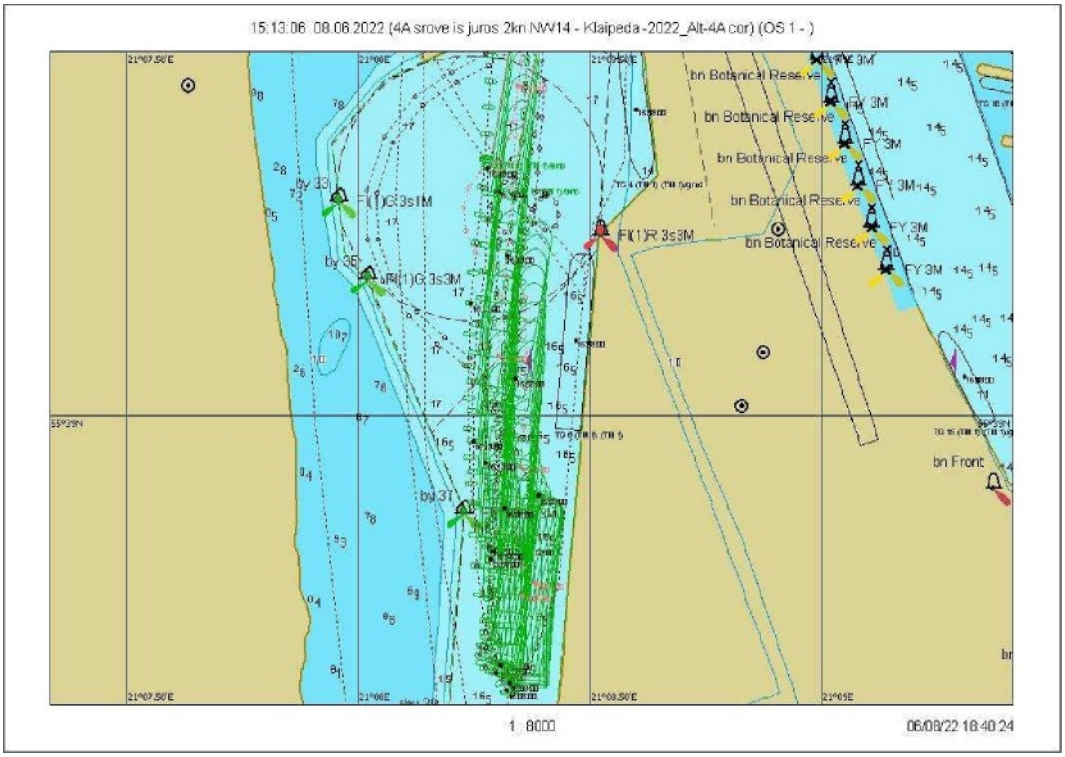
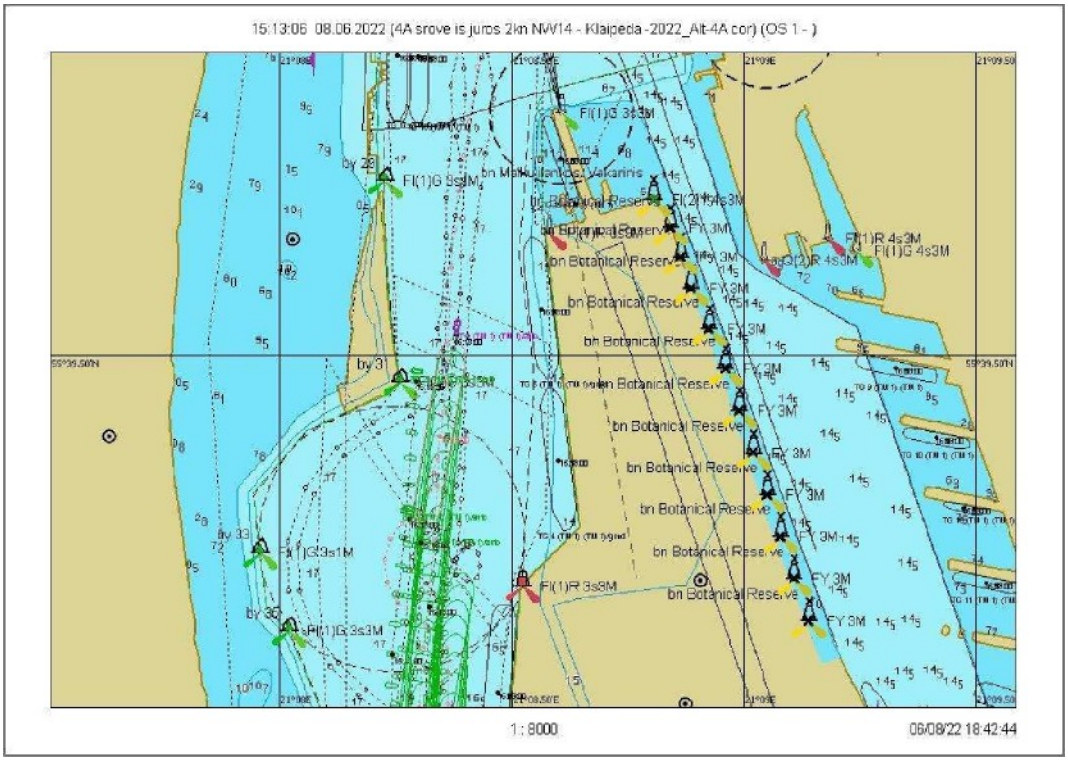


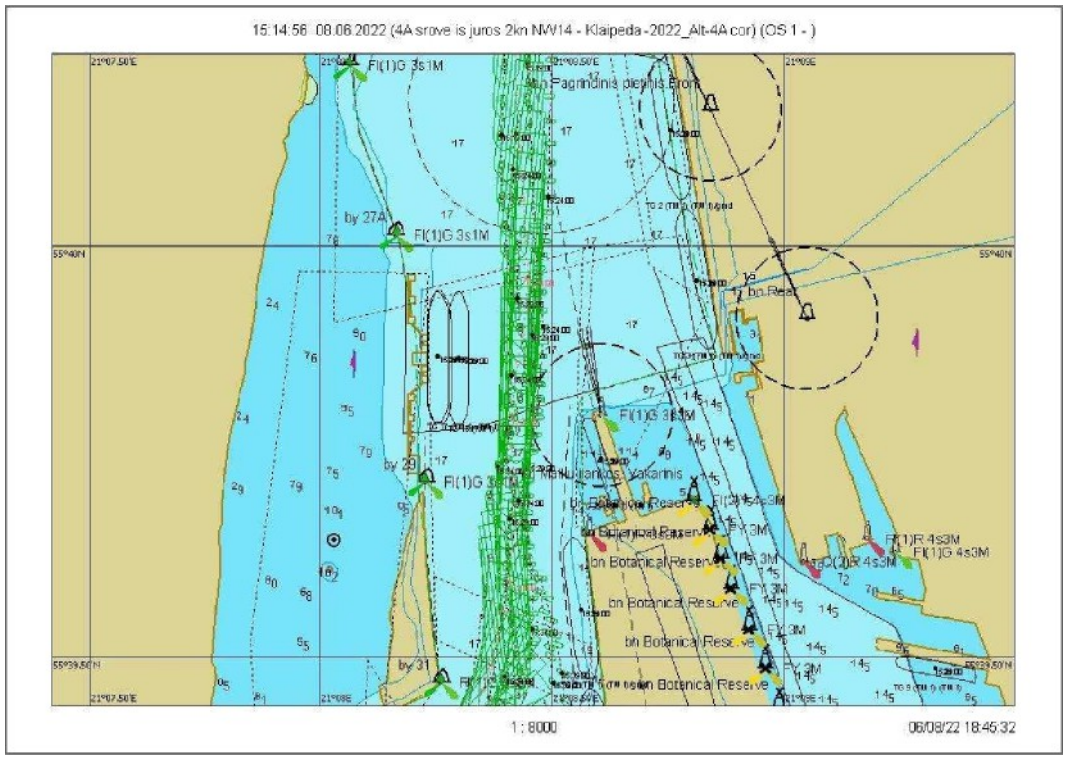
7.3.180 Fig. Course 24.2 — graphical representation of the course from the quay



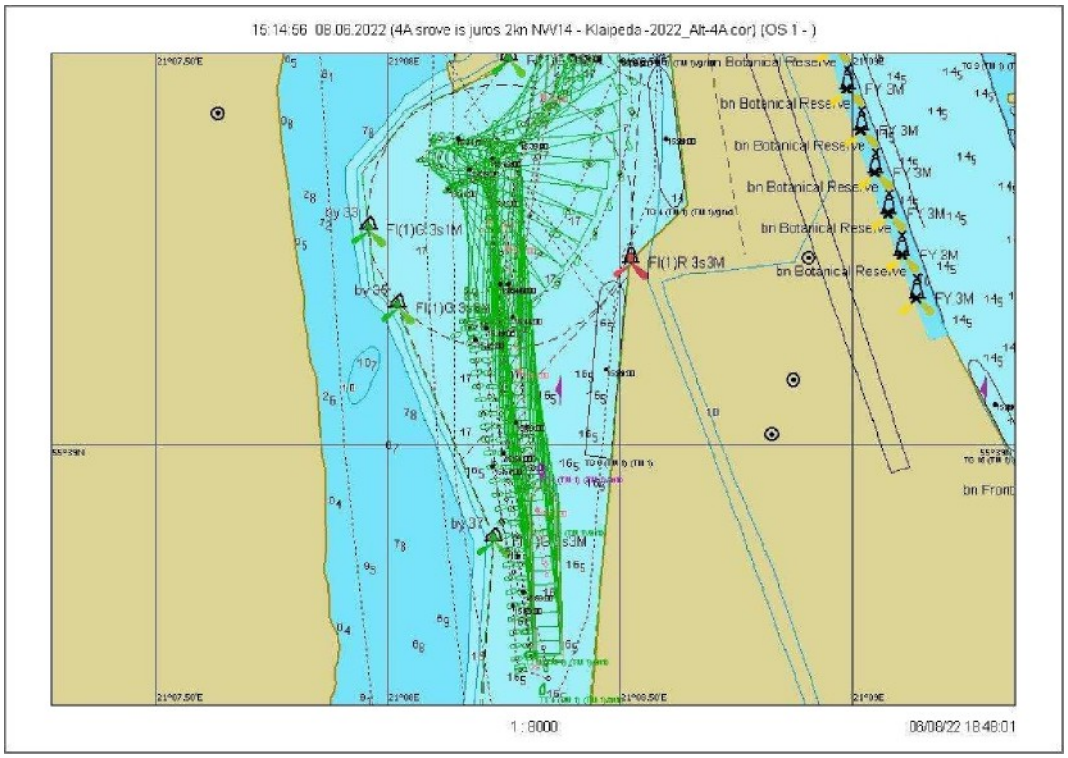
7.3.181 Fig. Sailing 24.2 — graphical representation of sailing from buoy No. 31 to No. 27A

Scenario 24. Wind NW/14 m/s, current from the shore at 2 knots

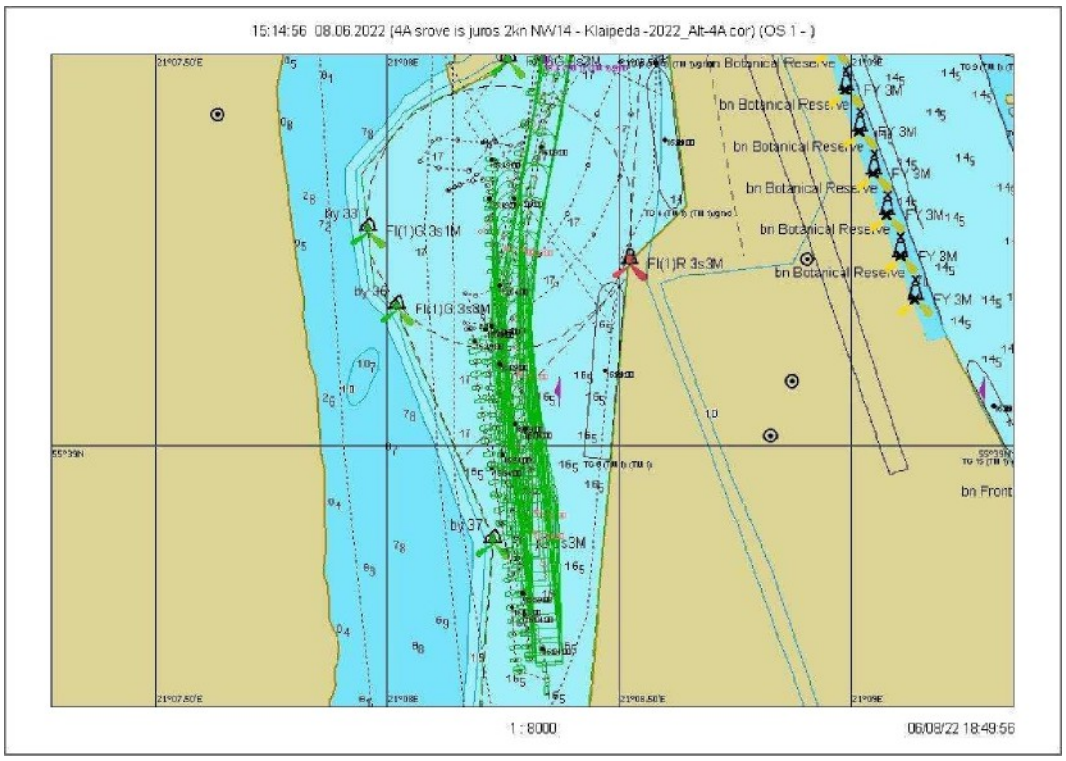
Voyage 24.3



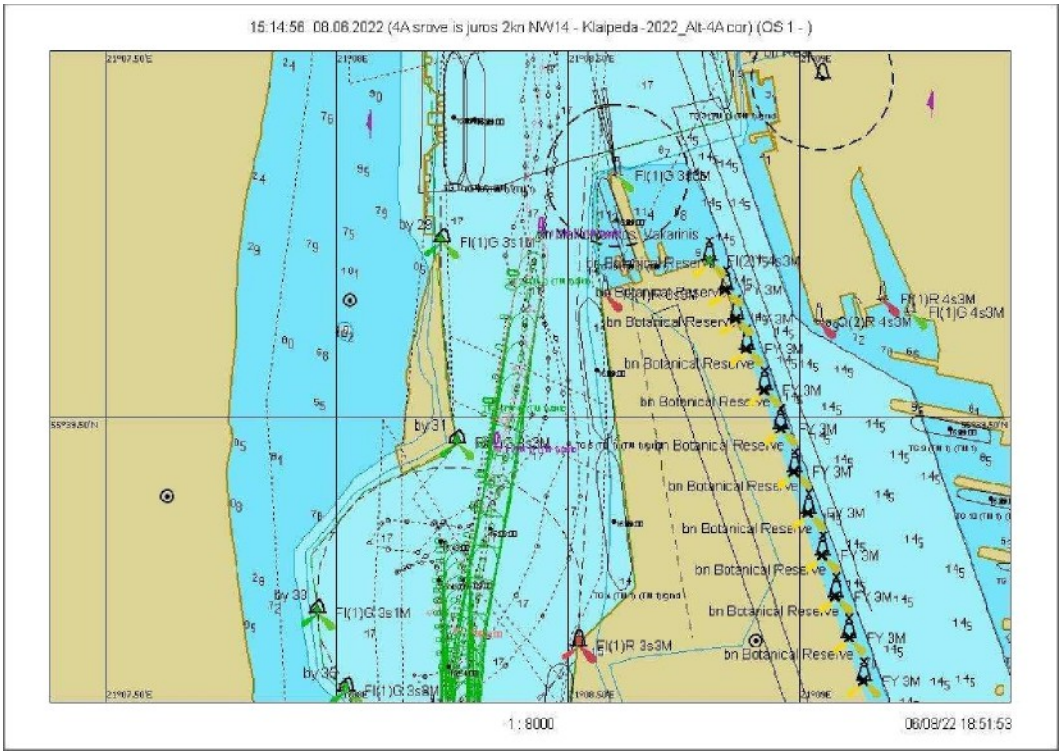
7.3.182 Fig. Voyage 24.3 — graphical representation of sailing from buoy No. 27A to No. 31



7.3.183 Fig. Course 24.3 - Ship's turning trajectory



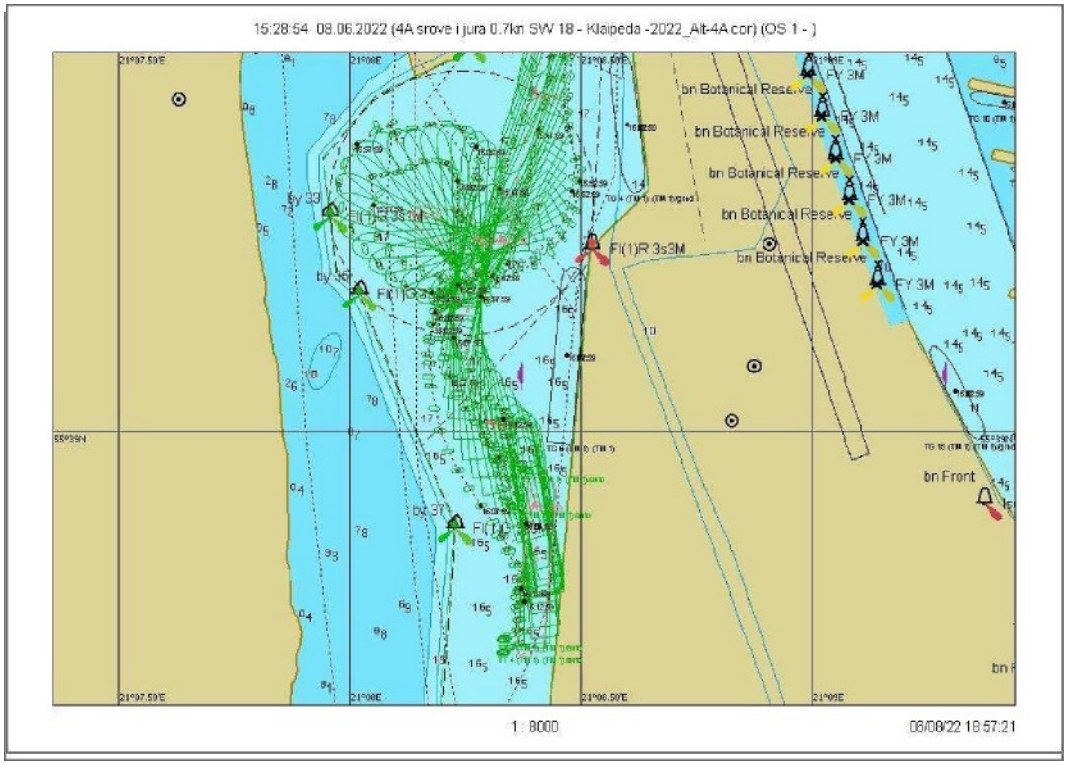
7.3.184 Fig. Course 24.3 — graphical representation of departure from the quay



