composition of intramorenic clast samples of morainic aleurite (morainic silt), the aleuritic fraction predominates, accounting for an average of 56–57% of the dry sample mass. The sand content averages 23–24%, while the clay fraction accounts for 15–20% of the mass. The mass of gravel in morainic silt samples does not exceed 1.5–2.5%. The bulk density of morainic soil varies between 1.98 and 2.27 Mg/m^3
^{3}, and the porosity coefficient ranges from 0.250 to 0.330. The physical condition of this soil is characterized by a semi-stiff to stiff consistency—consistency index values range from 0.84 to 1.44. Samples of undisturbed morainic silt with natural moisture content (water-saturated) exhibit brittle spontaneous disintegration, while monolithic samples that have been dried and repeatedly immersed in distilled water disintegrate immediately under the influence of capillary forces.

During the engineering geological mapping of the southern part of the KVJU conducted by the Lithuanian Geological Survey in 2009, the most challenging construction conditions (highest geotechnical risk) are found in the largest part of the KVJU water area, covering the entire Malkų Bay and the area north of the Smeltė Peninsula. This area is characterized by variable soil settlement conditions, frequent exposure of water-bearing fractures at the bottom, and phenomena in the vicinity of the quays caused by various processes.

Hydrogeological conditions of the KVJU territory

Groundwater

The groundwater table in the relatively flat and level sandy mainland part of the port is usually found at a shallow depth of 1.0–3.0 m. At a slightly greater depth of approximately 3.0–4.0 m and deeper, it is found only in rare and very limited, often elongated, surviving elevations, as well as closer to larger and more elevated areas in the vicinity of the railway, other access roads, and embanked sections within the port territory, and almost along the entire main access route in the northern and southern parts of the port. Shallow (0.5–1.0 m) groundwater is found in the estuary zone of the Smeltė Stream, in some depressions along larger main drainage canals, and on Kiaulės Nugaros Island. The main regional direction of groundwater flow on the littoral terrace is from east to west (toward the Klaipėda Strait and the Curonian Lagoon).

The underlying bedrock of the groundwater aquifer in the KVJU territory is mostly composed of firm morainic loam ($_{gd}$ III $_{nm2}$). In many places within the water area and on the Curonian Spit, the unconsolidated sedimentary and compacted layers of the groundwater aquifer, which are in direct contact with one another (and in the absence of separating water-retaining formations), establish a direct hydraulic connection. The glacial loam underlying the groundwater aquifer, aquifers of other origins, and low-permeability layers, along with the bedrock composed of these, dip westward by approximately 0.0 to -10.0 m below sea level. The filtration properties of the groundwater aquifer composed of marine clastic sediments vary greatly ($_{kf}$ = 0.02–325 m/day) and depend on the lithological and granulometric composition. Groundwater is fresh, in some places approaching slightly mineralized (total mineralization 0.1–1.43 g/l). The water is mostly calcium hydrocarbonate, and in local areas, various types of chloride and sulfate.

Based on potential corrosion levels and aggressive components such as pH, $NH4+$, $Mg2+$, $SO42-$, and $CO2$ [45], the groundwater is not aggressive toward concrete and port structures.

Groundwater

In the area under study, intermoraine deposits, with the exception of the very thick and poorly permeable coastal plain sequence (l II pm) deposits, aquaglacial intramorenic ($_{GD}$ II MD + L II PM, $_{GD}$ II MD) interlayers, are distributed very locally and are found somewhat more frequently only in the lower part of the Quaternary sequence—in possible rare paleo-gorges and depressions of the pre-Quaternary relief.

In the upper part of the Quaternary stratum, in some places immediately below the groundwater table or at the bottom of water bodies, highly complex aquifer interbeds are exposed, lying within fine sand. Their distribution and occurrence are not uniform and do not form a continuous aquifer. They often have a direct connection with surface (lagoon) and groundwater, while in some places they are sufficiently separated and isolated by thicker layers of morainic loam or low-permeability silt. In the northern part of the KVJU territory, the confined aquifers lie at -11.0
to -29.0 m below sea level, and in the southern part of the port, from -13.0 to -30.0 m below sea level. The thickness of these confined aquifers in the northern part ranges from 2.5 m to 7.0 m, and

in the southern part, from 1.0 m to 33.0 m.

The piezometric level of the confined groundwater is very close to the surface level of the lagoon, so in places where the confined water layers are sufficiently hydrodynamically open, the piezometric level stabilizes and fluctuates within a small range (0.0 ÷ 0.5 m abs.a.) and only in local zones of more isolated and closed layers can it rise to 0.88–3.62 m NN.

In the water area, the pressure in the water-saturated clayey layers rises by approximately 10.0–16.0 m above the bottom, and during dredging operations, it may even increase; therefore, it can be predicted that in certain areas of the seabed, upon exposing aquifer formations and the formation of a specific hydrodynamic situation, mechanical suffusion is possible.

In the port's land area, the filtration coefficient (k_f) of limnic and aquaglacial intramorenic layers ranges from 0.05 to 5.85 m/day, while within the water area it ranges from 0.25 to 8.5 m/day. In terms of general chemical composition, the groundwater is fresh (total mineralization – 0.21–0.98 g/l); occasionally, it has a direct hydraulic connection with surface lagoon water and may exhibit increased mineralization (up to 1.48 g/l). The water is mostly calcium bicarbonate, but in some places, sodium bicarbonate and even sodium chloride water occur locally.

In areas where distinct aquifer systems are identified within the KVJU water body, the total mineralization of this groundwater ranges from 0.32 to 1.86 g/l, and the range of water chemical types extends from calcium bicarbonate to sodium chloride. An increased concentration of chloride (Cl^-) indicates a closer connection to lagoon water, which sometimes also increases its total mineralization.

It should be noted that the aggressiveness of the spring water toward concrete is significantly higher than that of groundwater. Its aggressiveness, as measured by carbonic acid (CO_2 aggressiveness), often reaches 21–1,109 mg/l in the water body and can be equated to aggressive and highly aggressive brackish water.

Nearest water sources

The water source closest to the PŪV territory (Klaipėda III) is approximately 0.6 km away, and the boundary of its AZ 3 zone is 0.23 km to the southeast. At the Klaipėda III infiltration-type water source, the volume of exploitable resources in the aquifer is 80,000 m³/day. An artificial recharge system has been installed at the water source to replenish these resources. The water source's discharge is approximately 45,410 m³/day. In fact, approximately 22,000 m³/day is supplied to consumers. The water source supplies water to the southern part of the city of Klaipėda.

The water source is classified as subgroup IIIb² (open infiltration water sources). The geological index of the exploited aquifer is Q(mIV). The aquifer exploited at the water source consists of deposits from the marine littoral terrace, composed of layers of sand and gravel of varying coarseness. The thickness of the aquifer rocks near the King William Canal reaches 10–12 m, and up to 22 m toward the Curonian Lagoon. The filtration coefficient (k_f) of the sand and gravel varies from 17 to 28 m/day (Z. Šonta, V. Krikščiūnas, 1964). The water supply facility operates using an infiltration method. The infiltration system consists of the King William Canal and three infiltration ditches, each 3.1 km long. The calculated maximum infiltration area is 18,600 m². The collection system consists of 11 horizontal drains (total length – 3,000 m) and 63 boreholes connected to a siphon line.

The shortest distances from the project site to the Klaipėda I water supply area and the currently unused Klaipėda II municipal water supply area are approximately 5.7 km and 4.1 km to the northeast, respectively. Both water supply areas are classified as closed water supply areas (Group I). The Upper Permian (P_2) and Upper Devonian (D3žg) aquifers are exploited in these water supply

areas.

Nearest deposits of solid mineral resources

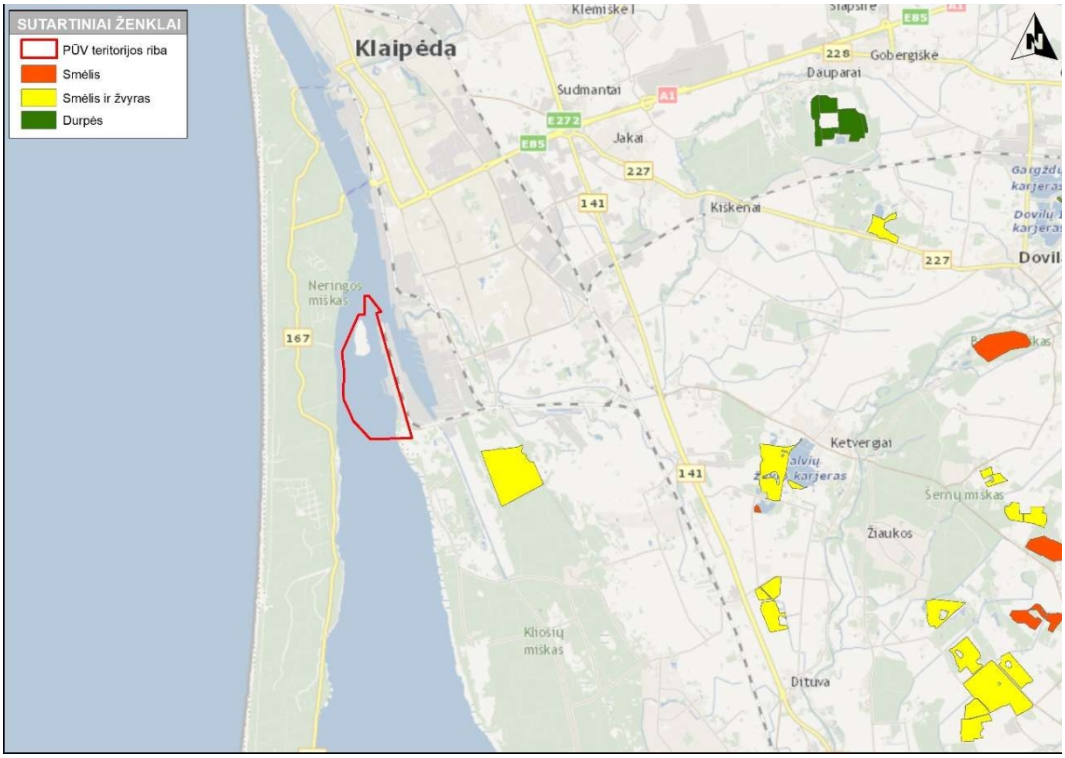
There are no solid mineral deposits within the territory of the Klaipėda City Municipality. The mineral deposits closest to the PŪV territory that have been thoroughly explored are shown in Figure 4.5.1.1 and Table 4.5.1.1. The most relevant to the PŪV may be the thoroughly explored sand and gravel deposits.