7.3.185 Fig. Voyage 24.3 - graphical representation of the voyage from buoy No. 31 to No. 27A

Scenario 25. Wind SW/18 m/s, current 0.7 knots Voyage 25.1

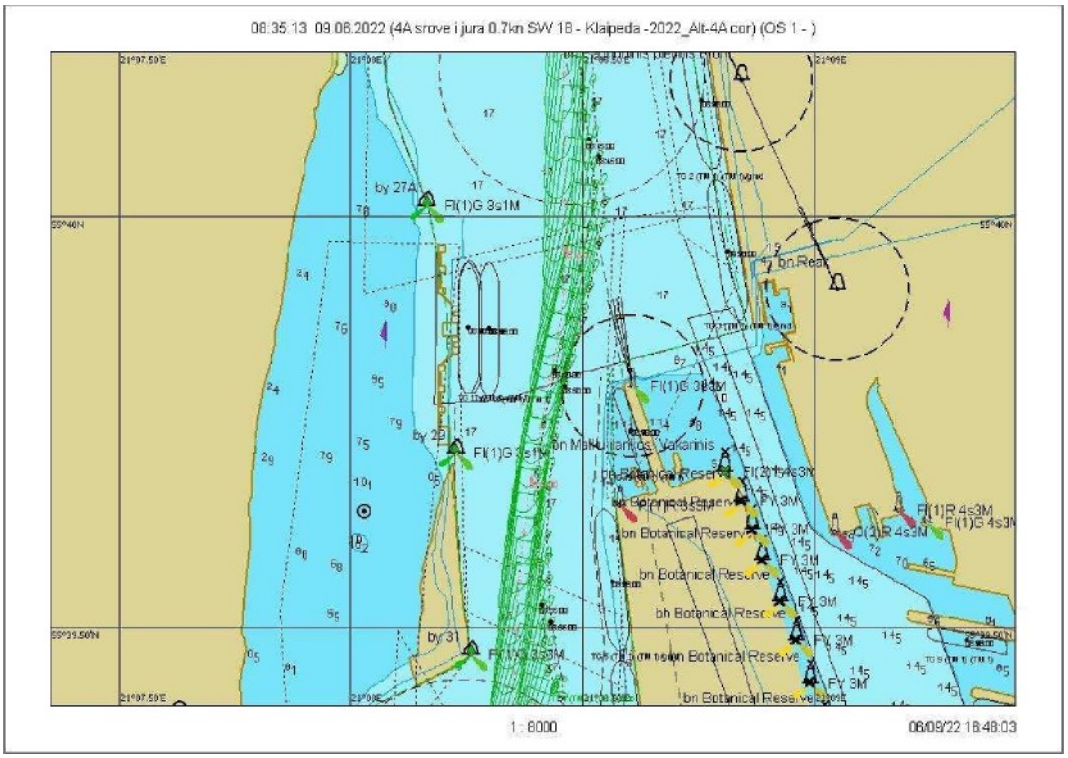
7.3.186 Fig. Voyage 25.1 — graphical representation of sailing from buoy No. 27A to No. 31



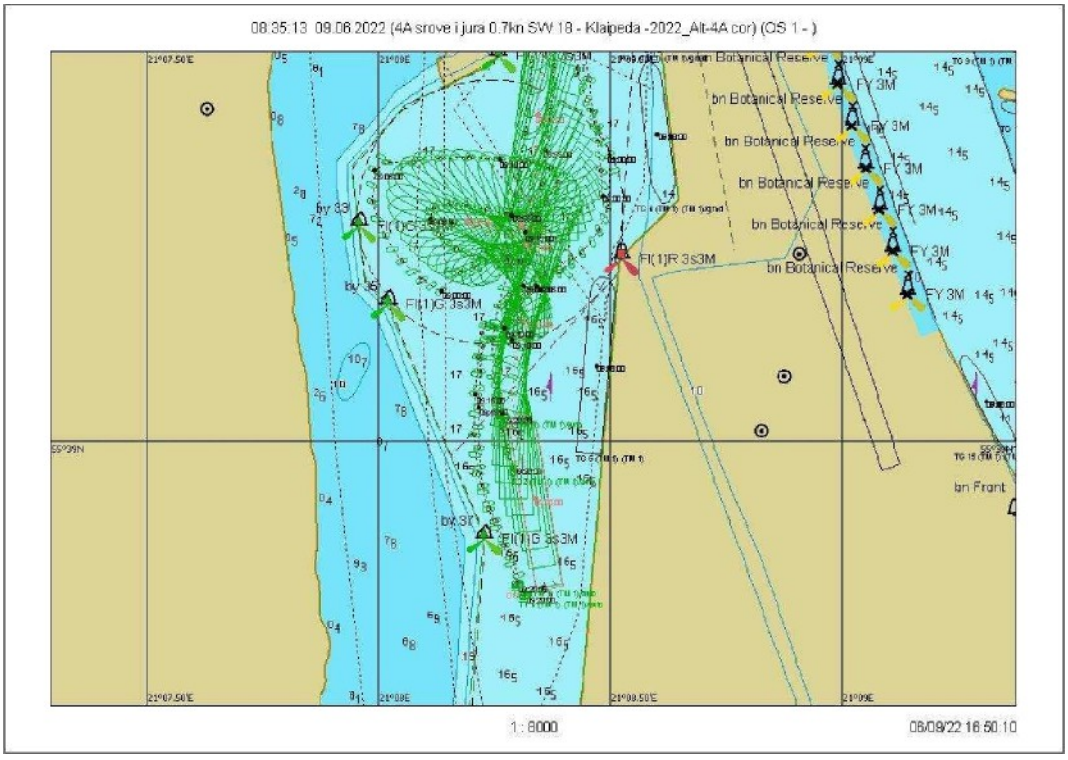
7.3.187 Fig. Course 25.1 – Ship's turning trajectory

Scenario 25. Wind SW/18 m/s, current toward the shore 0.7 knots.

Voyage 25.2



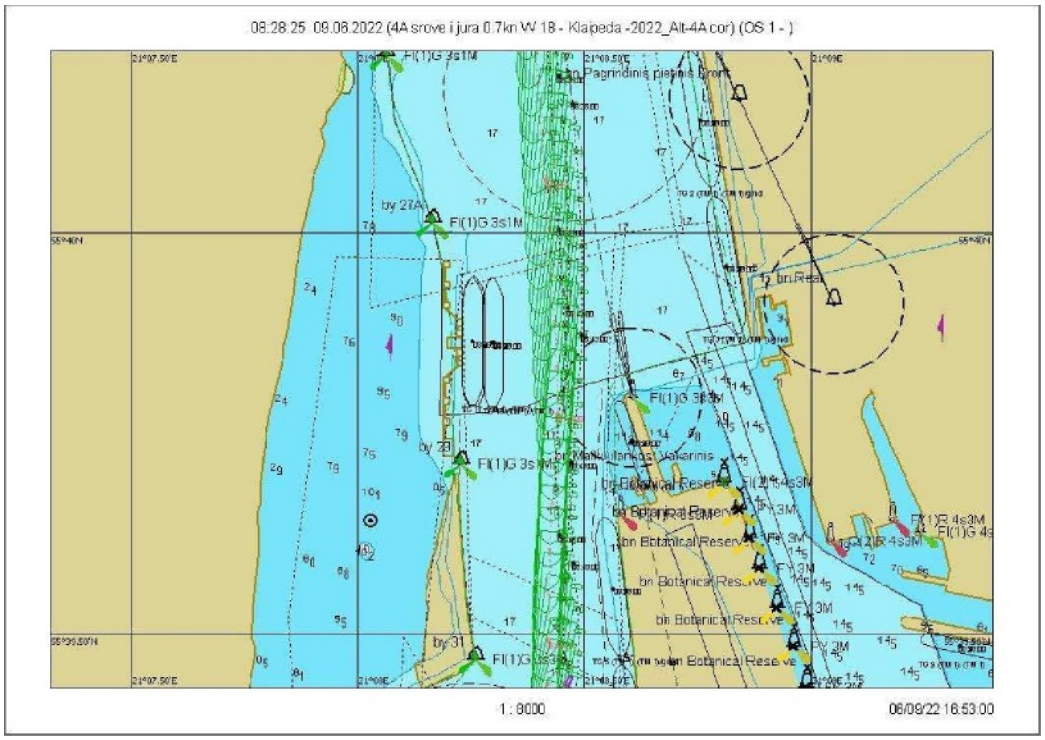
7.3.188 Fig. Course 25.2 – graphical representation of the course from buoy No. 27A to No. 31



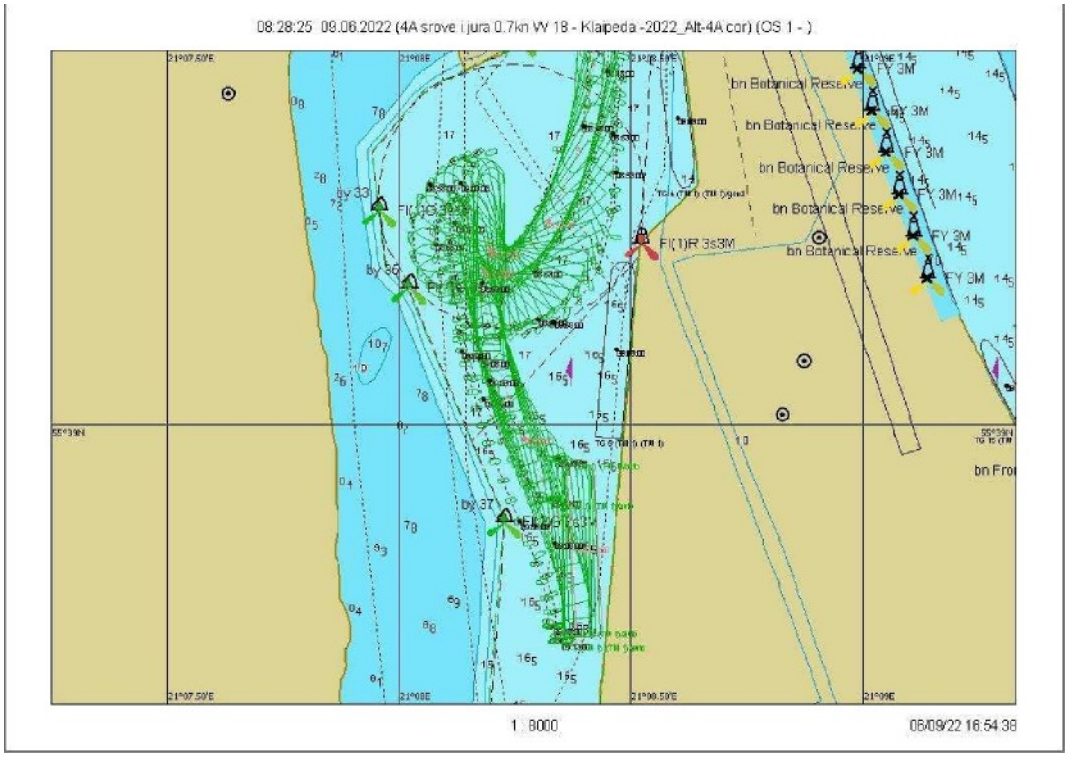
7.3.189 Fig. Voyage 25.2 – Ship's turning trajectory

Scenario 26. Wind W/18 m/s, current toward the shore 0.7 knots

Course 26.1

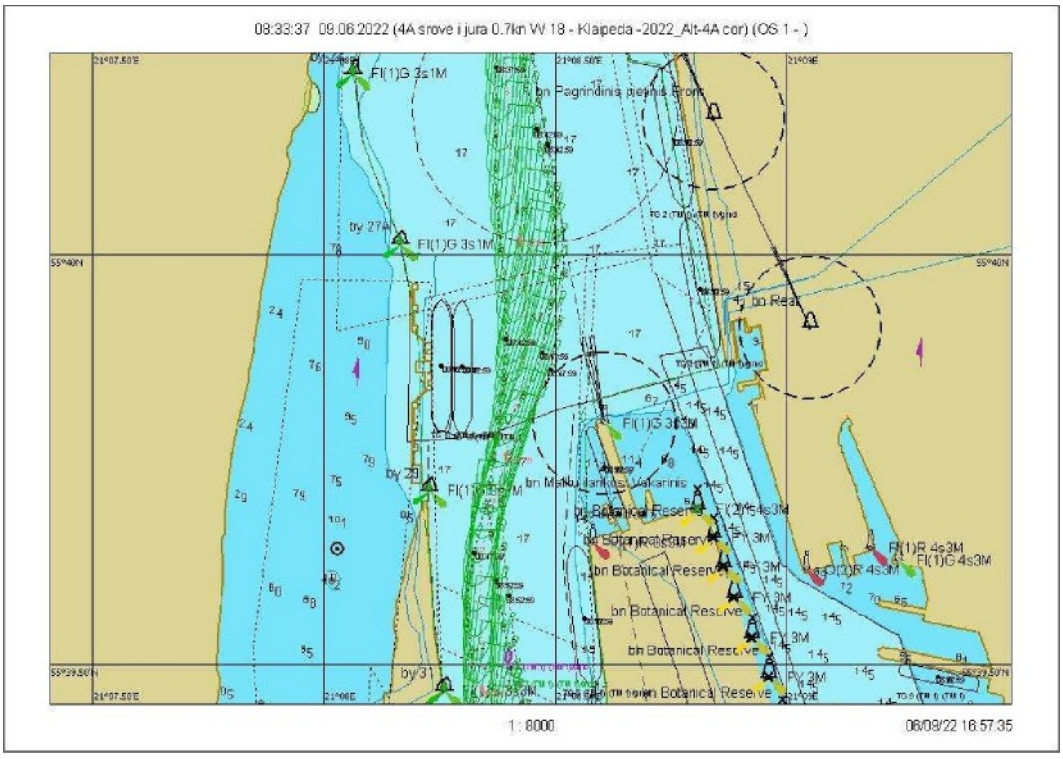


7.3.190 Fig. Course 26.1 – graphical representation of the course from buoy No. 27A to No. 31

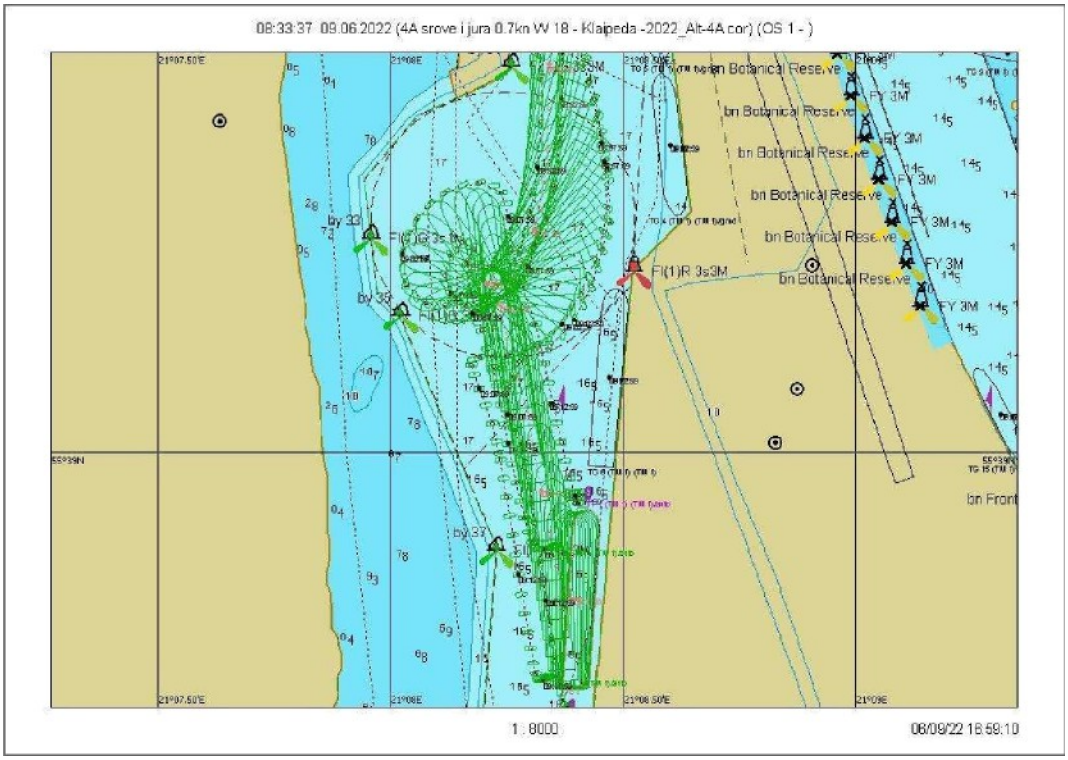


7.3.191 Fig. Voyage 26.1 – Ship's turning trajectory

Scenario 26. Wind W/18 m/s, current j 0.7 knots Course 26.2

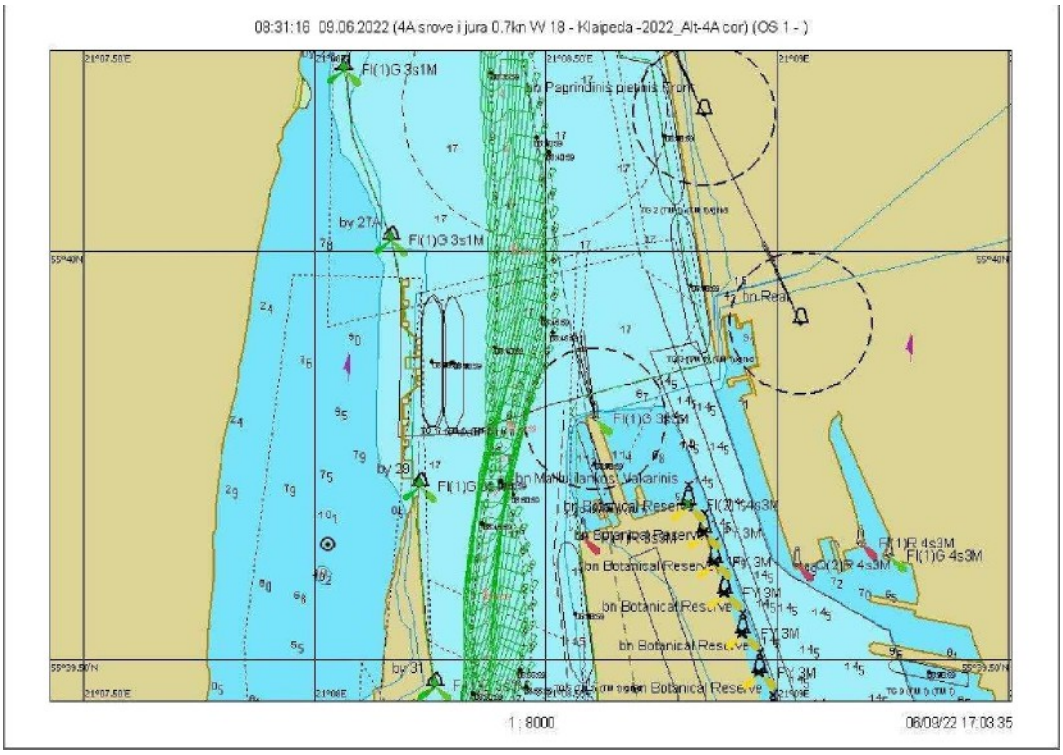


7.3.192 Fig. Course 26.2 – graphical representation of the course from buoy No. 27A to No. 31

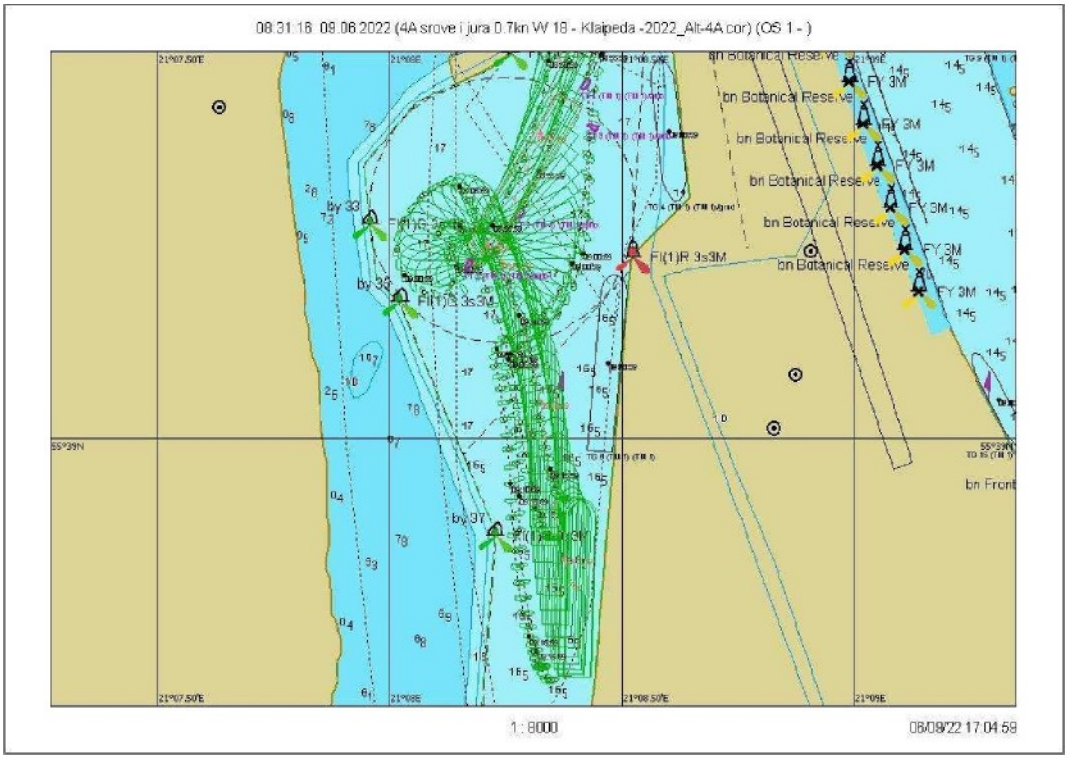


7.3.193 Fig. Voyage 26.2 – Ship's turning trajectory

Scenario 26. Wind W/18 m/s, current j 0.7 knots. Course 26.3

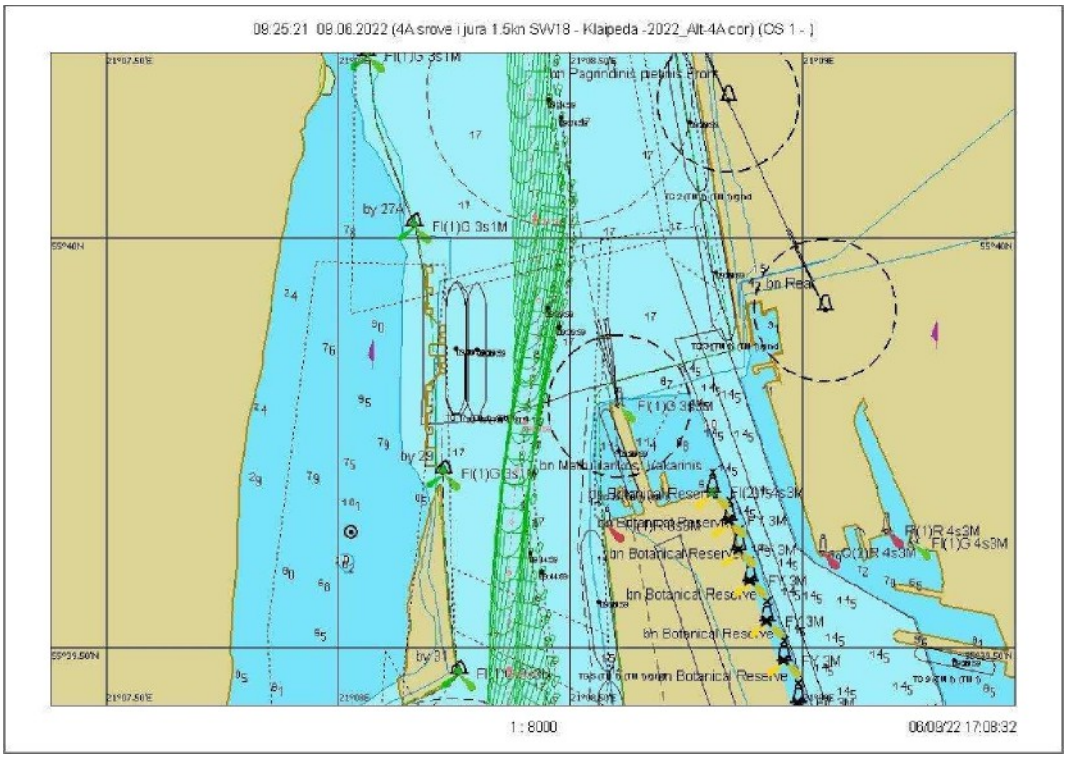


7.3.194 Fig. Course 26.3 – graphical representation of the course from buoy No. 27A to No. 31

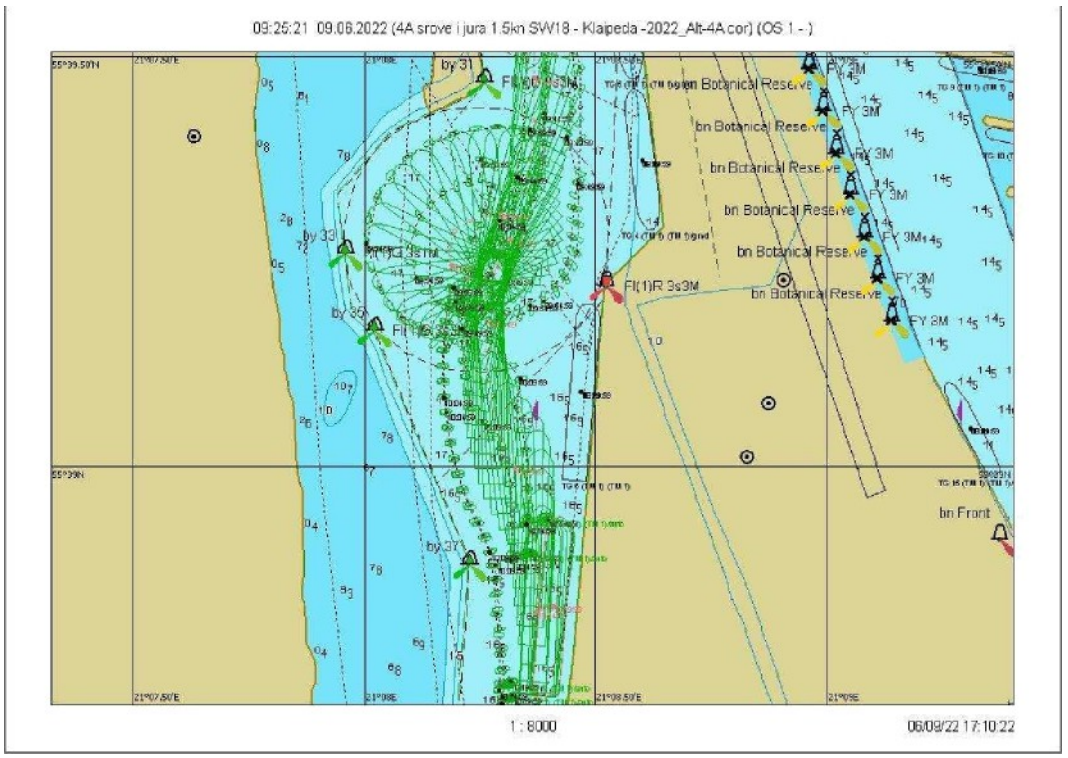


7.3.195 Fig. Voyage 26.3 – Ship's turning trajectory

Scenario 27. Wind SW/18 m/s, current 1.5 knots Voyage 27.1



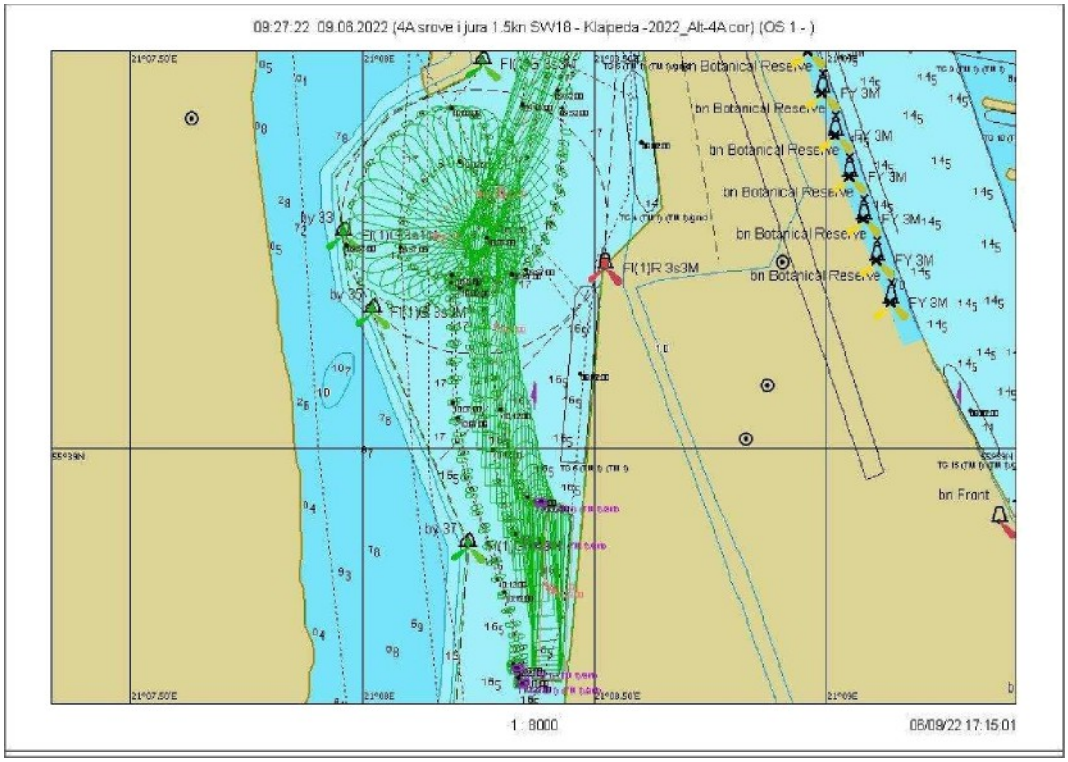
7.3.196 Fig. Course 27.1 – graphical representation of the course from buoy No. 27A to No. 31



7.3.197 Fig. Voyage 27.1 – Ship's turning trajectory

Scenario 27. Wind SW/18 m/s, current 1.5 knots. Course 27.2

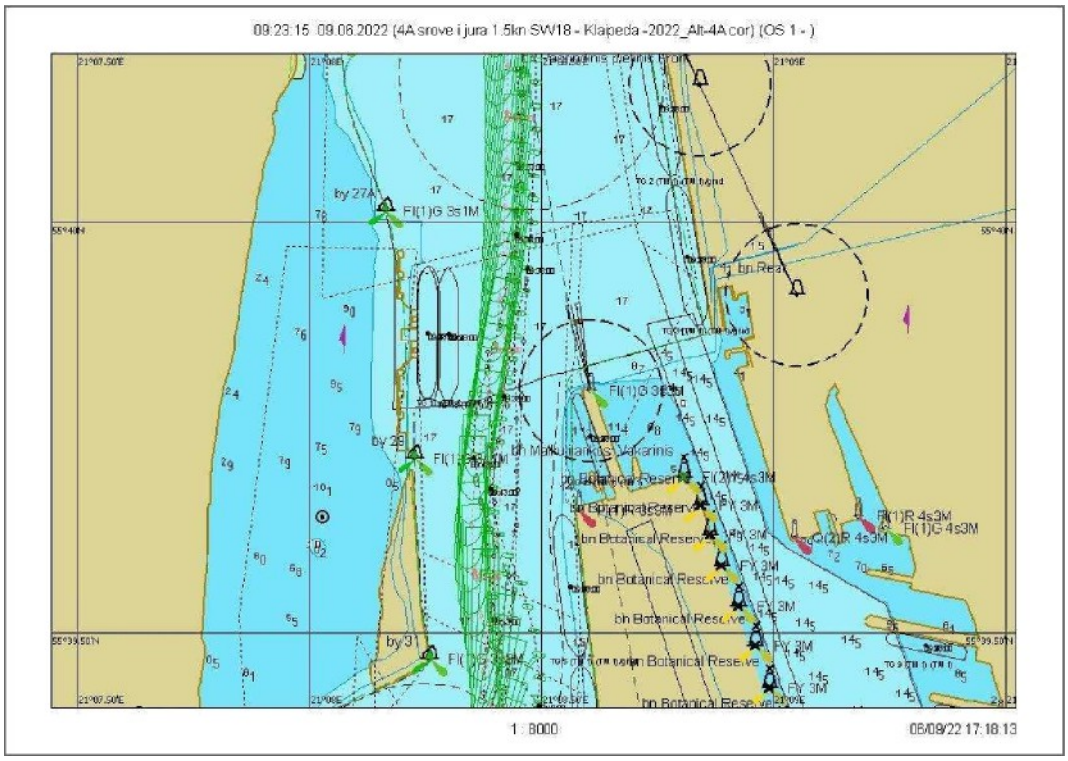
7.3.198 Fig. Course 27.2 – graphical representation of the course from buoy No. 27A to No. 31



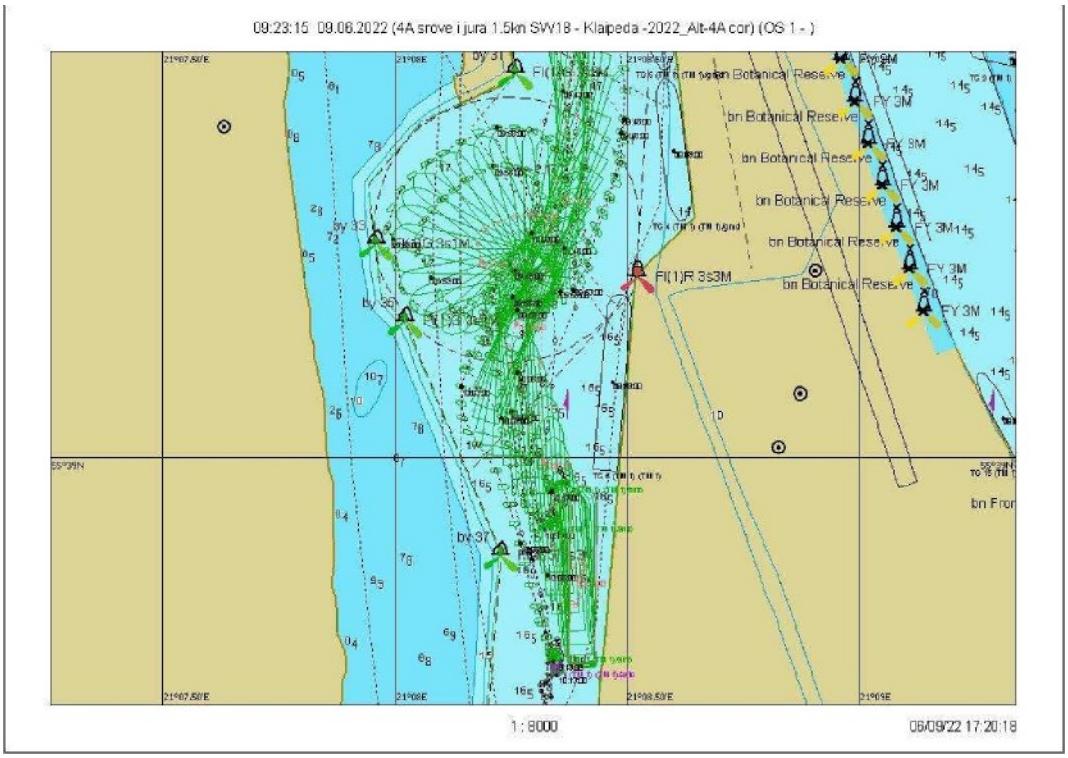
7.3.199 Fig. Voyage 27.2 – Ship's turning trajectory