In the southern part of the Port, in the Curonian Lagoon, west of the Smeltė Peninsula, there is the prospective Gintaras I area (No. 1651). The Smeltė amber deposit, which was previously located nearby, was depleted in 1997 and removed from the Subsurface Resources Register.

4.5.1.1 Table. Data on solid mineral deposits and prospective areas closest to the PŪV territory

Deposit code	Name	Type of mineral	Geological *exploration**	Status	Area, ha	Distance to the PŪV territory, km
4513	Kairiai	Sand and gravel	Dž	Not in use	101.62	1.49
4710	Rimkai	Sand and gravel	Dž	Used	11.99	5.81
2270	Rings	Sand	Dž	not used	19.1	8.29
1612	Kalviai II	Smėlis	Dž	previously used	1.6	7.47
1598	Blacksmiths	Sand and gravel	Dž	Used	58.1	7.49

Note: D – Detailed-surveyed resources – these are the mineral resources of a deposit or part thereof whose quantity, quality, technological properties, hydrogeological, mining, and other conditions of occurrence have been studied in sufficient detail to prepare a development plan. P – prospective resources – are the probable mineral resources of promising areas or plots.



4.5.1.1 e.g., mineral deposits in the vicinity of the PŪV area that have been thoroughly explored

The eco-geological condition of the PŪV territory

The PŪV solutions are planned for the land area in the southern part of the port (Smeltė Peninsula, Kiaulės Nugaros Island) and the water area (southern part of the Klaipėda Strait, northern part of the Curonian Lagoon) as well as the Curonian Spit.

Ecogeological condition of the land area where the PŪV solutions are planned

Western part of the Smeltė Peninsula

From an eco-geological perspective, the part of the Smeltė Peninsula where the PŪV is planned can be divided into three zones: the northern zone—where intensive economic activity by port enterprises is carried out; the central zone—where a contaminated soil storage site is operated; and the southern zone—a sparsely used area. According to the engineering-geological mapping data collected by LGT, a layer of fill deposits approximately 3–3.5 m thick lies at an elevation of up to 0 m a.s.l. on the Smeltė Peninsula; within the port area, this layer is covered by artificial surfaces (concrete slabs, asphalt) (Fig. 4.5.1.2).

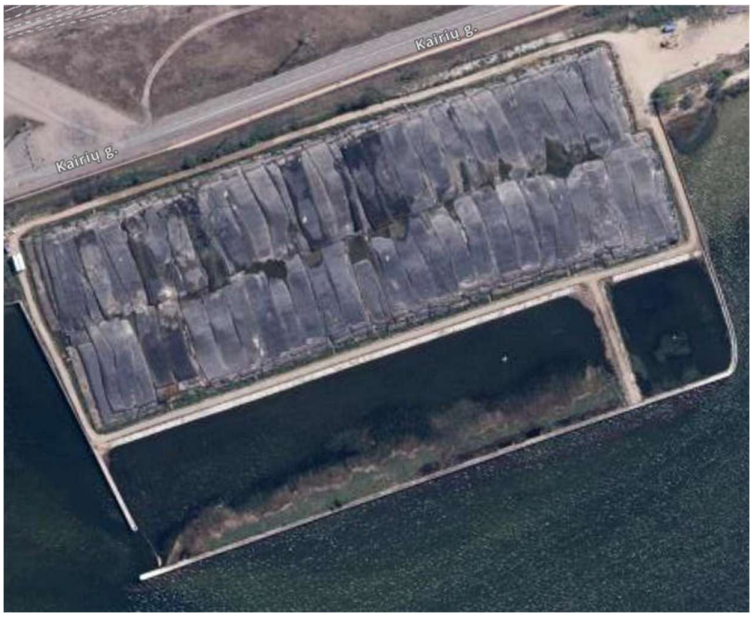
There is no precise information on the eco-geological condition of this part of the port area.



4.5.1.2 Fig. View of the northwestern part of the Smeltė Peninsula

In the central part of the Smeltė Peninsula, on its western side, there is an existing KVJU contaminated soil storage site (Fig. 4.5.1.3), south of which its expansion is planned. The EIA report [42] for the planned construction of the KVJU contaminated soil storage site at 19 Kairių St., Klaipėda, states that there is no information regarding past contamination of the plot in question.



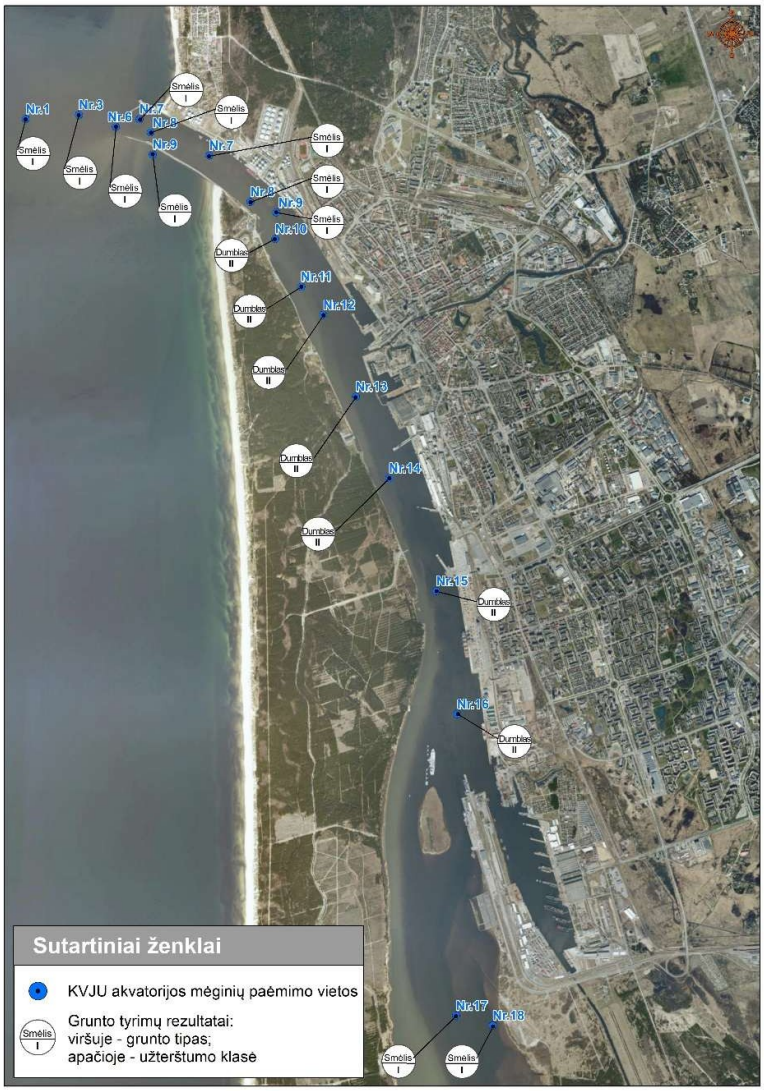


4.5.1.3 Fig. View of the KVJU contaminated soil storage site

There is no information on the eco-geological condition of the southwestern part of the Smeltė Peninsula (an area currently almost unused for port purposes).

Eco-geological condition of the water area where the planned PŪV solutions are to be implemented

During the EIA conducted in 2019, eco-geochemical studies of bottom sediments were carried out in the KVJU water area [19], during which 18 soil and sediment samples were collected from the seabed in the Baltic Sea (4 samples), the Klaipėda Strait (12 samples), and the Curonian Lagoon (2 samples). The locations where soil samples were collected are shown in Fig. 4.5.1.4. The chemical contamination of the samples analyzed from the Curonian Lagoon was classified as Contamination Class I (i.e., clean soil) (Fig. 4.5.1.4).



4.5.1.4 Fig. Study sites and results

4.5.2 Expected significant impact

Impact during construction of the PŪV facilities

Impact of the PŪV on the subsurface

When implementing solutions according to different PŪV alternatives, deepening the water area to a depth of 17 m and forming new land areas within the PŪV territory would involve the excavation, transport, and placement of large quantities of soil. Preliminary quantities of soil to be excavated and deposited for each PŪV alternative are shown in Figure 3.3.11.

The largest estimated volumes of excavated soil, reaching 12.3 million m^3, would be for Project Alternative 3A, while for the other two Project Alternatives, the volume of excavated soil would differ only slightly: 11.97 million m^3 for Alternative 2A and 11.68 million m^3 for Alternative 4A (Fig. 3.3.11). It should be noted that the calculated volumes are only indicative and must be refined when preparing technical designs for the dredging works.

According to the data from the report on the engineering-geological surveys conducted for the laying and installation of the LNG terminal pipeline along the bottom of the Curonian Lagoon [41], in the water area where the project solutions are planned (dredging and backfilling of the water area), a layer of silty sand approximately 4.7–11.8 m thick lies beneath the water layer, overlain by morainic loam (Figs. 4.5.2.1–4.5.2.2, Table 4.5.2.1). These are marine sediments (mIV), composed of fine and very fine brown, grayish-green, or dark gray sand mixed with organic matter.