Scenario 27. Wind SW/18 m/s, current toward the shore 1.5 knots

Course 27.3

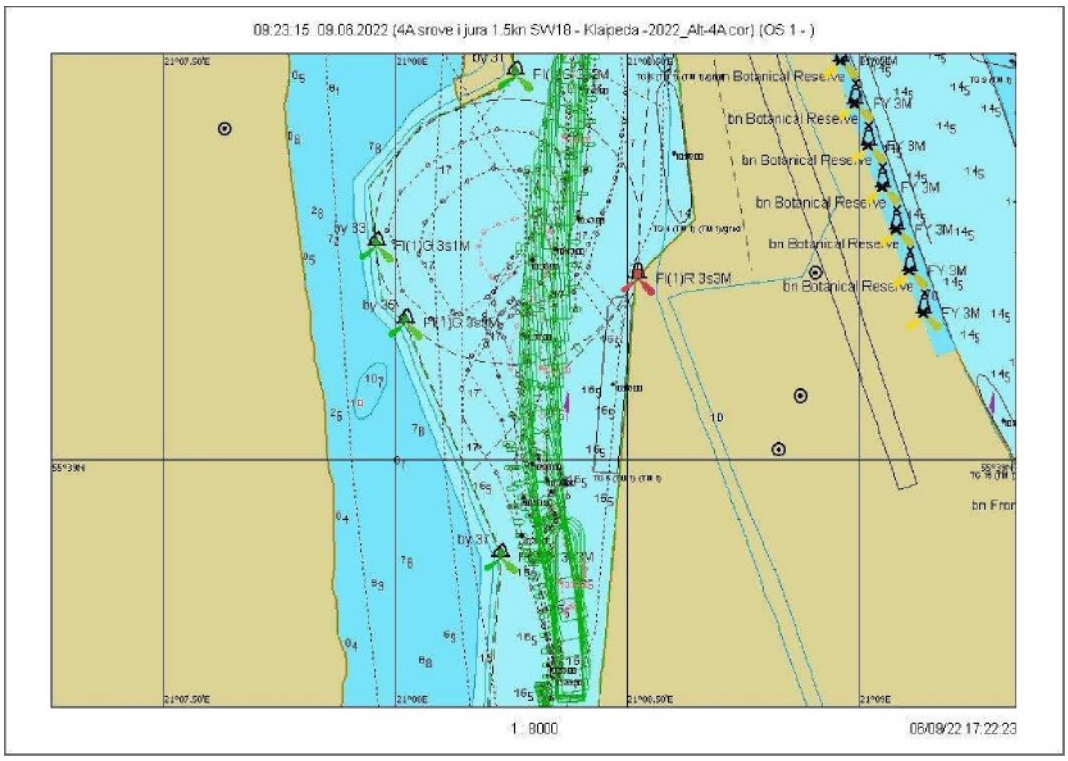


7.3.200 Fig. Course 27.3 – graphical representation of the course from buoy No. 27A to No. 31

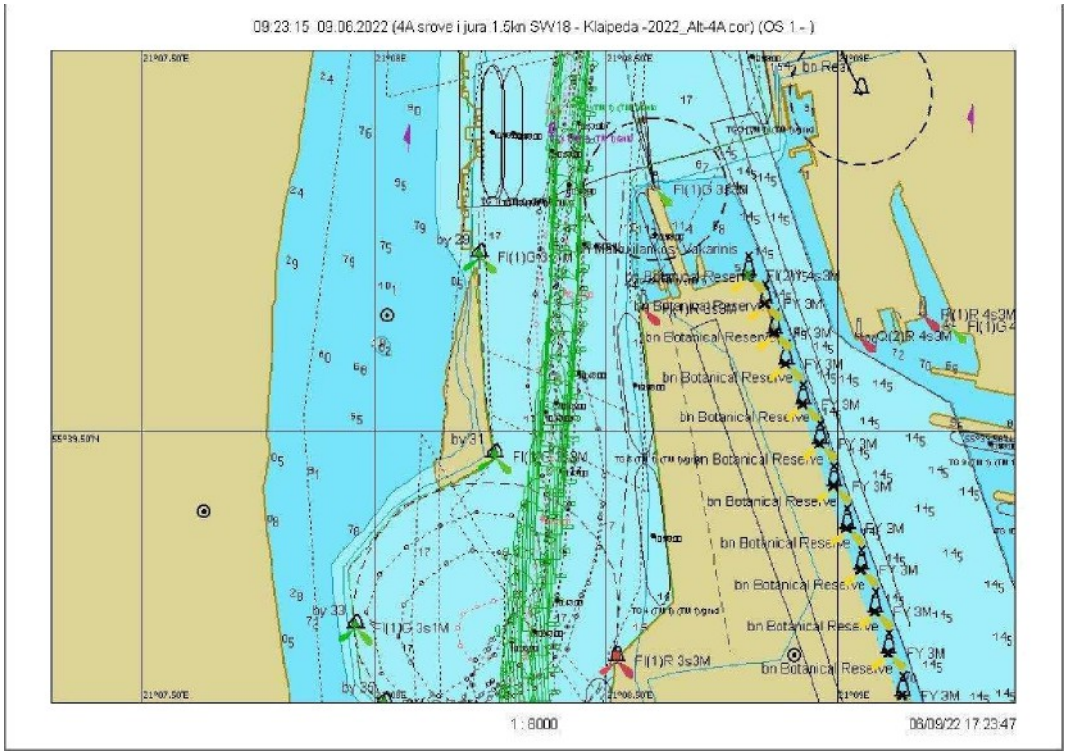


7.3.201 Fig. Voyage 27.3 – Ship's turning trajectory

Course 27.3

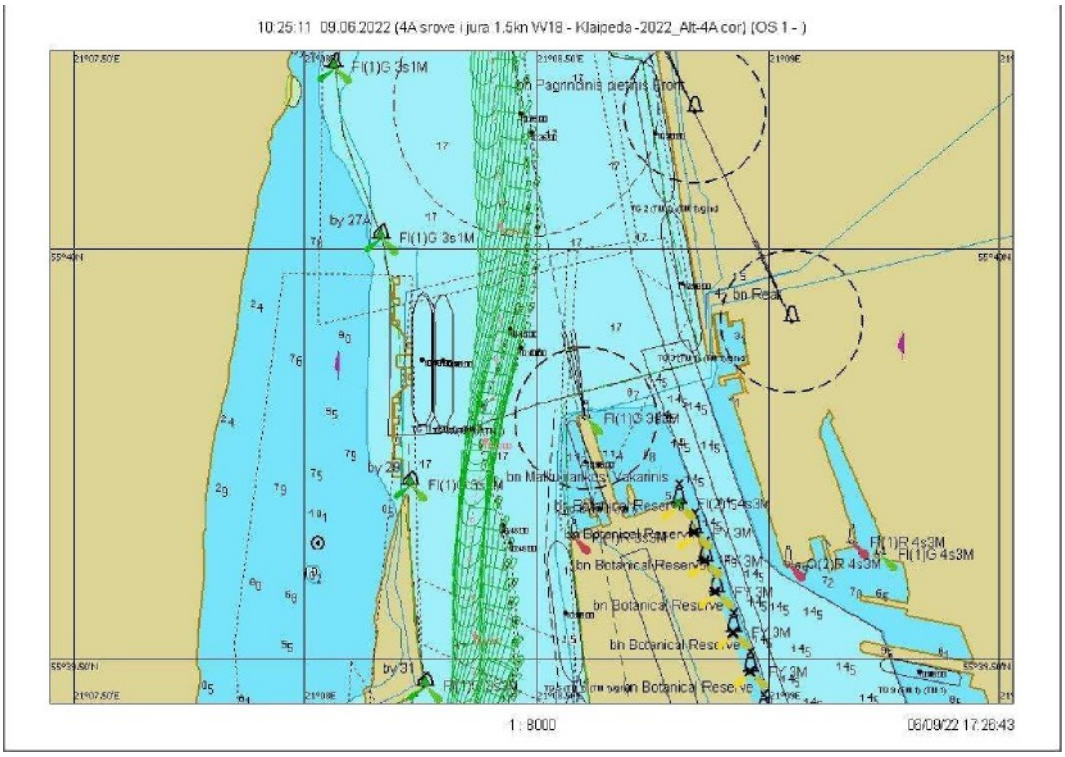


7.3.202 Fig. Course 27.3 — graphical representation of departure from the quay

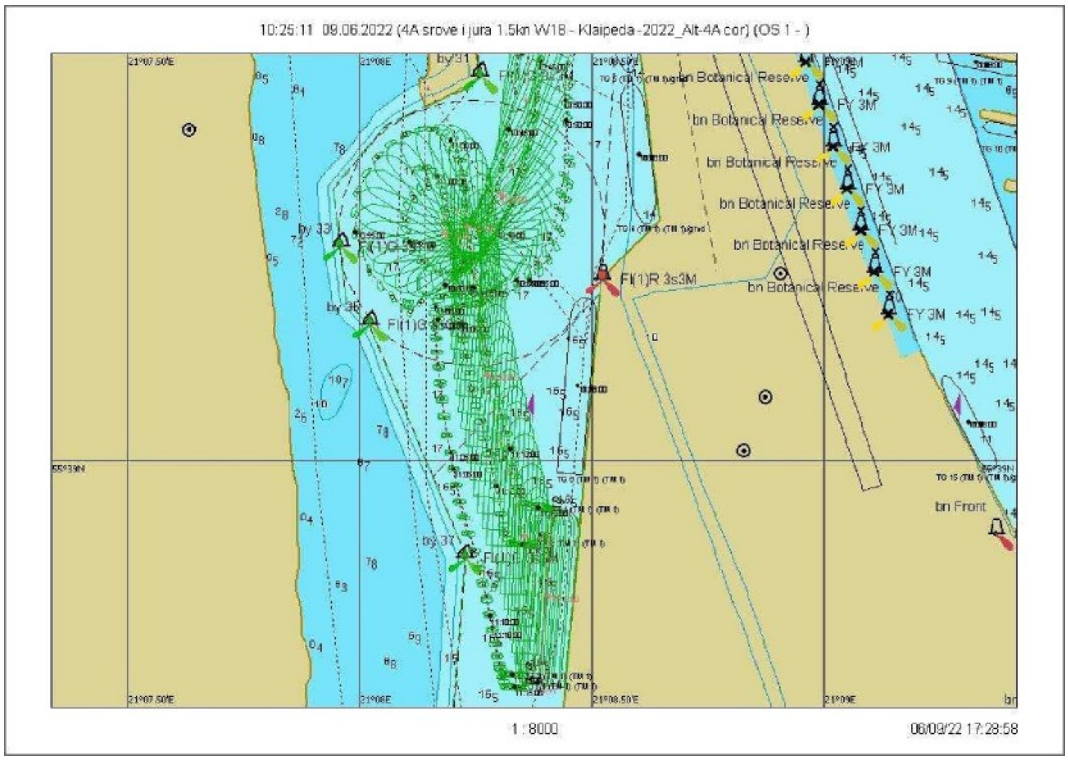


7.3.203 Fig. Voyage 27.3 – graphical representation of the voyage from buoy No. 31 to No. 27A

Scenario 28. Wind W/18 m/s, current 1.5 knots Course 28.1

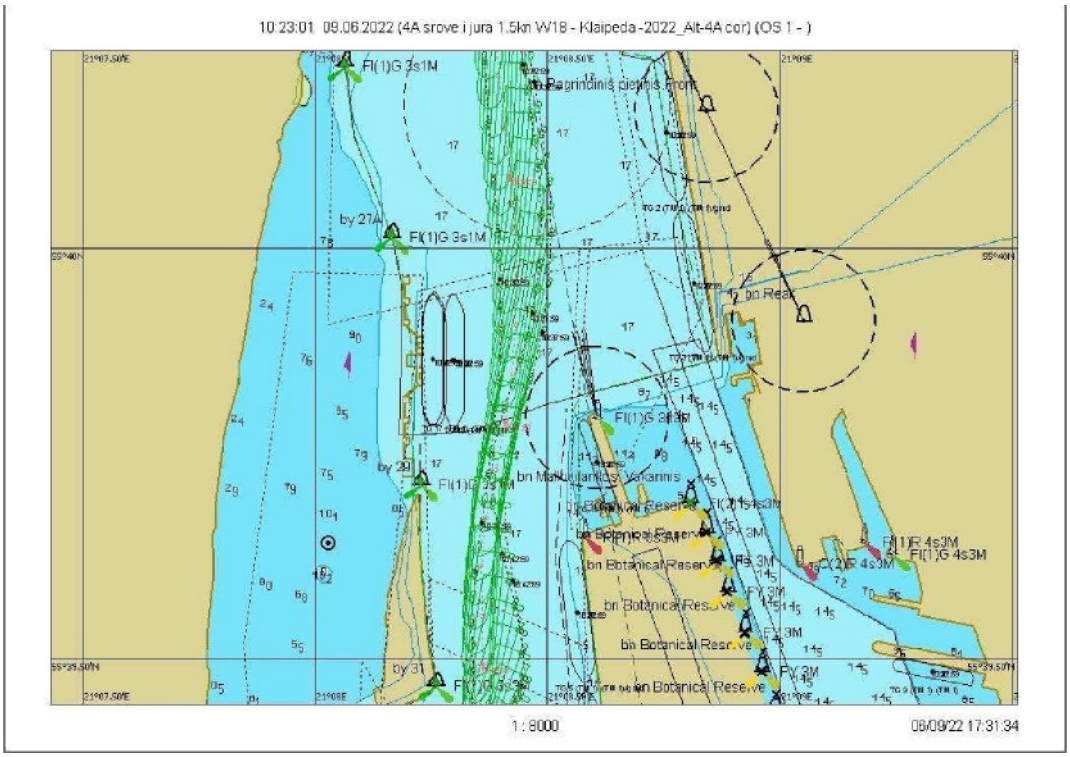


7.3.204 Fig. Sailing 28.1 — graphical representation of sailing from buoy No. 27A to No. 31

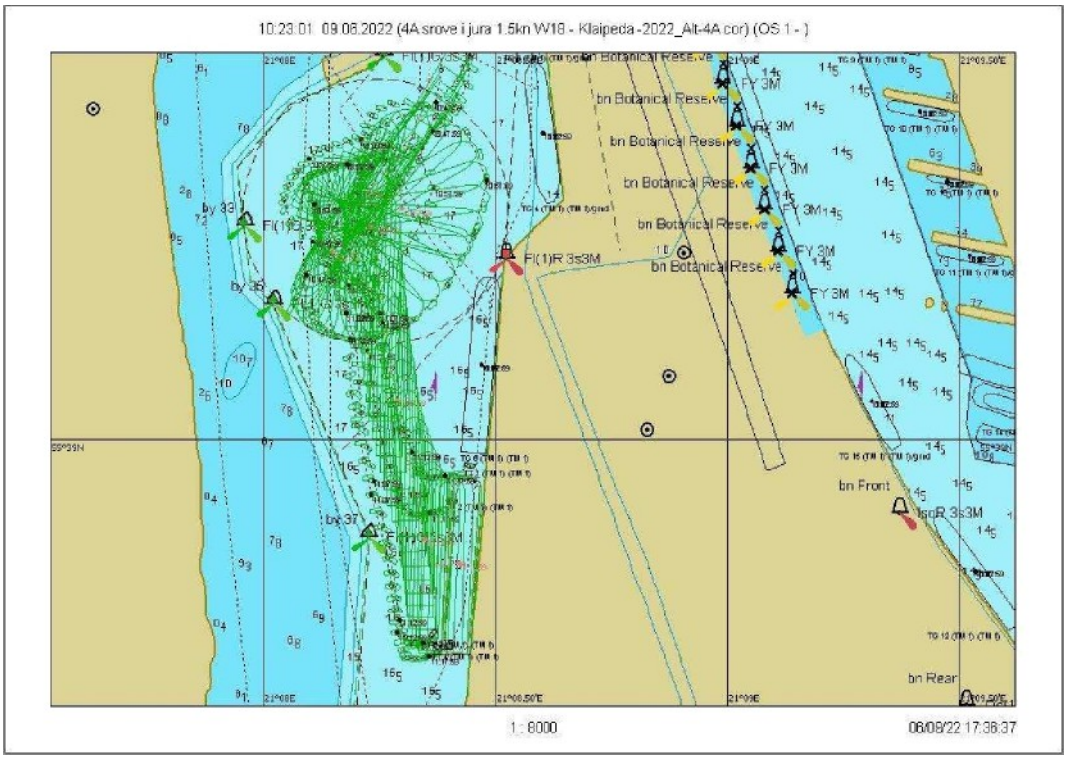


7.3.205 Fig. Course 28.1 - Ship turning trajectory

Scenario 28. Wind W/18 m/s, current 1.5 knots. Course 28.2

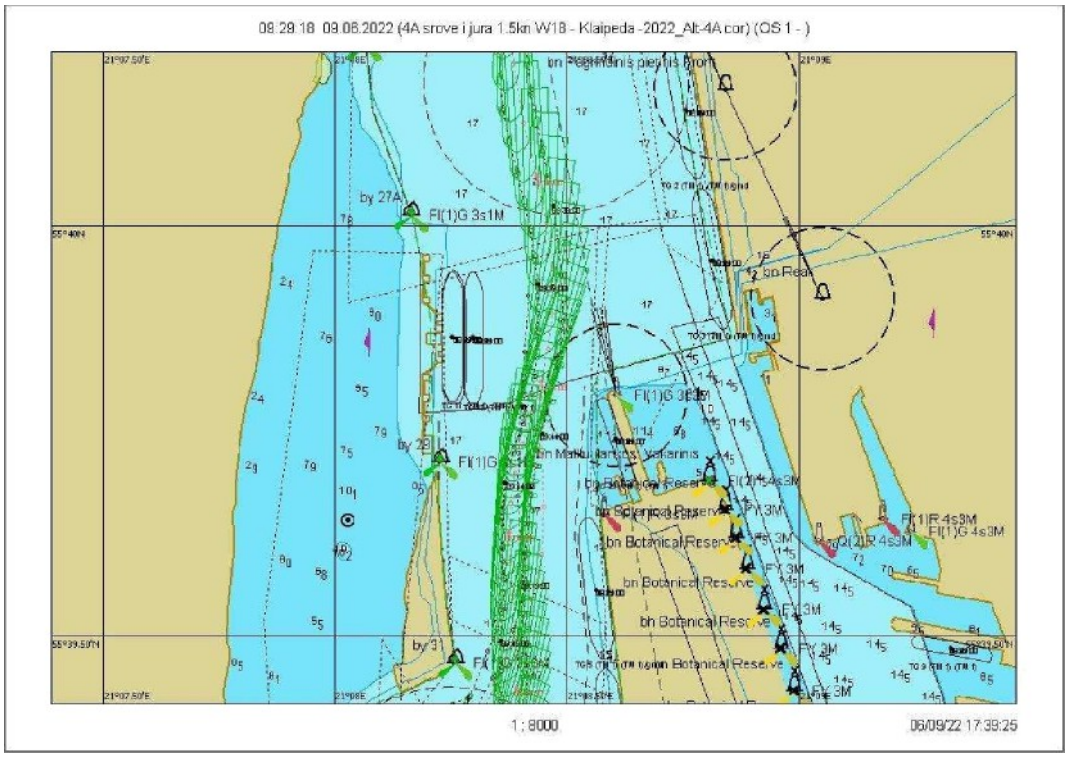


7.3.206 Fig. Course 28.2 – graphical representation of the course from buoy No. 27A to No. 31

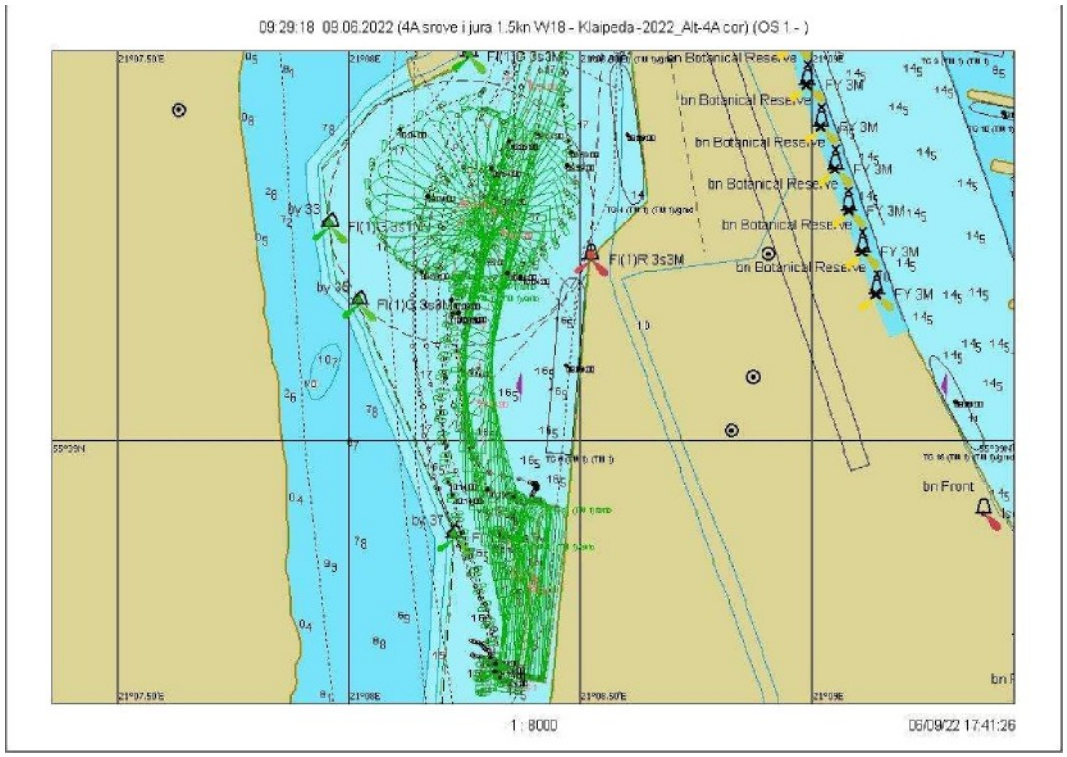


7.3.207 Fig. Voyage 28.2 – Ship's turning trajectory

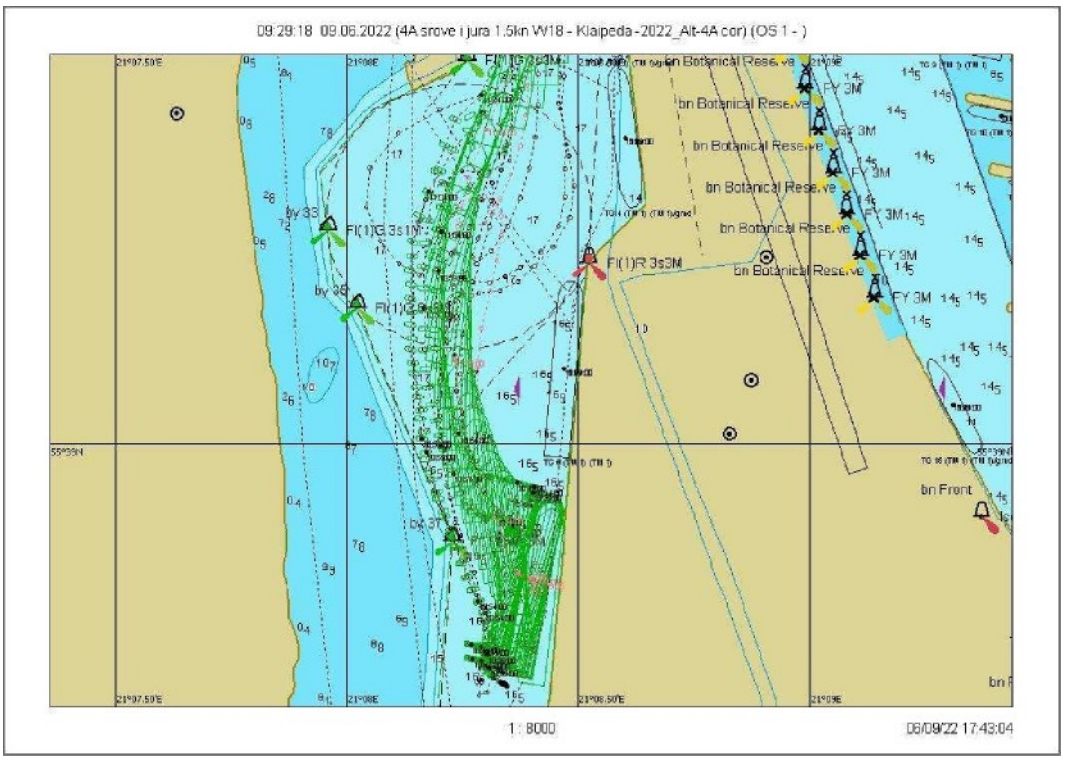
Scenario 28. Wind W/18 m/s, current j 1.5 knots Course 28.3