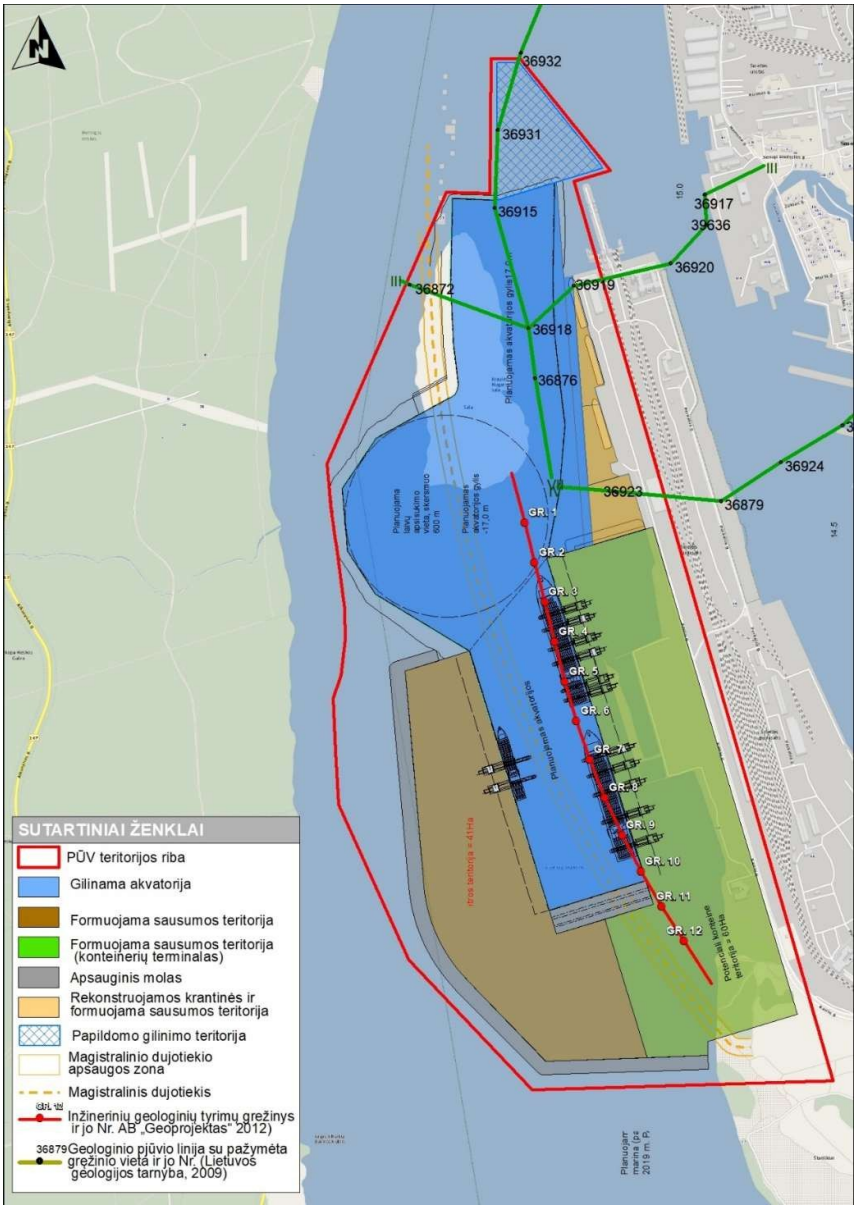
The geological conditions of the water area adjacent to the LNG terminal in the Klaipėda Strait, which is planned to be dredged to a depth of 17.0 m, are described based on the geological section data from borehole No. 36872 (Fig. 4.5.2.3) [43], which show that beneath the layer of water and silt lies a layer of sandy rock approximately 5.9 m thick, overlying a layer of clayey formations approximately 4.1 m thick, which in turn rests on a 2.25 m thick interlayer of sandy rock. Up to a depth of 17 m in the general cross-section, sandy rocks make up about 65% of the layer, while clayey rocks make up about 35%.

The geological environment of the planned excavation area on the Kiaulės Nugaros Island is illustrated by data from the engineering geological mapping of the southern part of the KVJU conducted by the Lithuanian Geological Survey (Fig. 4.5.2.4), which show that the island's surface is formed of alluvial technogenic soil (approximately 2.5–3 m thick sandy deposits, overlain by organic debris in the upper part). Deeper down lies a layer of sandy formations approximately 8.5 m thick, overlying a layer of loam approximately 4.0 m thick. Below this, sandy deposits extend to a depth of 17 m. In the overall section down to a depth of 17 m, sandy rocks account for approximately 76% of the total layer, while clayey rocks account for approximately 24%.

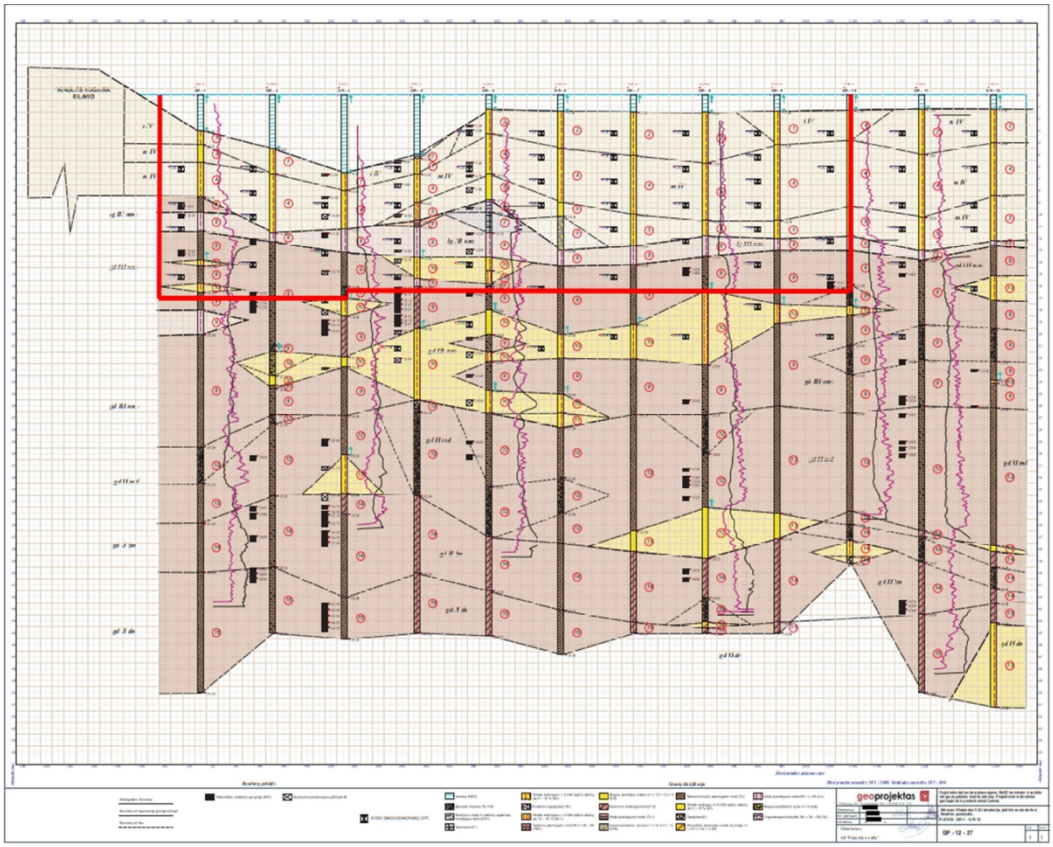
According to data from engineering geological surveys conducted for the construction of the LNG terminal gas pipeline [45], it is evident that, at the planned dredging depths (11–17 m), sandy rocks would constitute an average of approximately 55% (or about 6.58 million m^3), and clayey rock—about 45% (or about 5.39 million m^3) of the total volume of excavated soil (Table 4.5.2.1). Applying a similar proportion, in the case of Alternative 3A, sandy rock would account for an average of approximately 6.77 million m^3 , and clayey rock – about 5.53 million m^3 of the total volume of excavated soil, while in the case of Alternative 4A, these figures would be approximately 6.42 million m^3 and 5.26 million m^3 of the total volume of excavated soil, respectively. This shows that soil of any lithological composition would be entirely sufficient to form new land areas for the port. Sandy soil and soil corresponding to pollution group I are suitable for beach replenishment and shoreline management works; therefore, it is recommended to use part of it for this purpose, while clayey soil should be used more for the formation of new areas.

According to the summarized geological cross-section data from previous studies (Fig. 4.5.2.3) it can be seen that in certain areas of the deepened water area, sandy, water-bearing layers may be exposed, which could increase the risk of undesirable phenomena (underwater seepage); this must be taken into account when constructing quays.

Excavated clean excess soil may be disposed of at sea in accordance with the requirements of LAND 46A-2002 [16] and only at the soil disposal site specified in the permit issued by the Klaipėda Regional Environmental Protection Agency (RAAD), or temporarily stored at the KVJU or another site and used as needed.



4.5.2.1 Fig. Area of solutions for PŪV Alternative 2A with marked borehole locations and geological cross-section lines

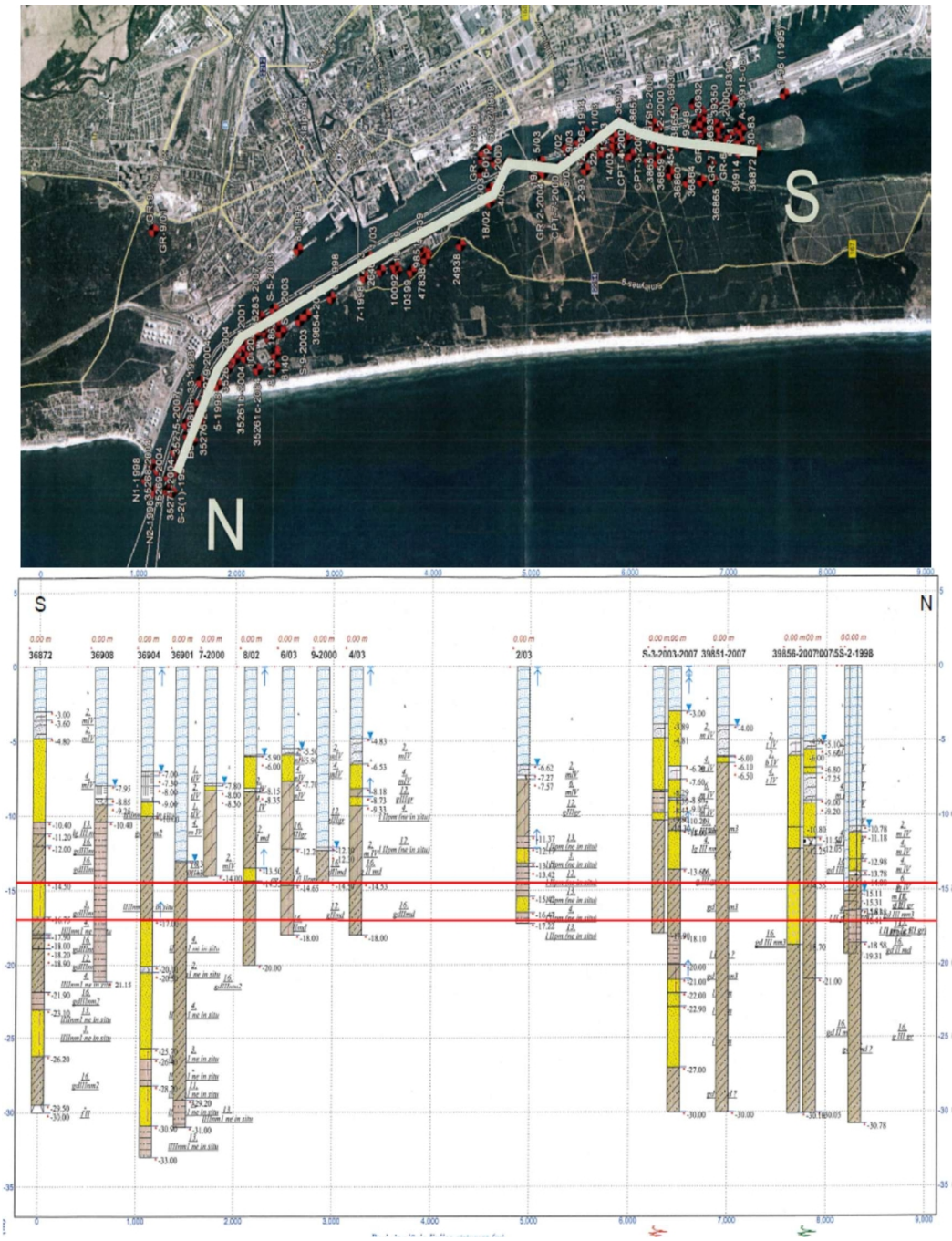


4.5.2.2 Fig. Geological cross-section showing the dredging location in the water area for Alternative 2A

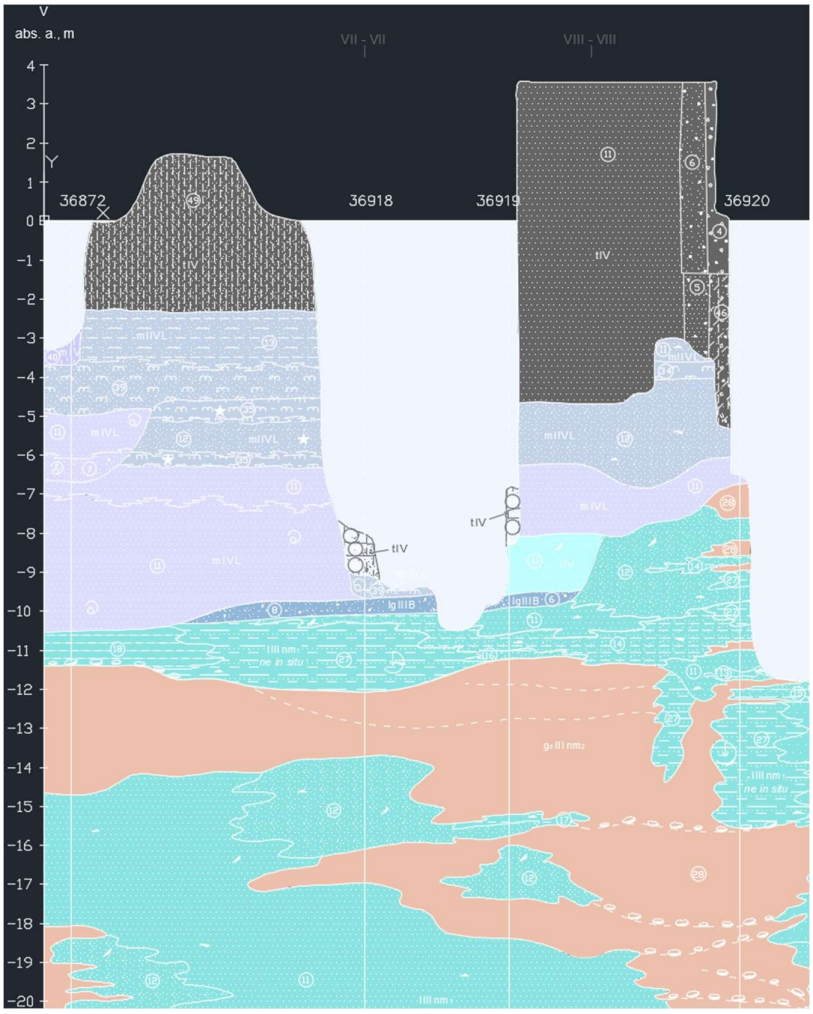
Table 4.5.2.1. Soil distribution in the cross-section of the planned dredging area according to its lithological composition

No.	Borehole No.	Thickness of sandy rocks, m	Percentage of total excavated layer thickness, %	Thickness of clayey rocks, m	Percentage of total excavated layer thickness, %	Notes*
1	G1	5.5	39.3	8.5	60.7	Maximum depth: 17 m
2	G2	7.0	56.0	5.5	34.0	Draft up to 17 m
3	G3	4.7	44.8	5.8	55.2	Depth up to 17 m
4	G4	5.2	44.4	6.5	55.6	Dredged to 16.5 m
5	G5	7.5	47.6	8.25	52.4	Dredged to 16.5 m
6	G6	8.70	55.8	6.9	44.2	Dredged to 16.5 m
7	G7	11.15	71.7	4.4	28.3	Draft up to 16.5 m
8	G8	11.0	64.7	6.0	35.3	Draft up to 16.5 m
9	G9	10.6	67.9	5.0	32.1	Dredged to 16.5 m
10	G10	10.5	61.8	6.5	38.2	Dredged to 16.5 m
11	G11	11.8	69.4	5.2	30.1	Water area to be filled
12	G12	13.1	81.9	2.9	18.1	Flooded water area

* - In the case of Alternative 2A.



4.5.2.3 Fig. Generalized geological cross-section of the KVJU water area (PŪV solutions are planned near Kiaulės Nugaros Island; relevant geological cross-section of borehole No. 36872) [43]



4.5.2.4 Fig. Fragment of the geological cross-section near Kiaulės Nugaros Island [47]

When implementing the "secondary" solutions—by upgrading the existing 110 kV EEPOL—the underground power cable on land will be laid at a depth of up to 2 m, and across the Curonian Lagoon by drilling to a depth of 30 m below the lagoon bottom. These solutions will not cause any significant negative impact on the subsurface.

Impact of the Project on the Klaipėda III Water Supply Area

The Klaipėda III water supply area is located 0.6 km from the PŪV site, and the boundary of its AZ 3 zone is 0.23 km to the southeast (Fig. 3.1.2). The water supply area is of the infiltration type. About 80% of the water resources consist of water taken from the King William Canal, which is used to replenish infiltration channels, and these, in turn, are intended to replenish groundwater resources. Water that has seeped through sandy rock is extracted via wells, treated physically and chemically, and supplied to consumers. In assessing the potential impact of the PŪV, we will examine the following aspects:

- the potential for contamination of the water in the King William Canal during the implementation of the PŪV solutions;

- the potential for groundwater contamination in the vicinity of the King William Canal and the Klaipėda III water supply area during the implementation of the PŪV solutions.

In both cases, the potential for pollutants to enter and spread in the aforementioned surface and groundwater bodies is limited due to the following factors:

- No PŪV works are planned in Malkų Bay. Water flows through the King William Canal from the Minija River into the Curonian Lagoon (the water flows out into Malkų Bay), therefore, even if potentially contaminated water enters Malkų Bay, its ability to flow and spread against the current is very limited to a very small area (the flow in the canal at the water intake boundary is regulated by locks) and during limited periods (when the current flows through the strait from the Baltic Sea into the Curonian Lagoon);

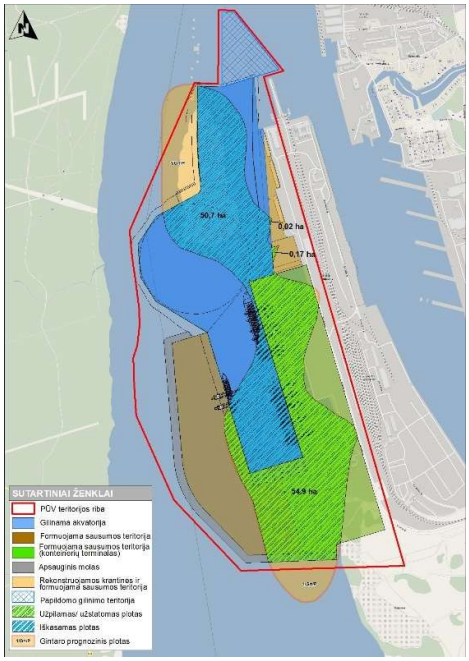
- groundwater flow also discharges largely into the Curonian Lagoon. On the western side of the water source area, there is a natural groundwater flow divide, at which the groundwater flow splits into different directions; part of it flows westward and discharges into the Curonian Lagoon, while the other part flows eastward and northward toward the King William Canal and Malkų Bay. In this case, the entry of pollutants from the Curonian Lagoon into the groundwater layer and into the area of the water supply system is minimal. It should also be noted that the water extracted from the water supply area is treated using physical and chemical methods before being supplied to consumers, and its quality is continuously monitored.

In summary, it can be noted that the PŪV will have no negative impact on the water resources extracted from the Klaipėda III water supply area.

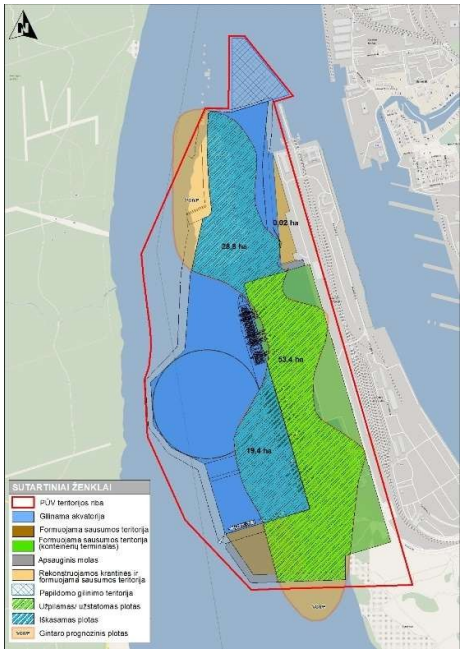
Impact of the PŪV on solid mineral resources

A large part of the PŪV territory falls within the boundaries of the approximately 122 ha Gintaras I prospect area (No. 1651) (Fig. 4.5.2.5, Graphic Appendix 1). In the case of PŪV Alternative 2A, the construction of PŪV facilities would result in approximately 55.09 ha (about 45.2%) of the projected area being backfilled with soil and covered with hydraulic structures, while in the case of PŪV Alternative 3A, approximately 50.7 ha (about 41.6%) water body dredging works are being carried out within the deposit area; in the case of PŪV Alternative 3A, approximately 53.4 ha (about 43.8%) of the projected area would be filled in and approximately 48.4 ha (about 39.5%) of the deposit area would be subject to water body dredging works; and in the case of PŪV alternative 4A, approximately 70.0 ha (about 57.4%) of the projected area is filled in, and dredging works are being carried out in approximately 33.5 ha (about 27.5%) of the deposit area (Fig. 4.5.2.5)

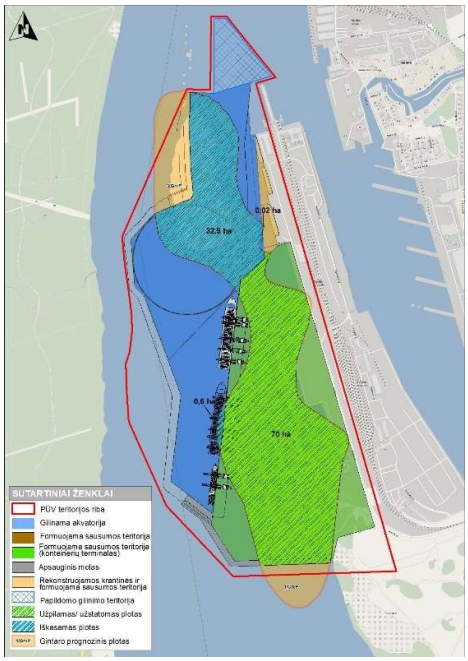
Current legislation does not impose any restrictions on economic activities within the projected mineral deposit areas.