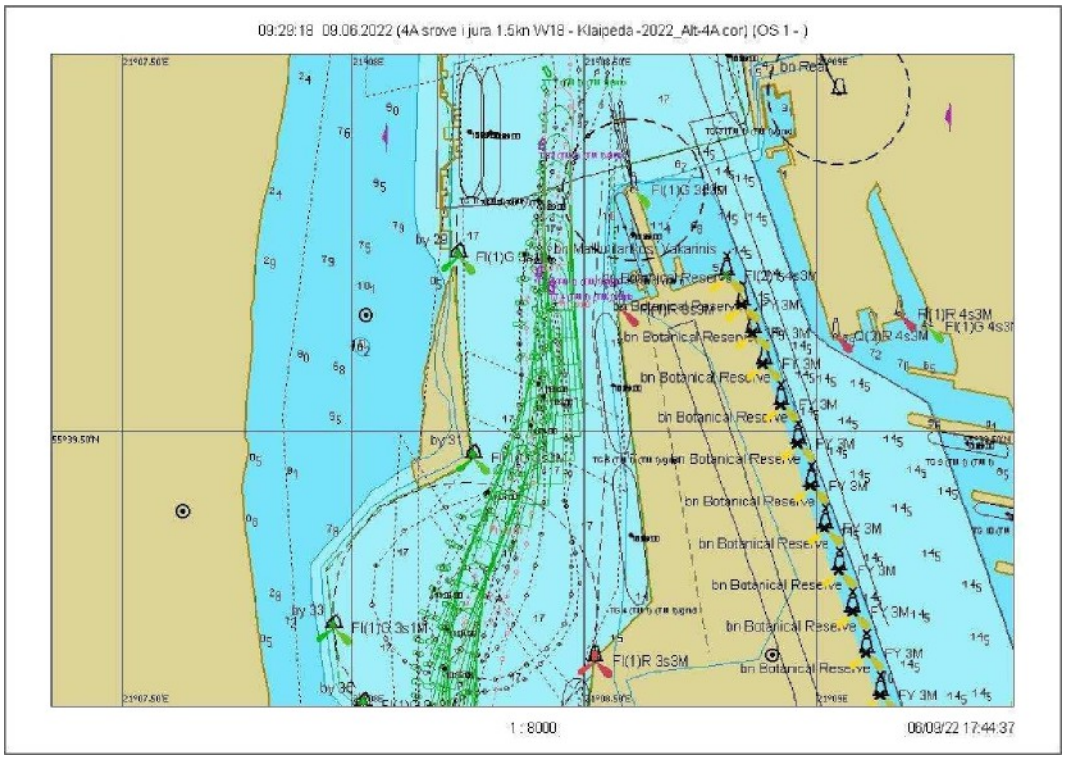
7.3.208 Fig. Course 28.3 – graphical representation of the course from buoy No. 27A to No. 31



7.3.209 Fig. Voyage 28.3 - Ship's turning trajectory

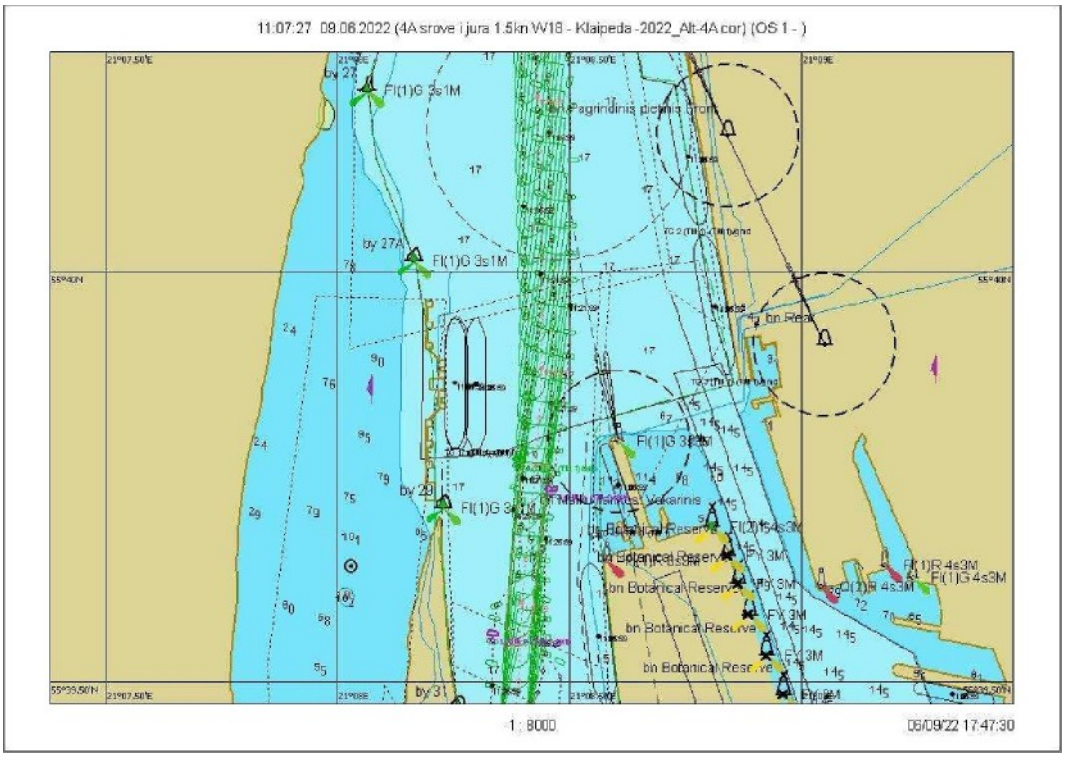


7.3.210 Fig. Voyage 28.3 — graphical representation of departure from the quay

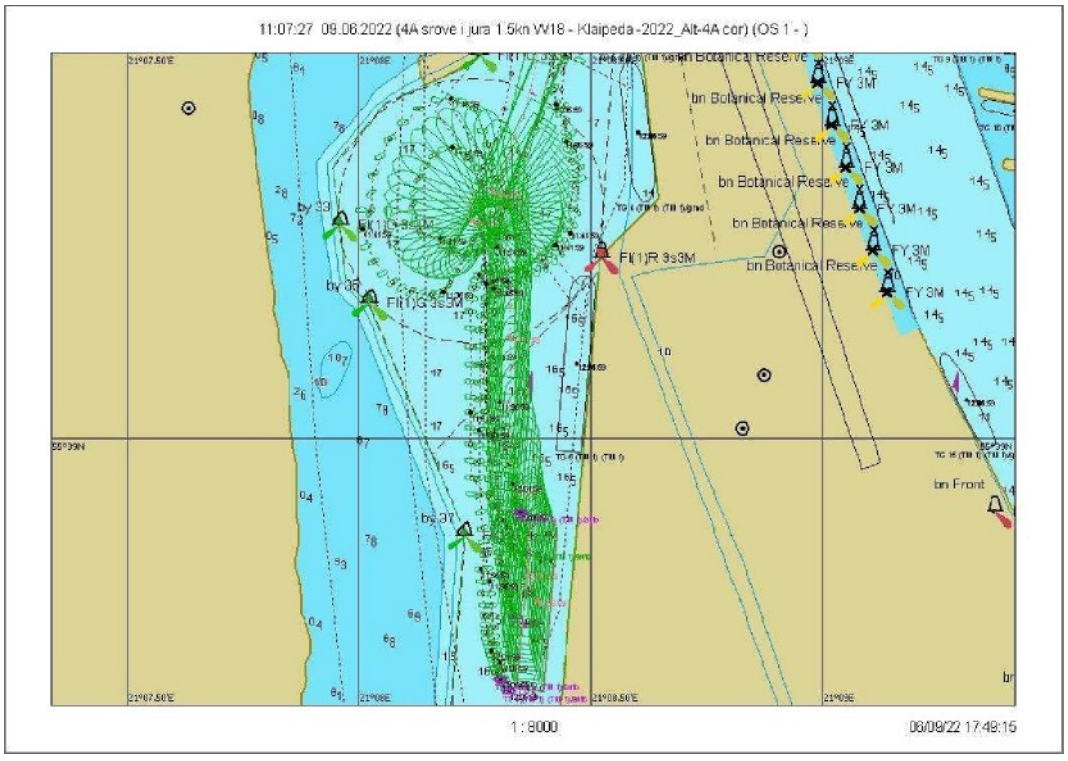


7.3.211 Fig. Voyage 28.3 - graphical representation of the voyage from buoy No. 31 to No. 27A

Scenario 28. Wind W/18 m/s, current 1.5 knots Voyage 28.4



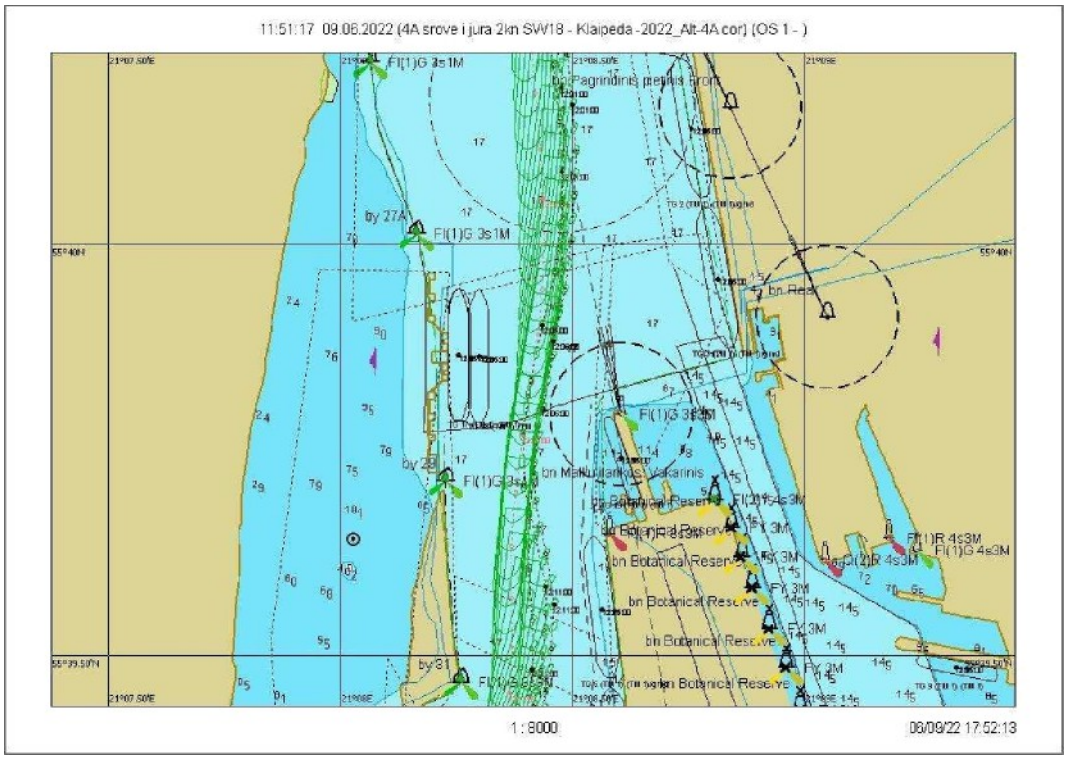
7.3.212 Fig. Voyage 28.4 — graphical representation of sailing from buoy No. 27A to No. 31



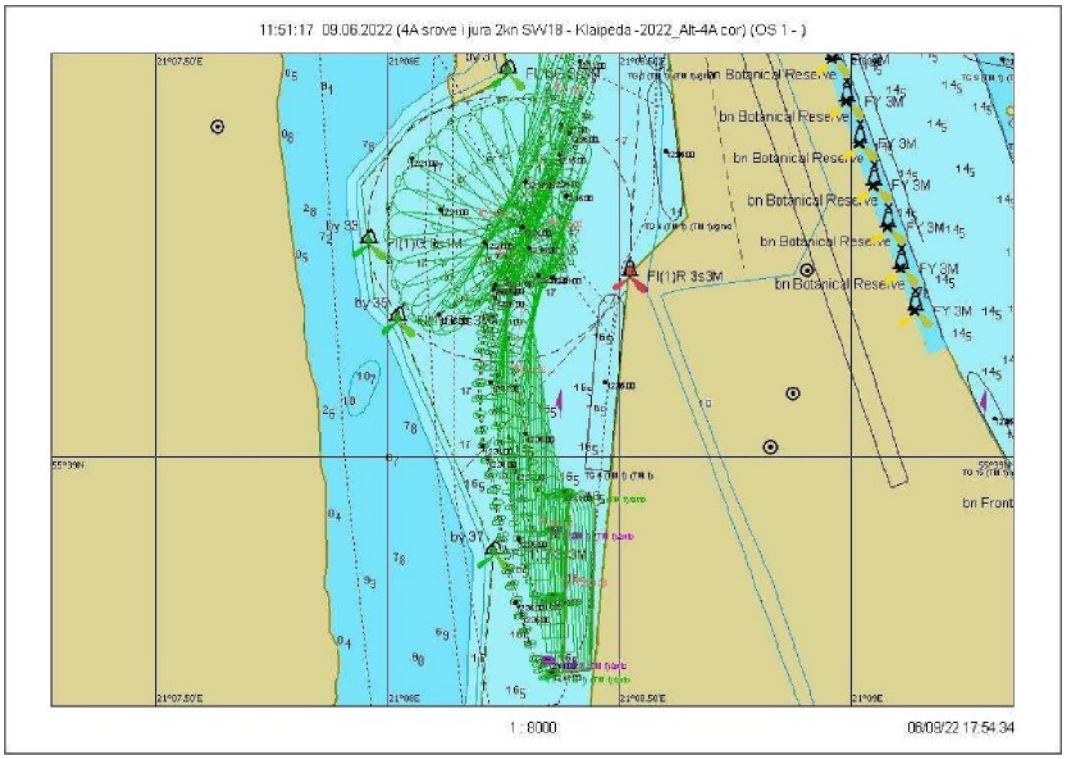
7.3.213 Fig. Course 28.4 – Ship's turning trajectory