Alternative 2A



Alternative 3A



Alternative 4A



4.5.2.5 Fig. Impact of the PŪV on the prospective Gintaras I area (No. 1651)

Construction work on the PŪV facilities may require additional loose construction materials (sand, gravel), which may need to be transported from the nearest quarries (if the soil of the required fraction and contamination level excavated and stockpiled during the dredging of the navigation channel and water areas is insufficient or does not meet the required quality standards).

Impact during the operation of the PŪV facilities

Once the PŪV solutions are implemented, a negative impact on the subsurface during the operation of the facilities is unlikely.

Conclusion: It is estimated that the implementation of the PŪV solutions may result in the excavation of approximately 11.97 million m^3 of soil in the case of Alternative 2A, approximately 12.3 million m^3 in the case of Alternative 3A, and approximately 11.68 million m^3 in the case of Alternative 4A. Most of it will be sand (about 55%), with the remainder consisting of morainic loam and sandy loam, silt, etc. Most of the excavated soil, after assessing its lithological composition and contamination, is planned to be purposefully used for the formation of new areas envisaged by the PŪV solutions (depending on the selected PŪV alternative, approximately 3.88–5.43 million M^3) or 32–45% of the total excavated soil). The remaining portion will be used for shoreline management and environmental protection works and/or disposed of in landfills.

In certain areas of the deepened water areas, sandy aquifers may be exposed, which could increase the risk of undesirable phenomena (underwater seepage) during the construction of quays; therefore, it is recommended to apply the mitigation measures specified in this report.

The solutions for any of the PŪV alternatives will not have any negative impact on the water resources extracted in the Klaipėda III water supply area.

Construction of the PŪV facilities may require loose construction materials (sand, gravel), which may need to be brought in from the nearest quarries (if the soil of the required fraction and contamination level excavated and stockpiled during the dredging of the shipping channel and water areas is insufficient). The existing surveyed resources within the territory of the Klaipėda District Municipality would be sufficient to meet the needs of the PŪV.

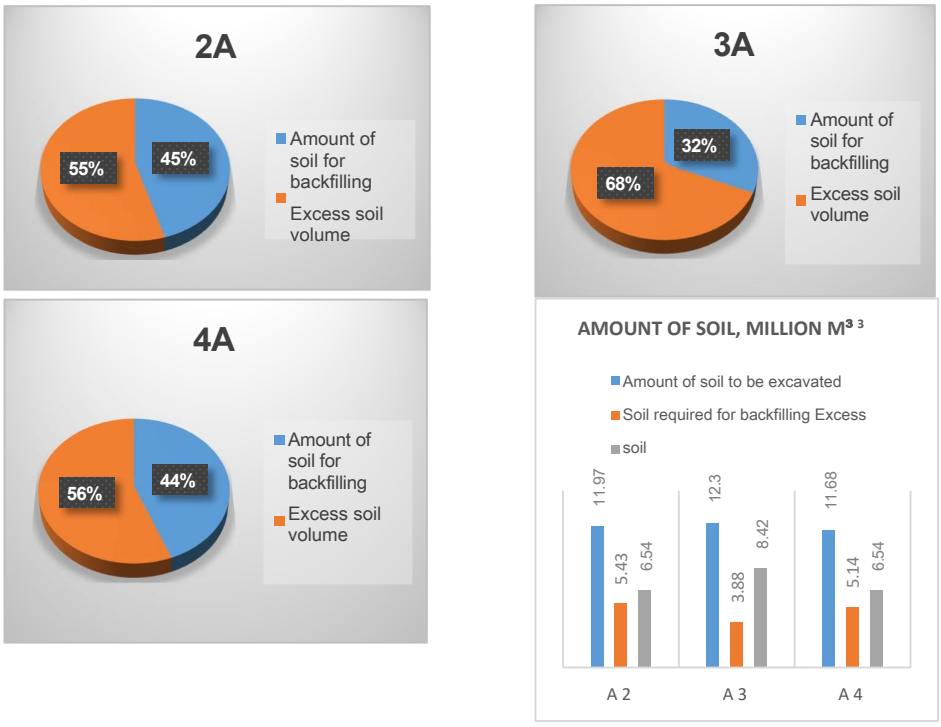
The impact on the subsurface during the implementation of the solutions should be considered direct, long-term, and interactive (it may also affect other environmental elements, such as water, soil, and ambient air), and of moderate significance (large-scale works, but most of the excavated soil will be used for land development in other areas). A negative impact on the subsurface during the operation of the PŪV facilities is unlikely. In terms of increasing impact, the PŪV alternatives are ranked as follows: 4A < 2A < 3A. During the construction and operation of the PŪV facilities, it is necessary to implement measures to prevent, reduce, and/or compensate for the negative impacts of the PŪV.

4.5.3 Measures to prevent, mitigate, and compensate for significant adverse environmental impacts

Proposed measures to prevent and mitigate adverse impacts on the subsurface:

- Before implementing the solutions, detailed engineering geological surveys are required (where they have not yet been conducted), to identify potential risk zones and, accordingly, to plan the necessary technical solutions to prevent or control the risk of subsidence processes, ensure the stability of the banks, and substantiate the technical parameters of other structures;
- In accordance with the requirements of LAND 46A-2002 “Rules for Soil Excavation in Marine and Seaport Water Areas and the Management of Excavated Soil,” bottom sediment studies must be conducted to the extent specified in the aforementioned document prior to commencing dredging works in the water area;
- When carrying out dredging works within the projected Gintaras area, it is recommended that a geologist-expert participate in the works to identify the potential presence or absence of exploitable resources;

- Optimal targeted use of excavated soil for the formation of new areas and the replenishment of shorelines with sand, minimizing the amount of soil disposed of in landfills, in accordance with the requirements of LAND 46A-2002 “Rules for Dredging in Marine and Seaport Waters and the Management of Excavated Soil.” Planned and recommended solutions: 1) use the soil excavated from dredged water areas for the formation of new land areas planned under the PŪV solutions (indicative requirement, depending on the selected PŪV alternative, is approximately 3.88–5.43 million m^3 (Fig. 4.5.3.1, Table 4.5.3.1), with clayey rock soil recommended for use as a first priority); 2) Use sandy soil of suitable lithology and quality (Pollution Class I) excavated from dredged water areas for replenishment works of the coastal seabed and shoreline deposits in the Melnragė–Giruliai area (estimated annual requirement of approximately 0.5 million m^3); 3) To replenish the sediment deposits in the shallow part of the eastern coast of the Curonian Spit, from the shoreline to the 1–1.2 m isobaths, from Alksnynė to the existing pier (Class I contamination), 4) To store excavated and temporarily unused sandy soil of pollution classes I–II at a temporary storage site in the southern part of the Smeltė Peninsula outside the port territory (until the need for its intended use arises) (estimated volume of approximately 5.6–5.9 million m^3) and subsequently use it as needed for shoreline management works.
-



4.5.3.1 Fig. Distribution of excavated soil utilization for all PŪV alternatives

- Table 4.5.3.1. Estimated quantities of excavated soil for reuse and disposal

PŪV solution	PŪV alternative					
	2A		3A		4A	
	Sandy rock (55%)	Clayey rocks (45%)	Sandy rocks (55%)	Clayey rocks (45%)	Sandy rocks (55%)	Clayey rocks (45%)
Volume of excavated soil, million m³	Approx. 6.59	Approx. 5.38	Approx. 6.76	About 5.54	About 6.42	Approx. 5.26
Soil for port area development (I and II contamination classes), million m³	-	Approx. 5.43	-	Approx. 3.88	-	About 5.14
Soil for bank and beach replenishment (I contamination classes), million m³	About 0.5	-	About 0.5	-	About 0.5	-
Submerged unsuitable soil (silt, Class II and higher contamination), million m³ (5%)	Approx. 0.33	-	Approx. 0.34	-	About 0.32	-
Remaining soil, million m³	About 5.76	Approx. - 0.05	Approx. 5.92	Approx. 1.66	About 5.60	About 0.12



4.5.3.2 Fig. Diagram of potential sites for the use and management of excavated soil

4.6 Shores

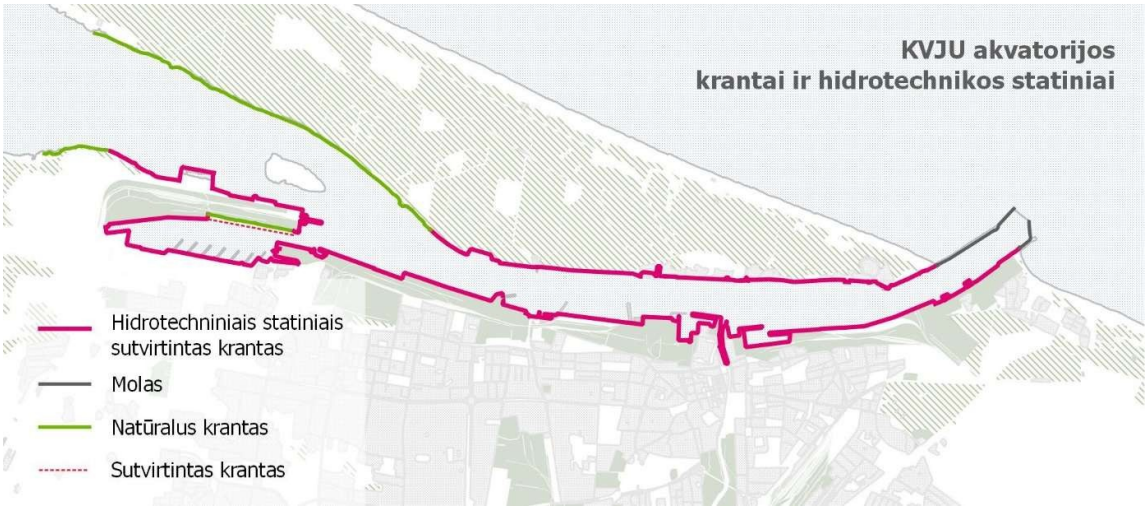
4.6.1 Description of the current condition

The assessment and description of the current condition of the banks and underwater slopes within the PŪV territory and its surroundings were carried out by expert Dr. G. Žilinskas, based on the results of direct investigations conducted during this EIA, long-term shoreline monitoring conducted by KVJUD [28–30, 49, 50], and data from other publicly available sources.