Scenario 29. Wind SW/18 m/s, current toward the shore 2 knots

Voyage 29.1

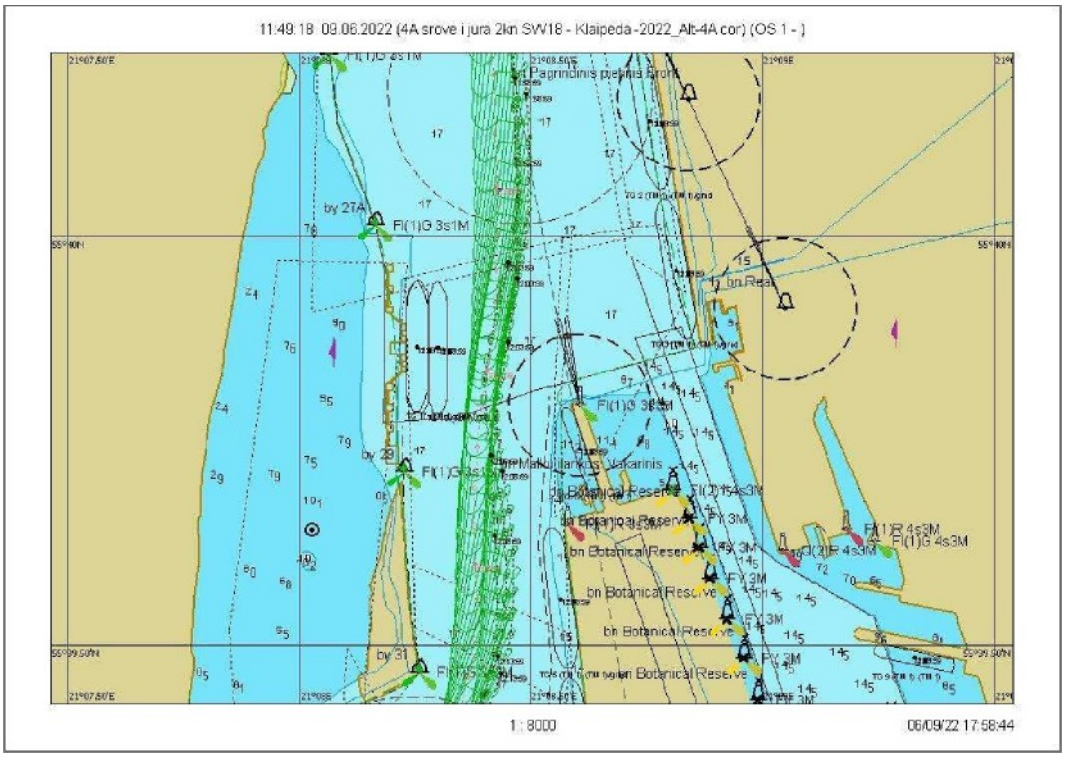


7.3.214 Fig. Course 29.1 – graphical representation of the course from buoy No. 27A to No. 31

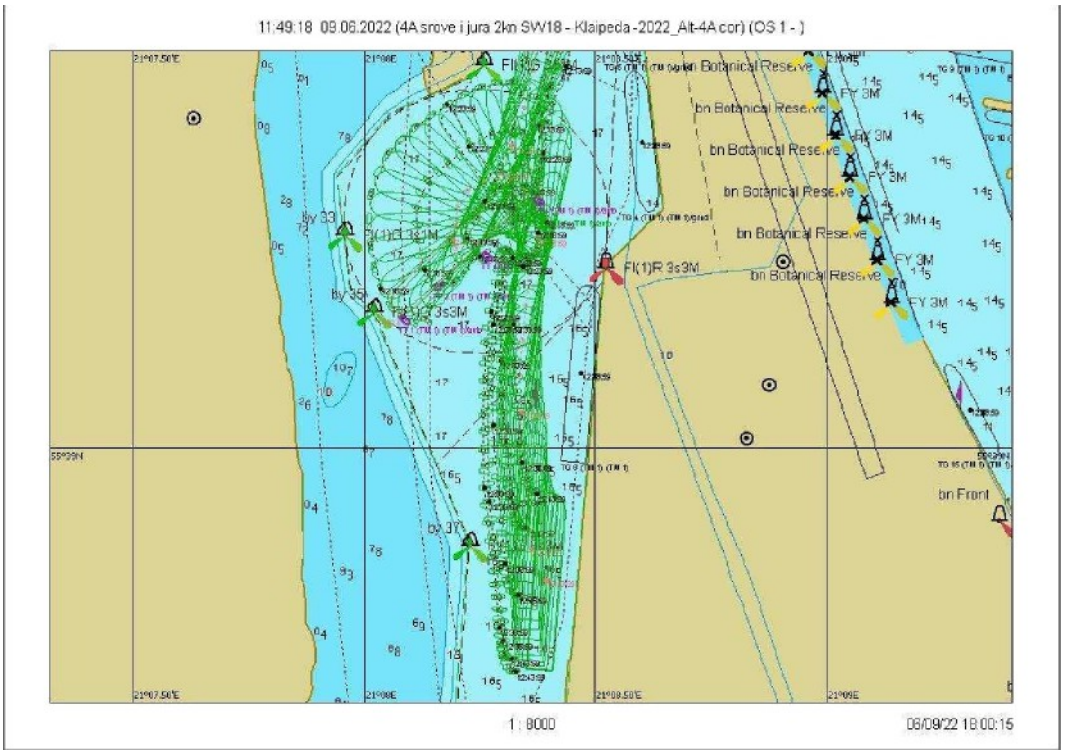


7.3.215 Fig. Course 29.1 – Ship's turning trajectory

Scenario 29. Wind SW/18 m/s, current 2 knots Course 29.2

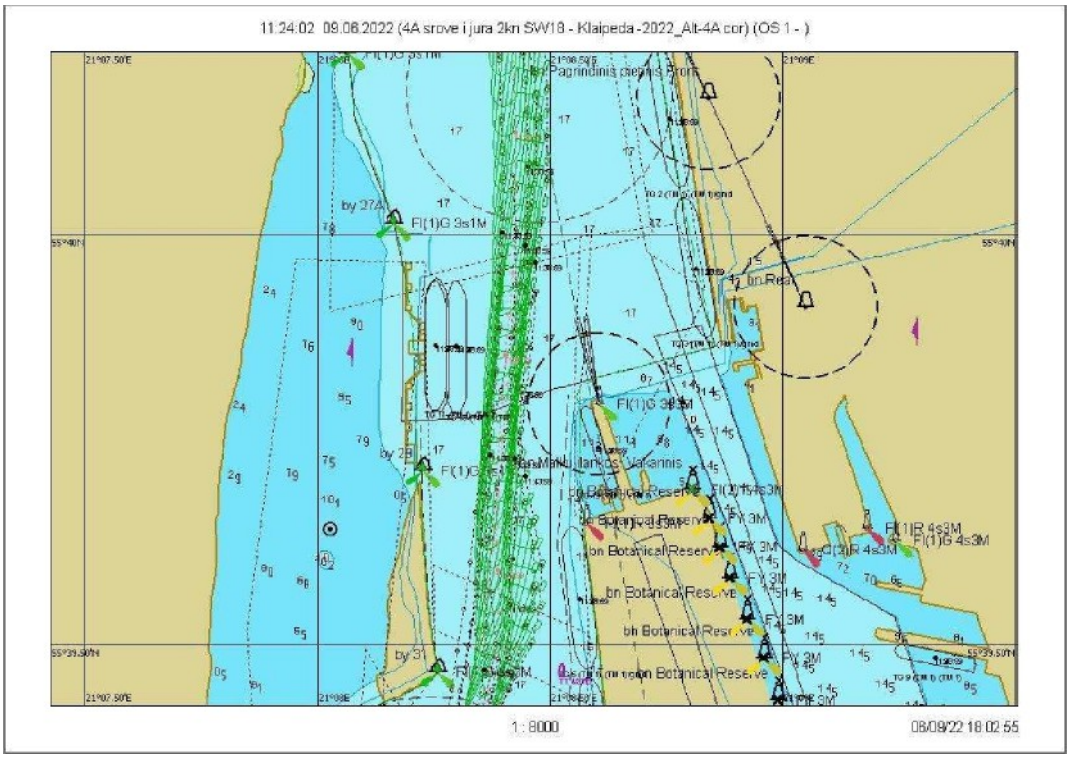


7.3.216 Fig. Course 29.2 – graphical representation of the course from buoy No. 27A to No. 31

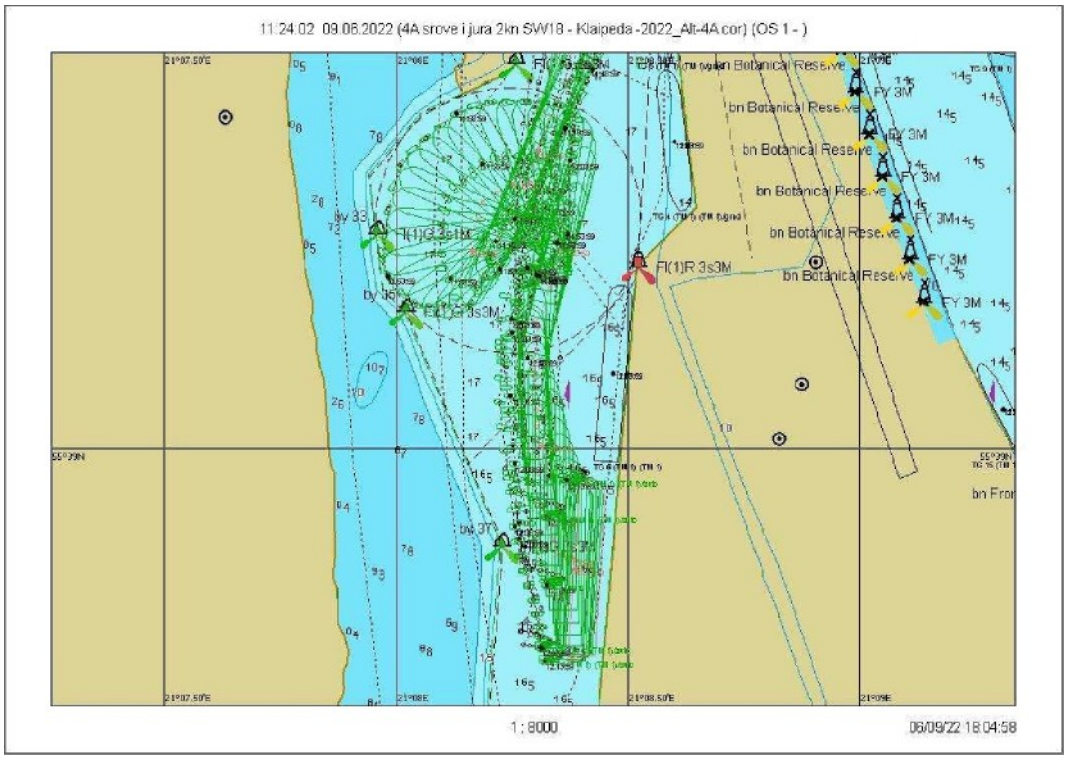


7.3.217 Fig. Course 29.2 – Ship's turning trajectory

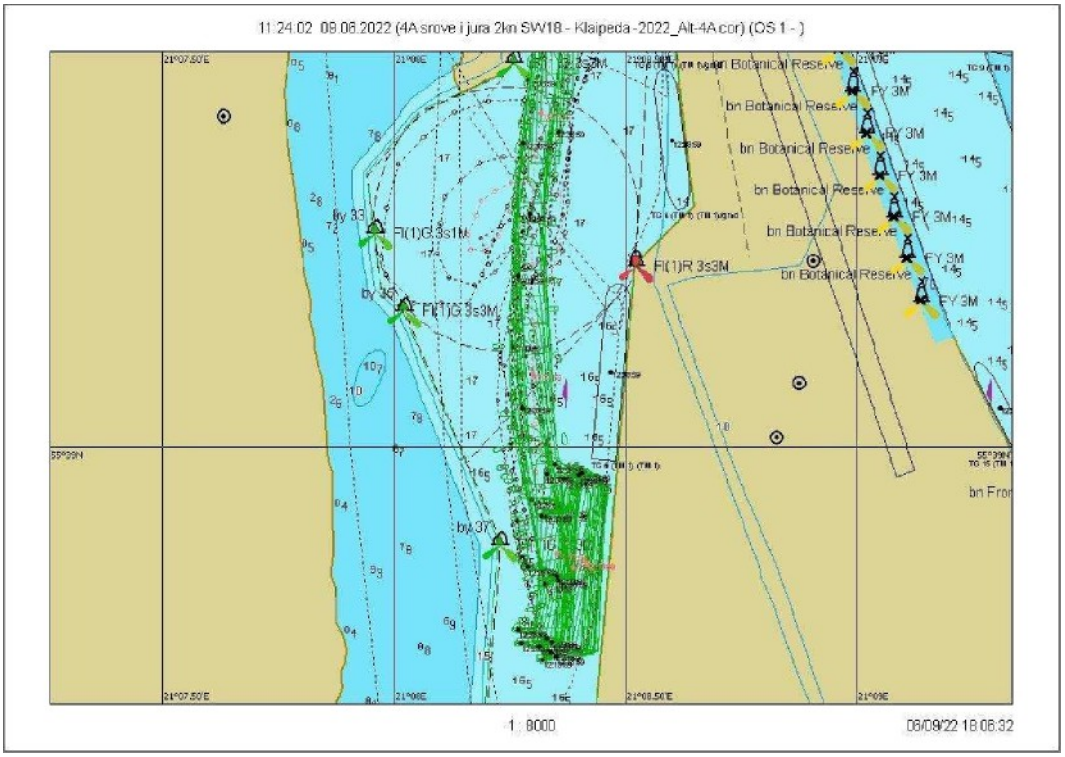
Scenario 29. Wind SW/18 m/s, current 2 knots. Course 29.3



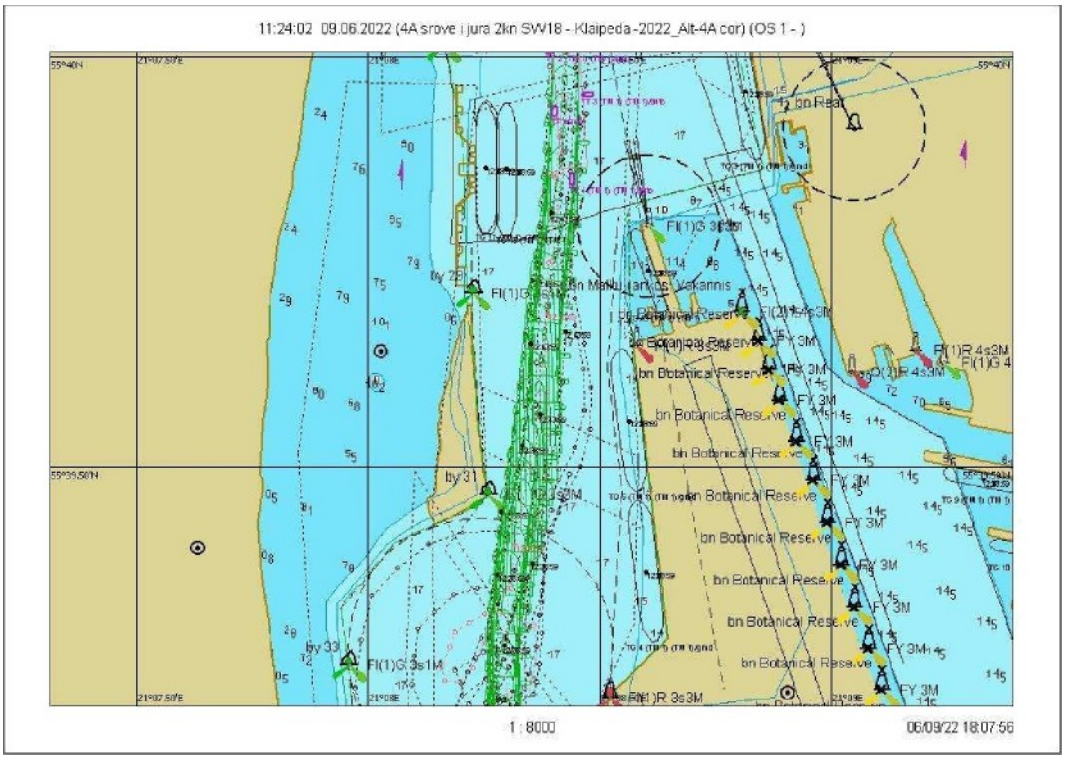
7.3.218 Fig. Course 29.3 – graphical representation of the course from buoy No. 27A to No. 31



7.3.219 Fig. Voyage 29.3 – Ship's turning trajectory



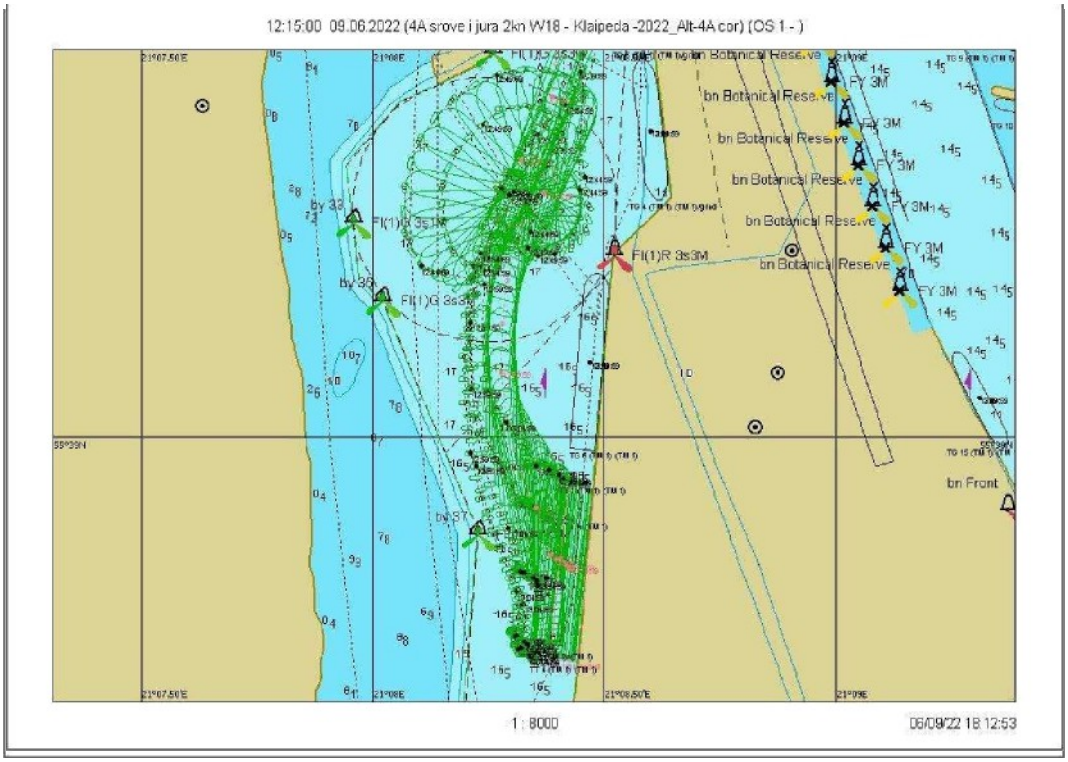
7.3.220 Fig. Voyage 29.3 — graphical representation of departure from the quay



7.3.221 Fig. Voyage 29.3 - graphical representation of the voyage from buoy No. 31 to No. 27A

Scenario 30. Wind W/18 m/s, current 2 knots Voyage 30.1

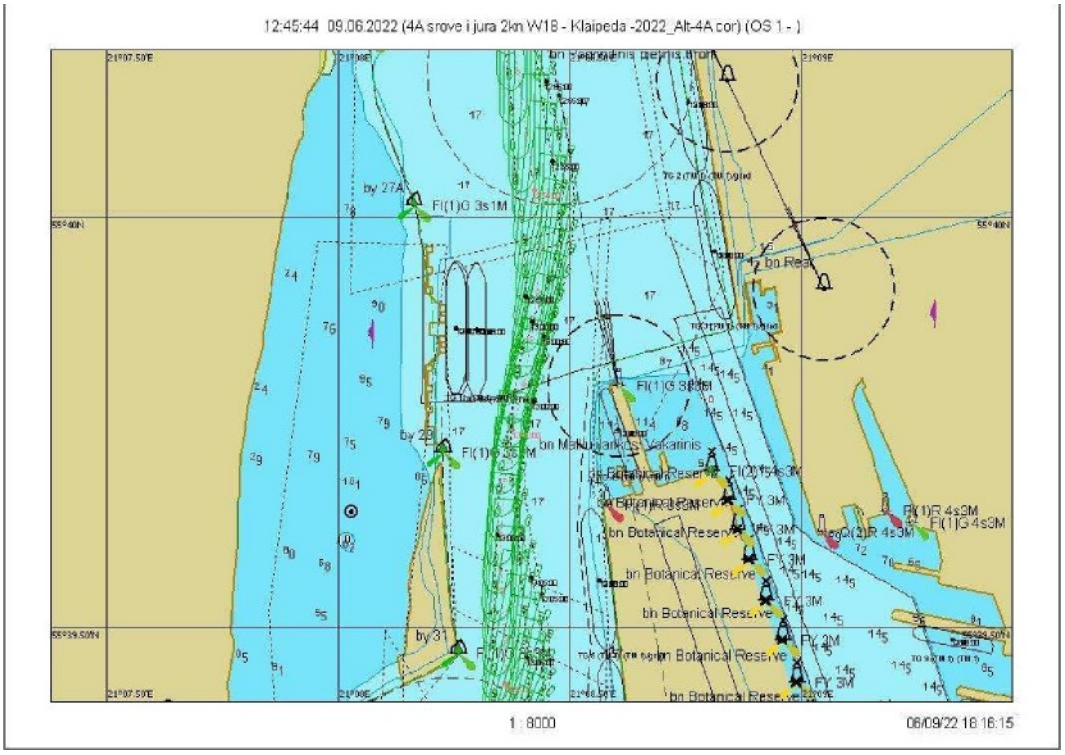
7.3.222 Fig. Course 30.1 — graphical representation of sailing from buoy No. 27A to No. 31



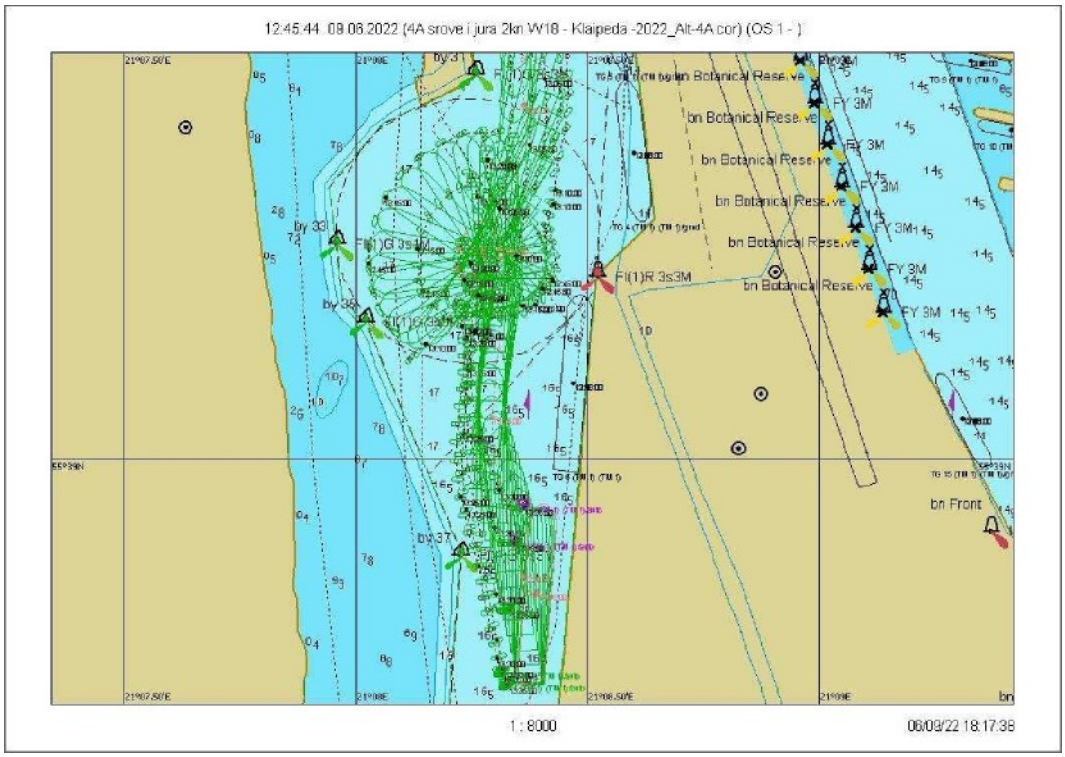
7.3.223 Fig. Course 30.1 – Ship's turning trajectory

Scenario 30. Wind W/18 m/s, current toward the shore 2 knots

Course 30.2



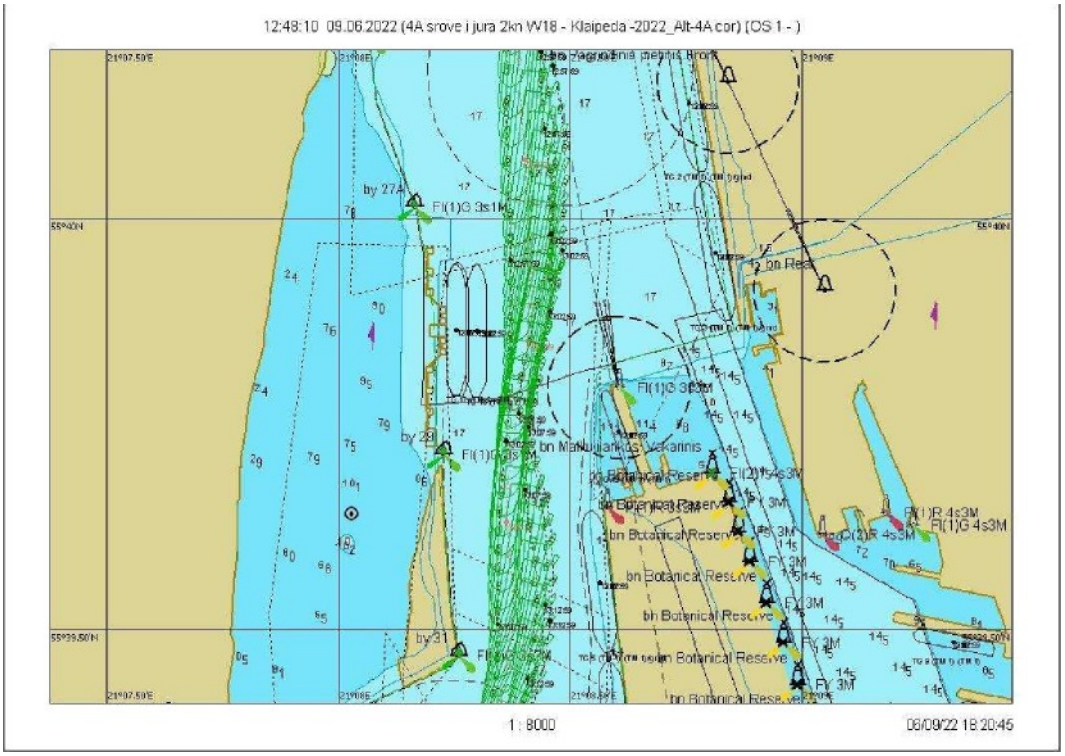
7.3.224 Fig. Course 30.2 – graphical representation of the course from buoy No. 27A to No. 31



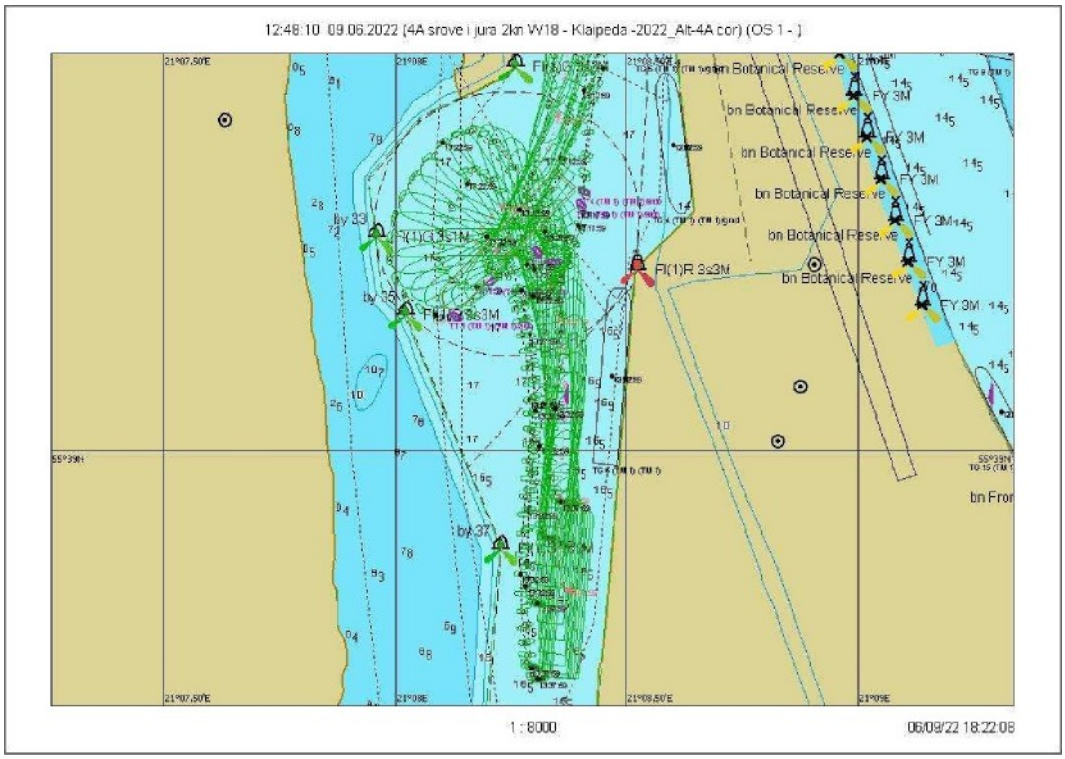
7.3.225 Fig. Voyage 30.2 – Ship's turning trajectory

Scenario 30. Wind W/18 m/s, current toward the shore 2 knots

Course 30.3



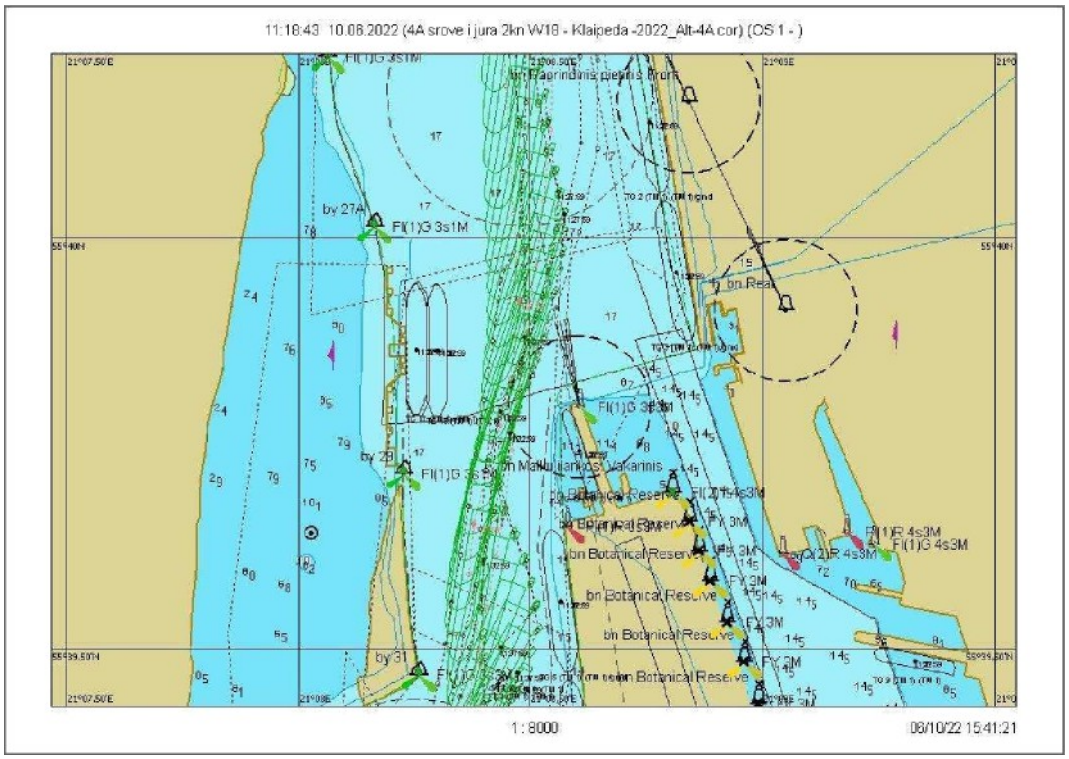
7.3.226 Fig. Course 30.3 – graphical representation of the course from buoy No. 27A to No. 31



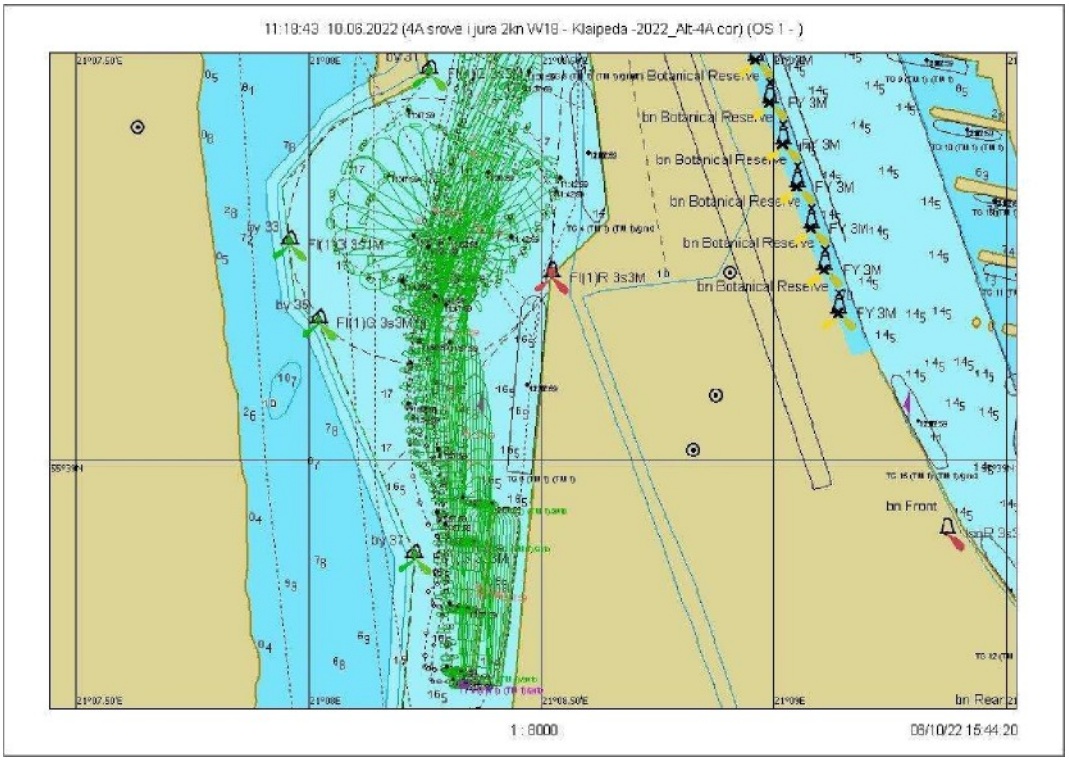
7.3.227 Fig. Course 30.3 – Ship's turning trajectory

Scenario 30. Wind W/18 m/s, current toward the shore 2 knots

Course 30.4

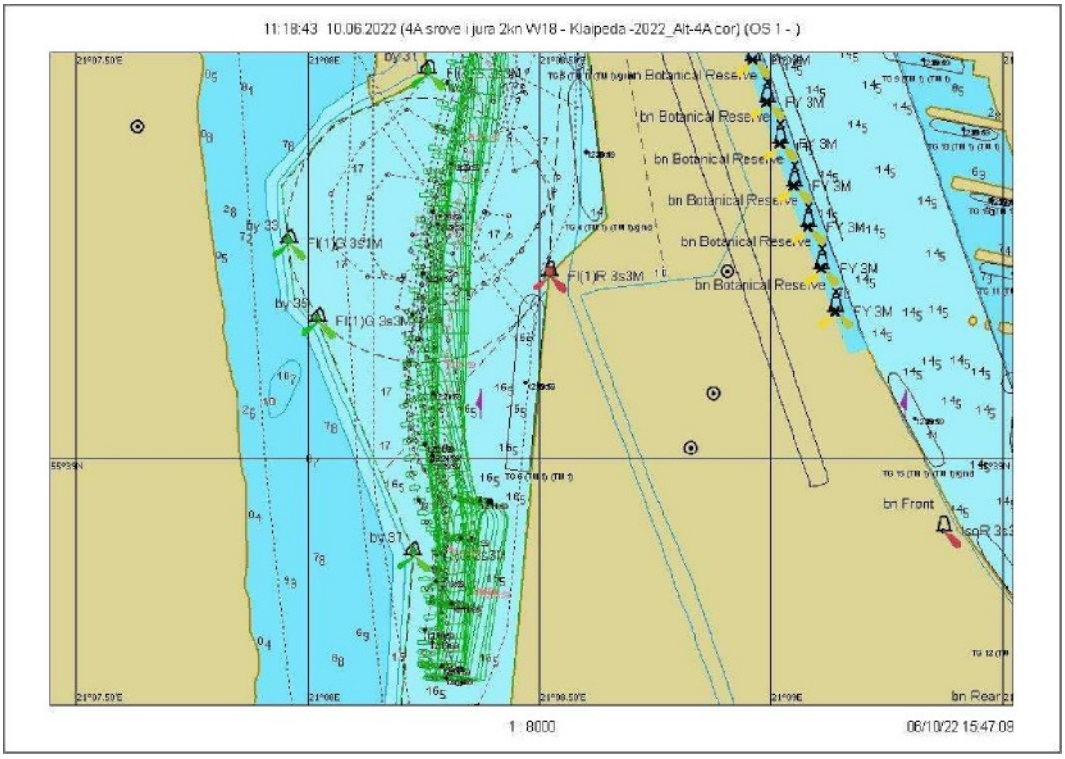


7.3.228 Fig. Course 30.4 – graphical representation of the course from buoy No. 27A to No. 31

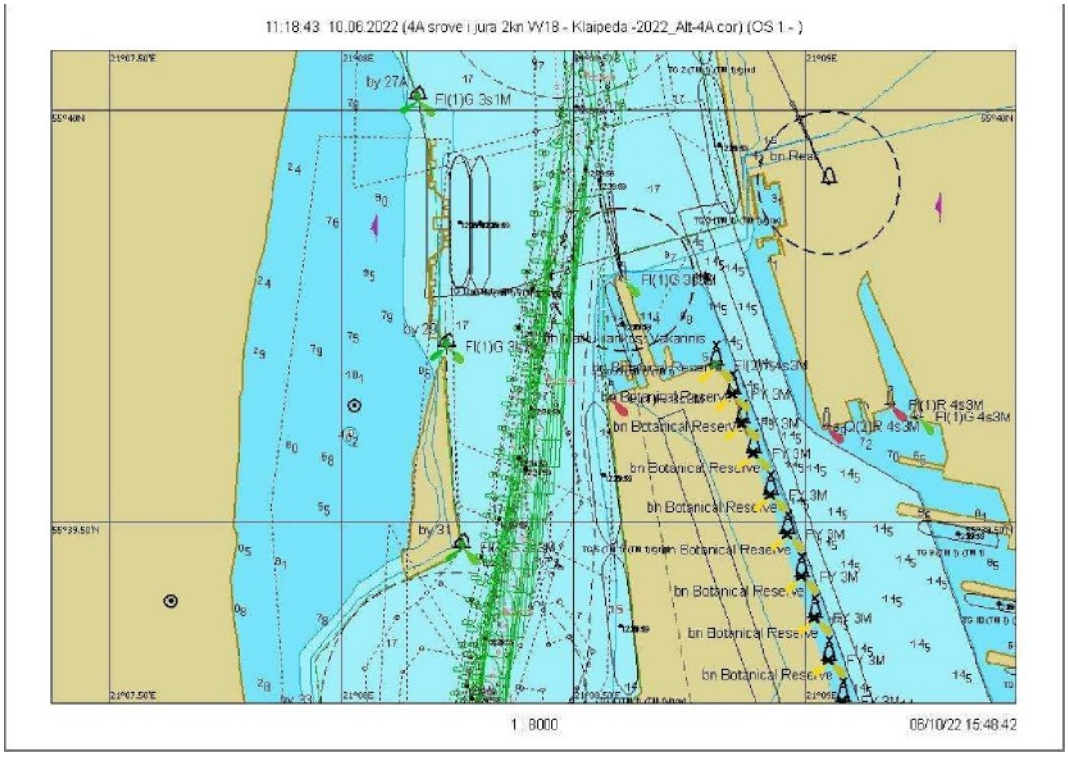


7.3.229 Fig. Course 30.4 – Ship's turning trajectory

Course 30.4



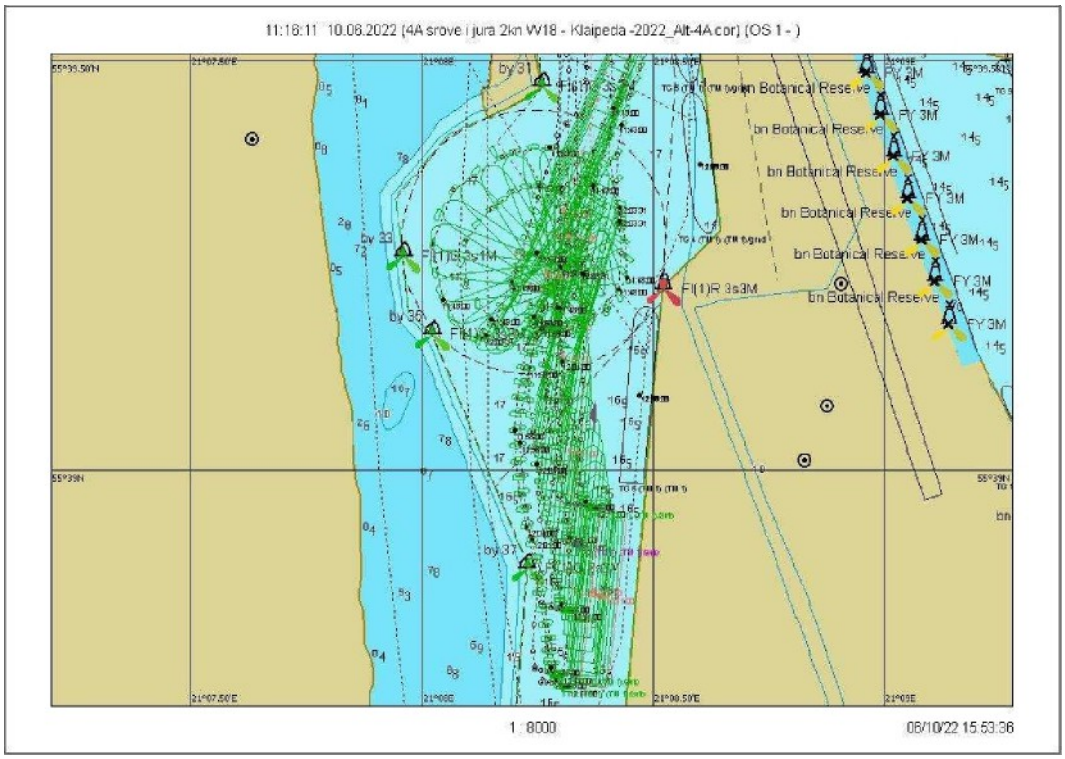
7.3.230 Fig. Course 30.4 — graphical representation of departure from the quay