In the KVJU water area in the Klaipėda Strait and Malkų Bay, quays or other hydraulic structures are installed along almost the entire length of the mainland coast; the quays also border most of the Smeltė Peninsula (except for the Smeltė Botanical Reserve zone on the eastern coast of the

peninsula, where

the protected coastal slope, where an underwater retaining wall was installed in 2017) (Fig. 4.6.1.1). A largely natural lagoon shore extends southward from PK 107. The eastern shore of the Curonian Spit within the port's water area, from the port entrance to PK 73, is also reinforced with protective walls or features quays and other hydraulic structures. The shore not built up with the aforementioned structures begins at PK 73 and extends southward within the port's water area. The shores of Kiaulės Nugaros Island are also not reinforced with protective measures. In the inner harbor area of KVJU up to the southern boundary of the port territory, the total length of the mainland and Curonian Spit shoreline is approximately 39.2 km, of which about 34.9 km is already reinforced or built up with hydraulic structures (quays, piers, protective walls, jetties, concrete slabs, etc.). The natural eastern shore of the Curonian Spit, unobstructed by hydraulic structures, extends for approximately 4.78 km within the KVJU territory, while the eastern shore of the Curonian Lagoon extends for approximately 0.85 km; in Malkų Bay—about 1 km. An underwater retaining wall has been installed in the section near the Smeltė Botanical Reserve.



4.6.1.1 Fig. Shores restricted by hydraulic structures

The assessment of the impact of the development of the southern part of the KVJU on the condition of the shoreline zone (Fig. 4.6.1.2) and the identification of preliminary compensatory measures that would help mitigate potential negative impacts on the shorelines in this study are based on:

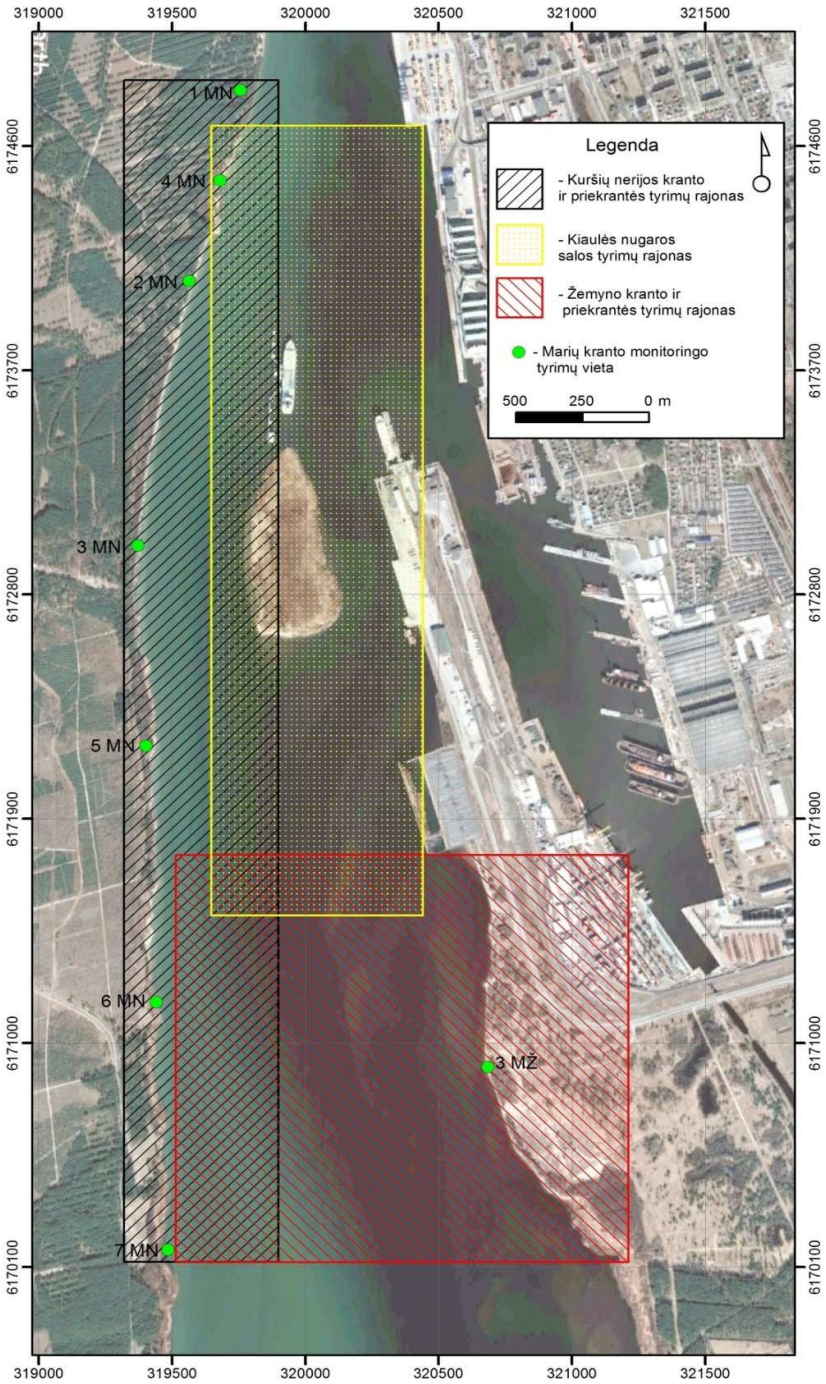
- morphometric and lithological data collected during field surveys (September 10–14, 2022, and October 14–18, 2022);
- bathymetric maps of the study area from 2017 and 2022 (KVJU), supplemented by measurement data from the experts who conducted this assessment between the shoreline and the 1.5 m isobath;
- data from the monitoring of the dynamics of the Curonian Lagoon shores and foreshore;
- A comparative analysis of cartographic materials and orthophotos from the 20th–21st centuries;
- data collected during detailed comprehensive field research (conducted by experts in 1999, 2007, 2010, 2011, and 2016–2018) on the shores and foreshore of the Curonian Lagoon;
- the results of hydrodynamic modeling of the Curonian Lagoon conducted by LEI;
- research results related to the subject of this work, published in various scientific papers and reports;

- research data and the experience accumulated by experts in determining shoreline management measures and managing various hydrotechnical structures during preliminary design studies, construction supervision, and facility operation.

Definitions of terms used in the analysis below. *Lagoon shore* – a strip of land along the lagoon where the relief forms and sediment accumulations have developed at the current long-term water level. *Shore line* – the line separating the lagoon from the land at low tide. *Foreshore* – the foreshore and its slope. *Foreshore* – the part of the lagoon foreshore from the shoreline to the foreshore slope (1.0–1.5 m deep), formed due to shoreline abrasion/accumulation fluctuations, and currents. *The foreshore slope* is the relatively steep part of the lagoon foreshore located between the foreshore and the lagoon bottom. *The shoreline zone* is the area of direct interaction between land and the lagoon, encompassing the lagoon shoreline

The slope of the Curonian Lagoon foreshore (the foreshore and its slope) and its morphological features are the most important factor protecting the lagoon shores from the negative effects of hydrodynamic forces (waves, currents, water level fluctuations) and drifting ice. For example, a wide and shallow foreshore and a gentle foreshore slope "dampen" wave action, reduce current velocity, break up ice floes, etc. Therefore, in this study, when assessing the condition of the foreshore slope (hereinafter—FS), significant attention is paid specifically to the width and slope of the entire underwater slope, as well as the width and slope of the foreshore and its slope. It should also be noted that the configuration of the CS profile is very important: a CS with a straight profile is more sensitive to both external natural factors (water level fluctuations, wave action, currents, ice drift, etc.) and anthropogenic factors (dredging works, construction and operation of various hydrotechnical structures, wave action caused by ships, etc.) than a slope with a profile consisting of several sections of varying gradients.

Taking into account the specific characteristics of the analyzed area, three sectors are distinguished: the mainland coast of the Curonian Lagoon, Kiaulės Nugaros Island, and the coast of the Curonian Spit (Fig. 4.6.1.2).



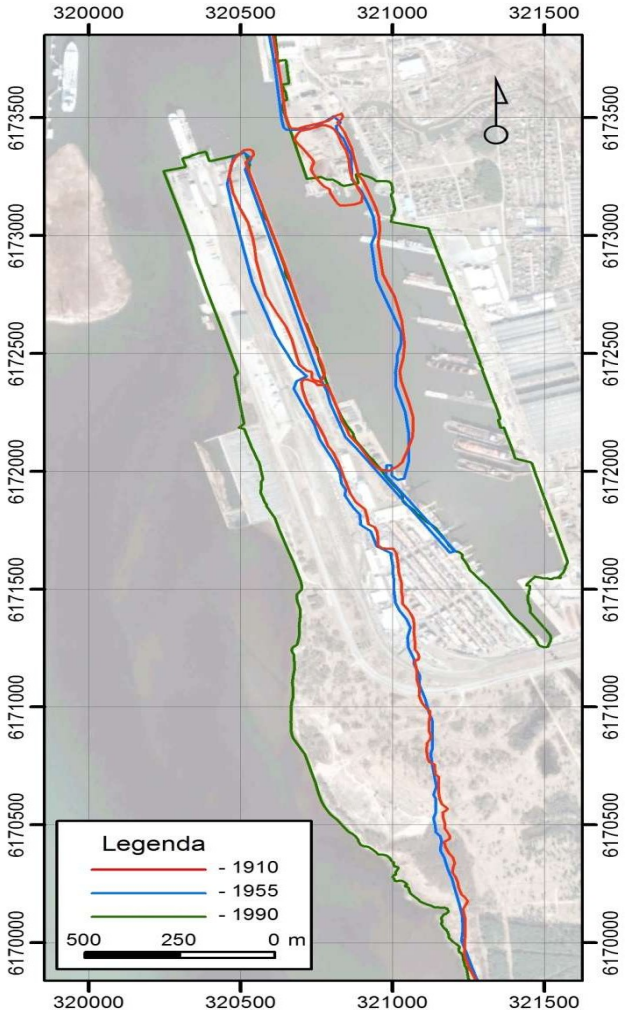
4.6.1.2 Fig. Study area for the impact of the southern part of the KVJU expansion on coastal zones. The 2022 shoreline position corresponds to the situation in the satellite image from March 14, 2022 *(Google Earth*).

Coast of the Curonian Lagoon mainland

Coastal condition. During the planned expansion of the southern part of the KVJU, the entire coastal environment of the Smeltė Peninsula will be altered. From the start of the northern breakwater at the Klaipėda Port sea gate to the middle of the Smeltė Peninsula, the shoreline is reinforced with quays of various purposes and types, reinforced concrete slabs, or stone revetments (Fig. 4.6.1.1). South of the end of the reinforced shoreline (PK108), a 1,100-meter-long stretch of a dune-type shoreline begins, dominated by narrow (5–18 m wide) and low (0.4–0.8 m high) beaches. The active (dynamic) part of the beach here is only 6–10 m wide; further on, up to the embankment, the beach is overgrown with grasses, macrophytes, shrubs, and trees in places. In many places, reeds and rushes also grow in the foreshore. On the eastern side, the beach abuts a dike (polder) 1.5–2.5 m in relative height and about 5–10 m wide, overgrown with grass and shrubs. The dike has been eroded in several places by ice drifts and extreme storms. The beach consists of various fractions of sand, gravel, pebbles, clay, and silt.

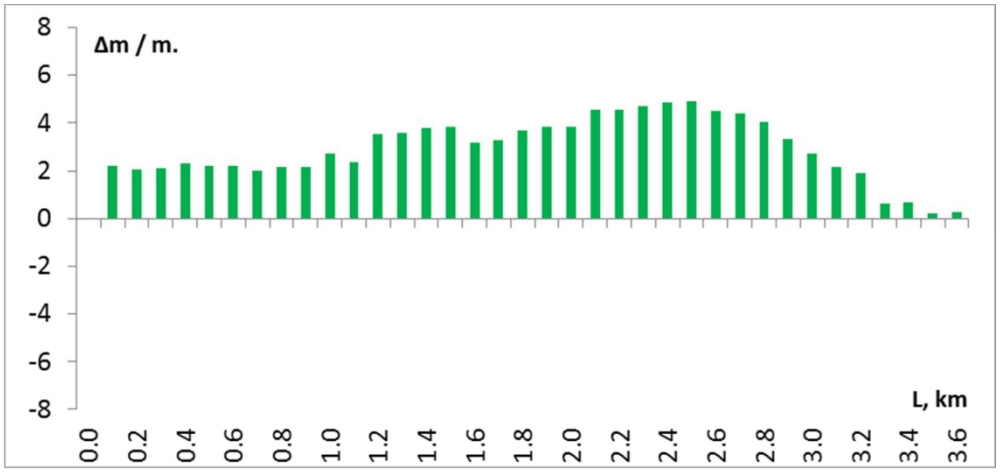
It should be noted that this section of the Smeltė Peninsula's coastline has been subjected to anthropogenic impact on multiple occasions: an embankment was constructed here, sand excavated from Kiaulės Nugaros Island was stored here (part of which was later removed), and so on. In the southernmost part of the Smeltė Peninsula, along a stretch approximately 350 m long, the shoreline is dominated by areas that have become swampy and overgrown with reeds, cattails, willow thickets, and alders. South of the Smeltė Peninsula begins a stretch of stable, reed-covered shoreline, marshy in places, which extends almost to Cape Ventė. It should be noted that south of the port's boundary begins the Natura 2000 site of the European ecological network.

Geodynamic trends. The Smeltė Peninsula is a geomorphologically very young landform. It does not even appear on a map from 1834. In 1910, its southern side consisted of a narrow spit, while its northern side was a narrow, elongated island. In the first quarter of the 20th century, due to extremely active accretion processes, the spit merged with the island (Fig. 2). Later, the western coast of the peninsula advanced significantly into the lagoon (from 150–170 m in the north to 300–400 m in the south). The western shoreline of the Smeltė Peninsula advanced most intensively into the lagoon in the second half of the 20th century (Figs. 2, 3) until approximately the end of the 20th century, when signs of shoreline erosion began to appear in the central section of the stretch. It should be noted that in the 1990s, during the construction of the International Ferry, breakwater construction began on the western side of the northern part of the Smeltė Peninsula. Currently, the quays extend across nearly the entire northern section (Fig. 4.6.1.3). Therefore, the shoreline here is stable both over time and in space.



4.6.1.3 Fig. Changes in the Curonian Lagoon mainland shoreline on the Smeltė Peninsula between 1910 and 2022. The 2022 shoreline position corresponds to the situation shown in the satellite image from March 14, 2022

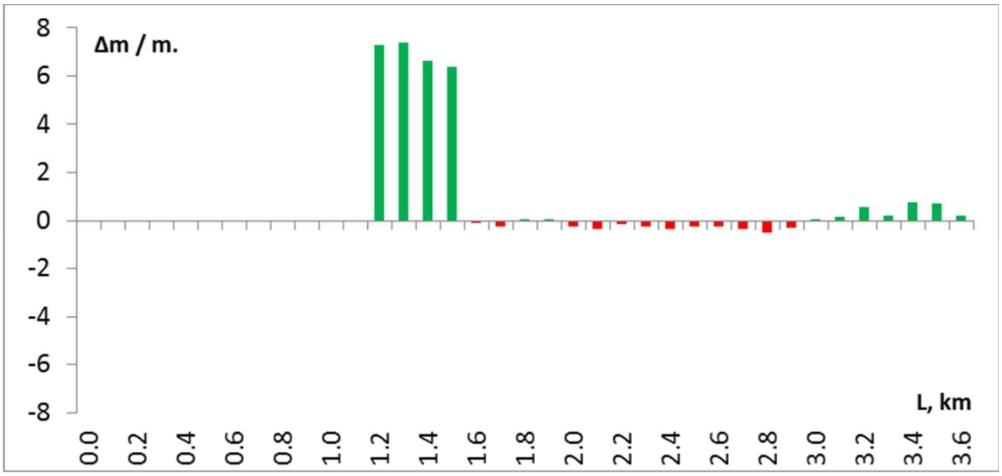
(*Google Earth*).



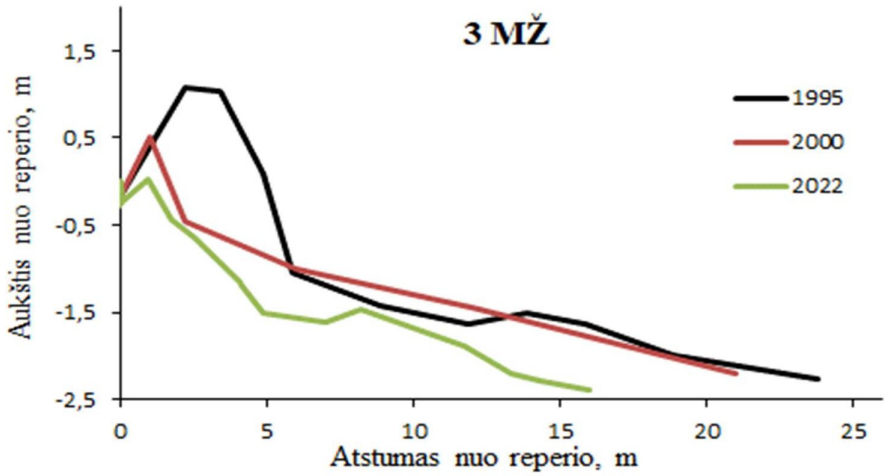
4.6.1.4 Fig. Dynamics of the Smeltė Peninsula shoreline (m/m) from 1910 to 2022

The relatively natural shoreline now covers only the southern part of the Smeltė Peninsula. Over the past 30 years, changes in geodynamic trends in its central part (Fig. 4.6.1.4) have been influenced by frequent storms of extreme intensity, during which parts of the beach and, in some places, the embankment along the shore were damaged or eroded.

Since westerly winds (from W to NW) typically prevail during extreme storms, water levels on the eastern shore of the Curonian Lagoon often reach extreme values. Consequently, waves—and ice floes during the ice drift season—reach the seawall and erode it. No significant changes to the shoreline were recorded here between extreme storms. Figure 4.6.1.6 presents data from measurements conducted at the 3MŽ monitoring profile site on the Klaipėda Port shoreline (since 1995). The greatest change here occurred in December 1999 during the extreme storm “Anatolijus,” when a large portion of the shoreline embankment was eroded. However, shoreline erosion has continued to be observed at this location in subsequent years. Over the past 27 years, the shoreline here has retreated by an average of 10 m (0.4 m per year), and the shoreline has lost an average of 12.5 m³/m (0.46 m³/m per year) of sediment (Fig. 4.6.1.6). It should be noted that the greatest shoreline changes on the entire Smeltė Peninsula have been recorded at this profile location. In the adjacent 3MŽ profile sections, shoreline erosion is significantly weaker, and in some places not even detectable (Fig. 4.6.1.5).



4.6.1.5 Fig. Dynamics of the Smeltė Peninsula shoreline (m/year) from 1990 to 2022



4.6.1.6 Fig. Dynamics of the continental shore's cross-section from 1995 to 2020 on the Curonian Lagoon's continental shore (3MŽ profile; location indicated in Fig. 4.6.1.2)

Foreshore. The morphological characteristics of the Smeltė Peninsula foreshore are reflected in the data presented in Fig. 4.6.1.7. In the northern part of the study section, the foreshore is shallow; its slope increases slightly from 0.0021 (Profile 0) toward the south to 0.0066 (Profile 5), from where it decreases again to 0.0047 (Profile 7). The width of the foreshore changes accordingly: it narrows from 596 m (0 m.e.) to 303 m (5 m.e.), and then widens again to 420 m (7 m.e.).

On the southern side of the section, the channel of a relict eastern branch begins to emerge, whose distance from the shoreline, like its depth, increases in a southerly direction: the distance ranges from 200 m (2nd profile), 400 m (5th profile) to 680 m (7th profile), while the channel depth ranges from 2.0 m (profile 2), 3.9 m (profile 5), to 4.8 m (profile 7).

A shallow and wide foreshore near the Smeltė Peninsula would be fully sufficient for the transformation of wave energy in the nearshore zone, and at the same time for maintaining the stability of the shoreline. However, due to prevailing westerly winds, the water level rise during severe storms (evidence of erosion on the shore indicates it can rise by 30–50 cm or more) floods the low-lying beach and "allows" waves (and in winter and spring, ice) to erode the shore. A significant rise in the lagoon's water level due to the dam near the Smeltė Peninsula often occurs during the spring flood/ice break-up. This is also influenced by the narrowing of the lagoon's waterway near the former boat dock (part of which is currently used as a storage site for contaminated soil) by piers/dams.

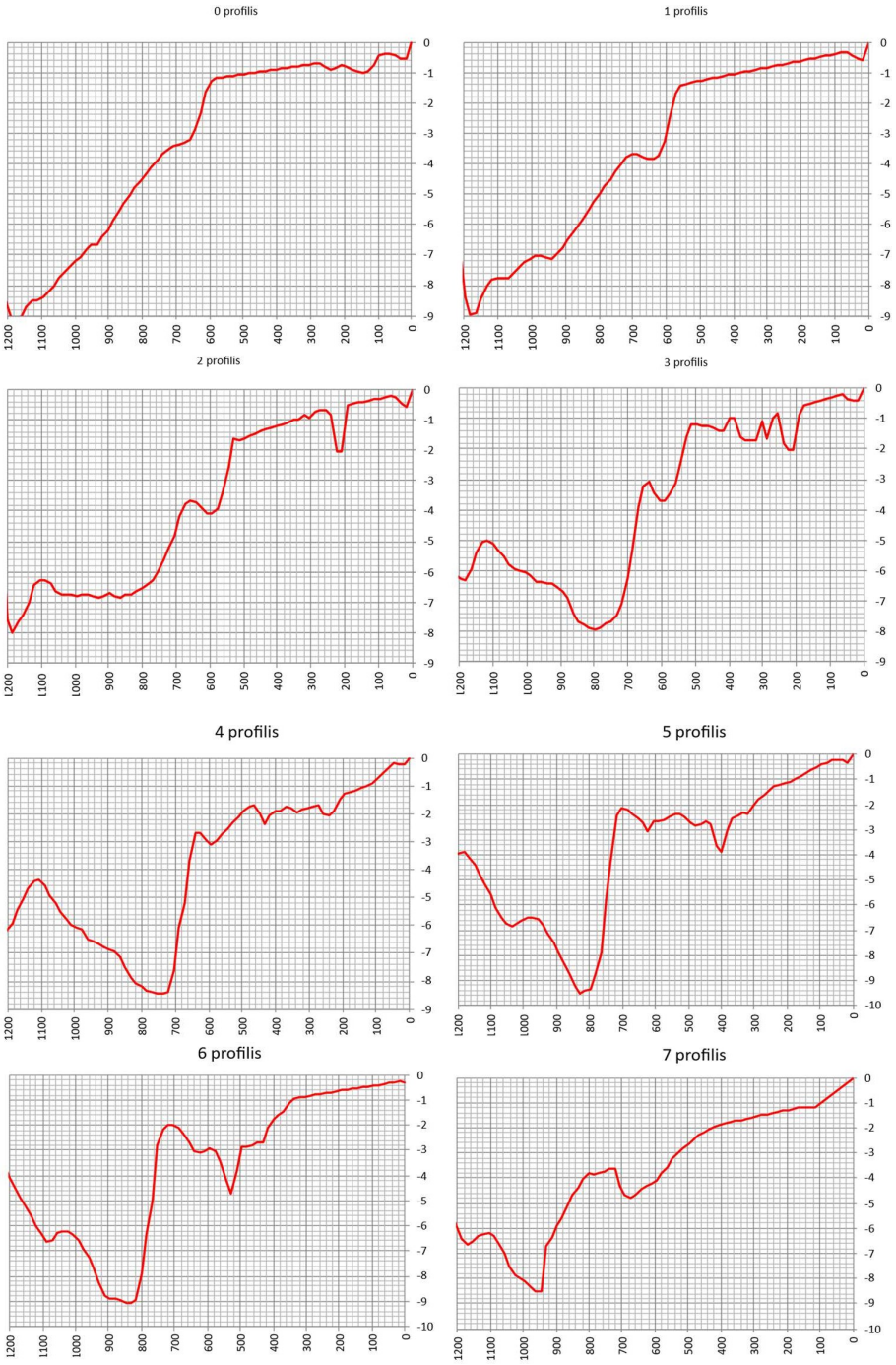
Kiaulės Nugaros Island

In the northern part of the Curonian Lagoon, almost halfway between the Curonian Spit and the mainland coast, lies Kiaulės Nugaros Island. The Kiaulės Nugaros shoal formed as a natural sediment barrier during the circulation of water masses between the Curonian Lagoon and the Baltic Sea. This shoal was formed both by marine sediments reaching this location during severe storms and (largely) by sediments deposited from the Curonian Lagoon as the channel parameters changed rapidly at this section (Gailiušis et al., 2005). This sediment barrier existed as a shoal until the second half of the 20th century (Fig. 4.6.1.8). Later, as sediments accumulated, it emerged from the water in several places during the 1970s and 1980s (Fig. 4.6.1.8). The further natural development of

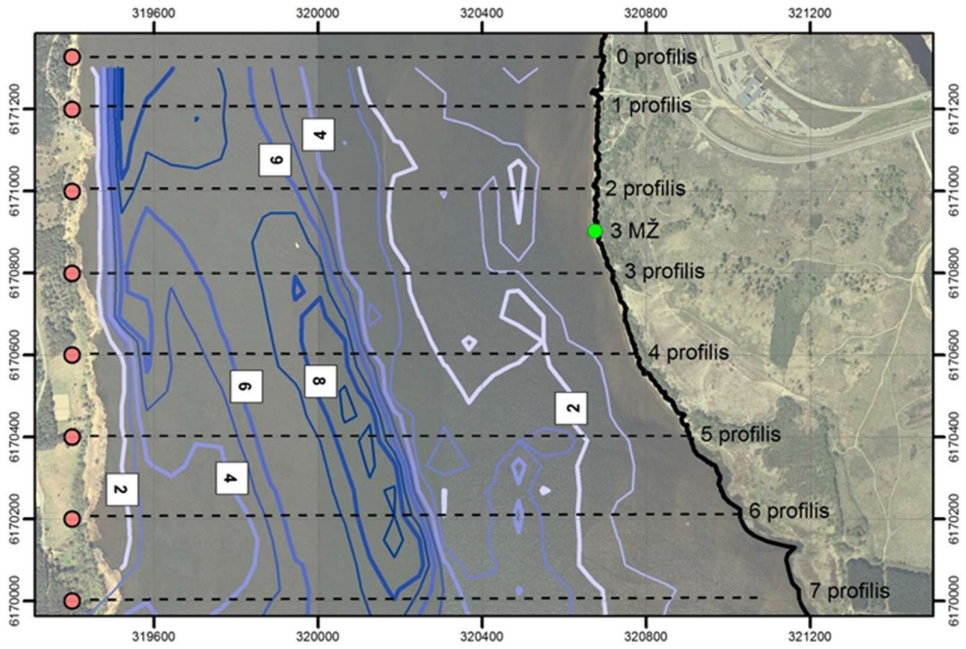
Kiaulės Nugaros Island was halted in the 1980s, when it was decided to construct a new pier on the northern part of the island. As sand was deposited,

the small islets that had been on the northern side of Kiaulės Nugaros Island merged with the “main” island (Fig. 4.6.1.8).

The height of the sand embankment here reached 14 meters in 1981. After the idea of building the pier was abandoned, part of the deposited sand was excavated in 1982 and transported to the Smeltė Peninsula. Kiaulės Nugaros Island underwent another major transformation during the construction of the International Sea Ferry. While forming the ferry turning basin, not only was the water area adjacent to Kiaulės Nugaros Island deepened, but the northern part of the island was also excavated (Klaipėda Port Ro-Ro..., 1996). In total, 4 million $m^3$of soil was excavated, 10,000 piles were driven, and 58,000 $m^3$of concrete was used. Construction was completed in September 1986. Later, as reeds and shrubs took root on the island and the hydrological regime of the surrounding water area stabilized, the island’s position in time and space stabilized.



4.6.1.7 Fig. Transverse profiles of the Smeltė Peninsula's foreshore (profile locations shown in Fig. 4.6.1.8).



4.6.1.8 Fig. Locations of the Smeltė Peninsula's coastal cross-sections. The 2022 shoreline position corresponds to the situation in the satellite image from March 14, 2022 (Google Earth).

Relatively minor changes to the island's shoreline, mostly caused by ice drift and biogenic processes, have also occurred over the past 50 years. The construction (2014) and operation of the LNG terminal did not have a significant impact on changes in the island's shoreline contour or its morphology (Fig. 4.6.1.9).

Coast of the Curonian Spit Lagoon

Coastal condition. From the start of the distal part of the southern pier (PK10), along a stretch of approximately 8.8 km (up to PK73), the Curonian Spit coast is reinforced with breakwaters of various purposes and types. Therefore, no shoreline changes are occurring in this section. It should be noted, however, that in certain locations along this stretch of the shoreline, where water from the Klaipėda Strait seeps through the embankment openings and washes away the soil, sinkholes are forming. It should be noted that some of them were filled in after 2018, but south of II Perkėla, three new ones are currently forming, with the following coordinates (LKS-94): 1 – 319701 6175761 (5 m x 1 m), 2 – 319712, 6175743 (5 m x 2 m), 3 – 319709, 6175478 (1 m x 1 m). The southernmost section of the pier (approximately 360 m long) was not fully completed (coordinates of the pier's end in LKS-94: 0319745, 6174630).

South of the breakwater, along a stretch of approximately 4.6 km along the shoreline (up to the Alksnynė station), there is a section of natural shoreline (Fig. 4.6.1.2). The beaches in this section are narrow and shallow. The beaches widen southward from 7–9 m in the northern part to 15–17 m in the southern part, and at Alksnynė, the beaches, overgrown with reeds, widen to 17–20 m. It should be noted that the position of the shoreline, and consequently the width and height of the beach in this section, vary considerably over time and space. The cause of these changes is frequent, sudden, and relatively large-amplitude fluctuations in water level. They are particularly significant during the

spring flood and ice drift: due to the spread of debris and reed fragments