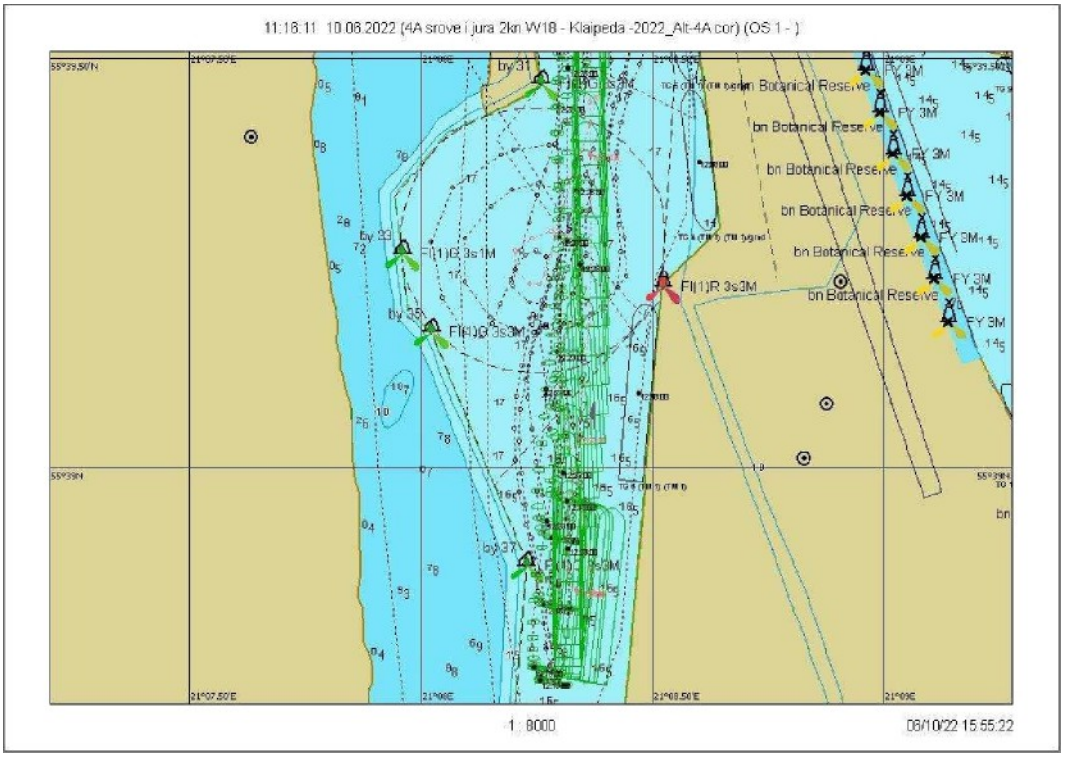
7.3.231 Fig. Voyage 30.4 – graphical representation of the voyage from buoy No. 31 to No. 27A

Scenario 30. Wind W/18 m/s, current 2 knots Course 30.5

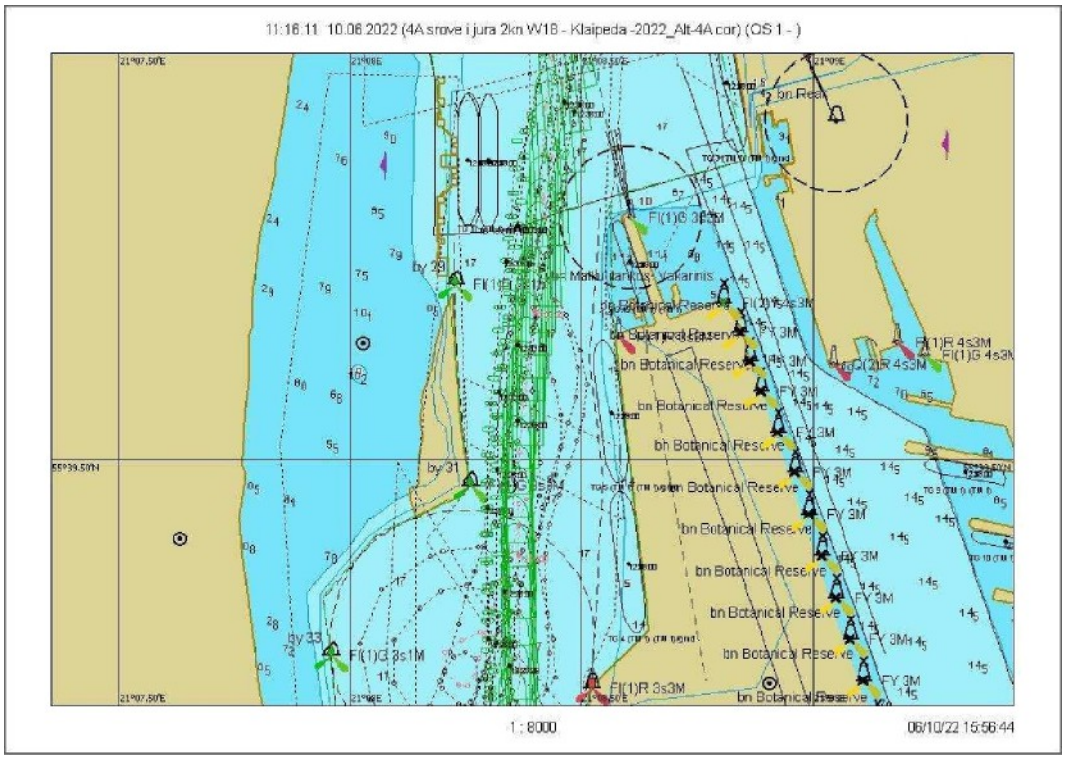
7.3.232 Fig. Course 30.5 — graphical representation of sailing from buoy No. 27A to No. 31



7.3.233 Fig. Course 30.5 – Ship’s turning trajectory



7.3.234 Fig. Course 30.5 — graphical representation of departure from the quay



7.3.235 Fig. Voyage 30.5 – graphical representation of the voyage from buoy No. 31 to No. 27A

Scenario 30. Wind W/18 m/s, current 2 knots Voyage 30.6

7.3.236 Fig. Course 30.6 — graphical representation of the course from buoy No. 27A to No. 31

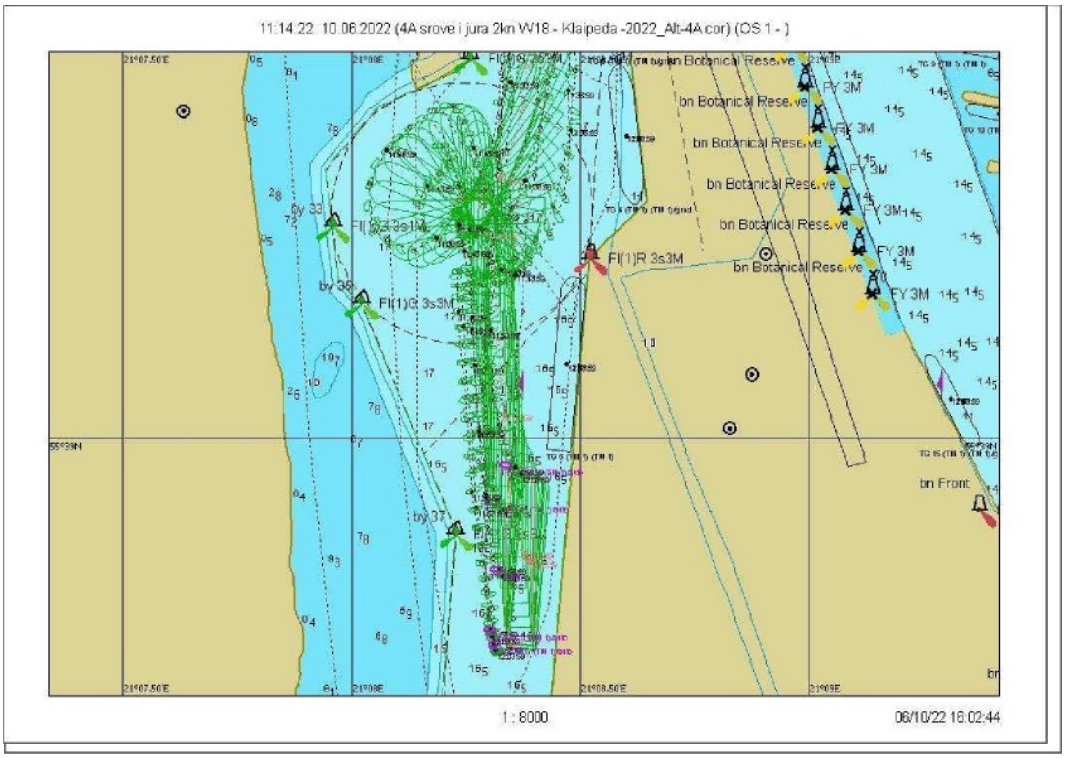
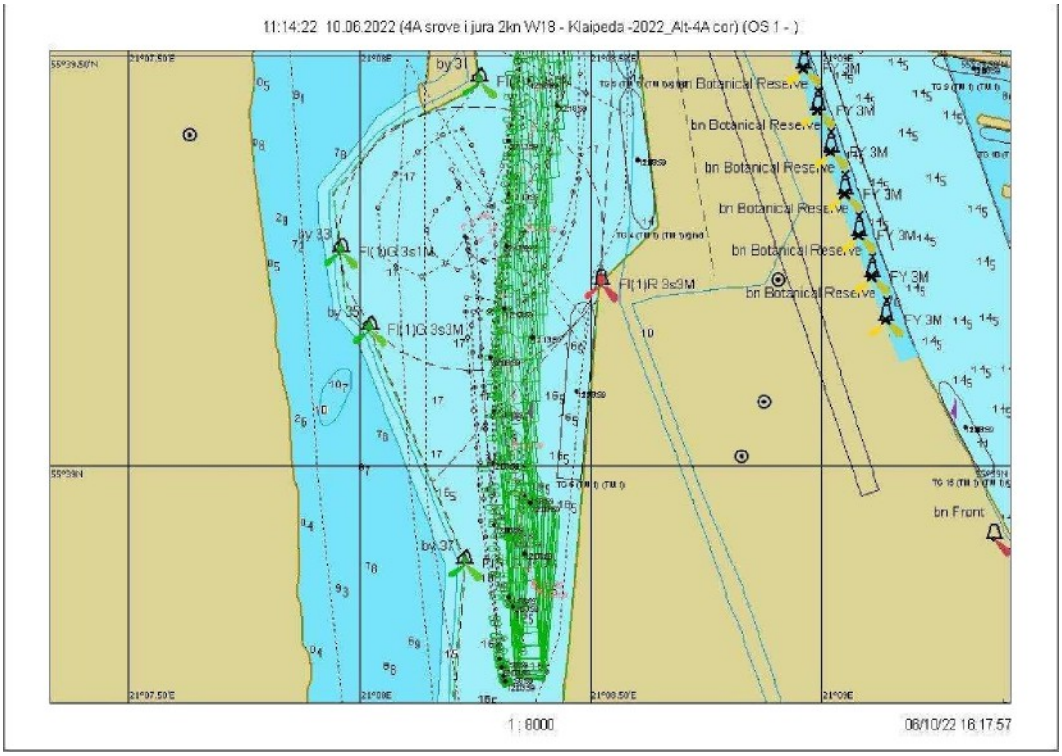
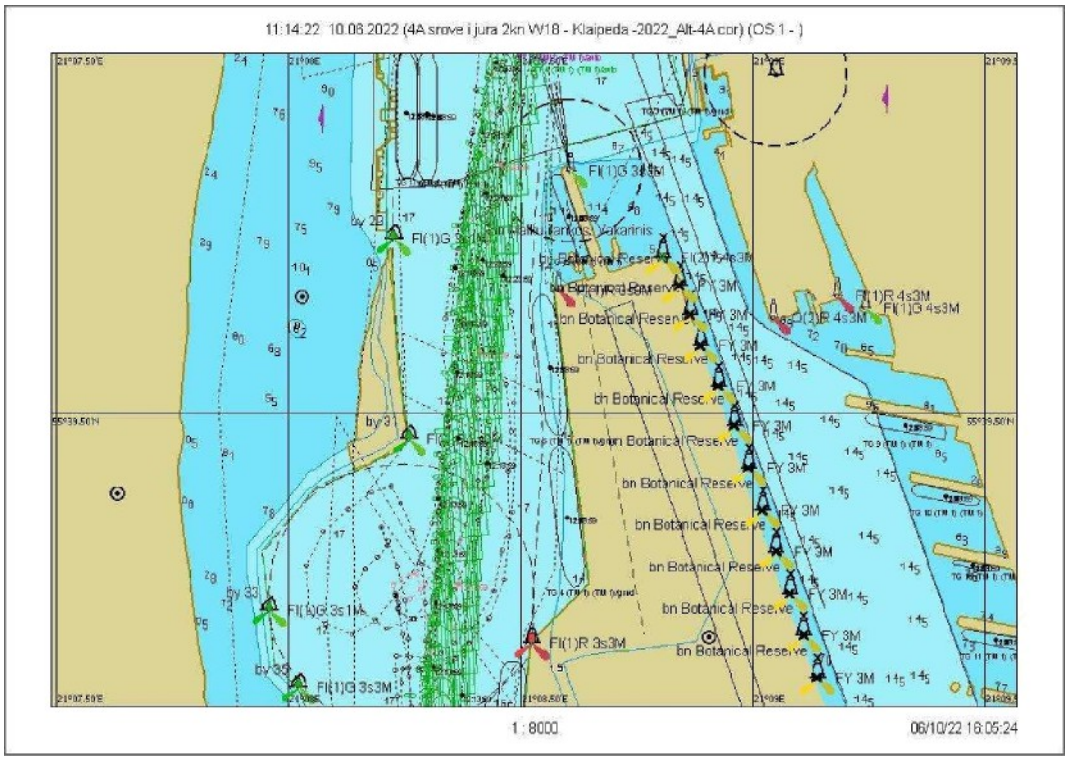


Fig. 7.3.237. Course 30.6 – Ship's turning trajectory



7.3.238 Fig. Course 30.6 — graphical representation of sailing from the quay



7.3.239 Fig. Voyage 30.6 – graphical representation of the voyage from buoy No. 31 to No. 27A

Scenario 30. Wind W/18 m/s, current 2 knots Course 30.7

7.3.240 Fig. Course 30.7 — graphical representation of the course from buoy No. 27A to No. 31

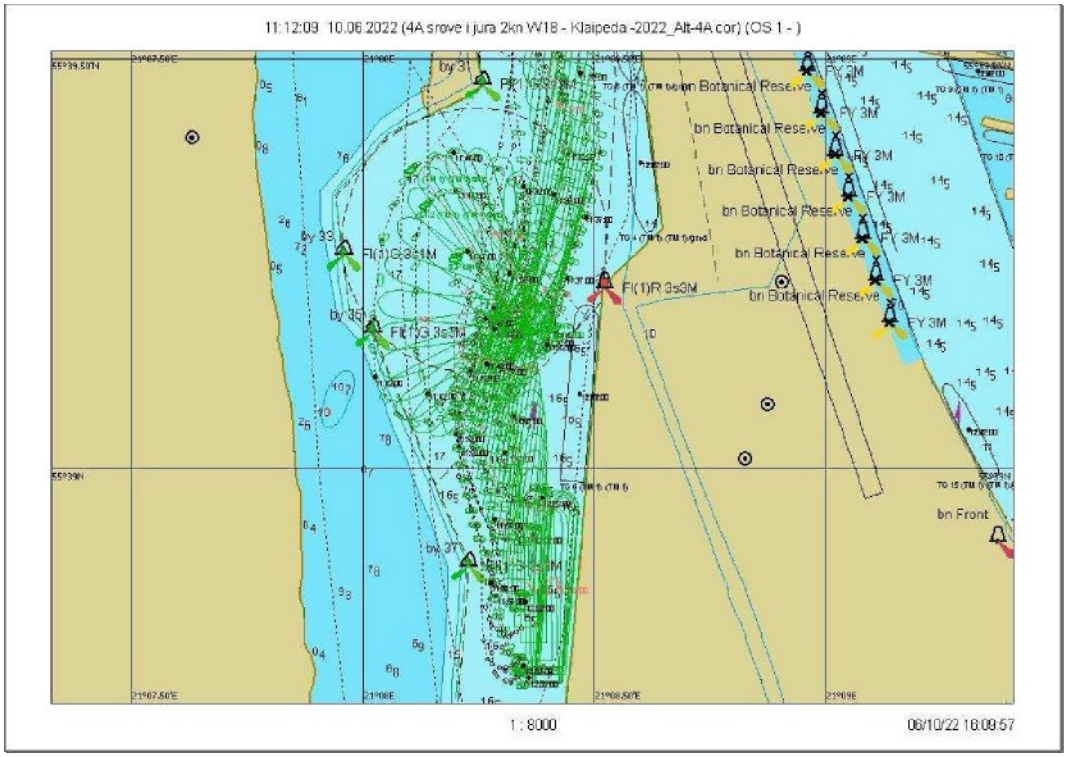
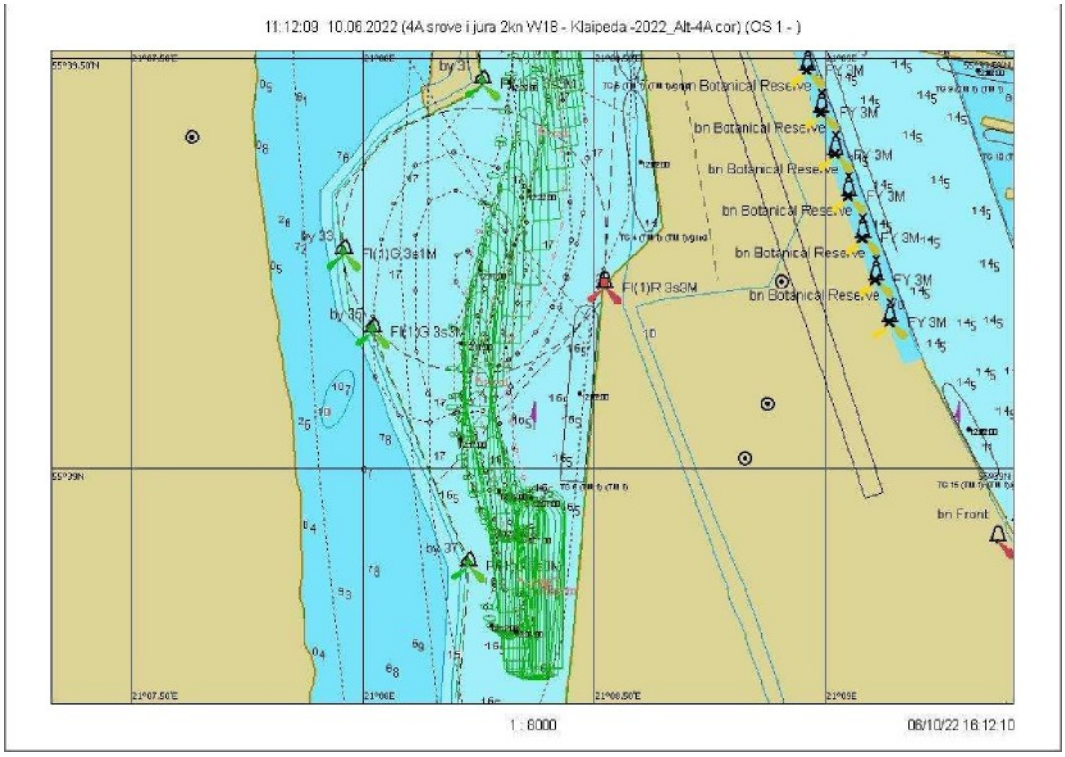
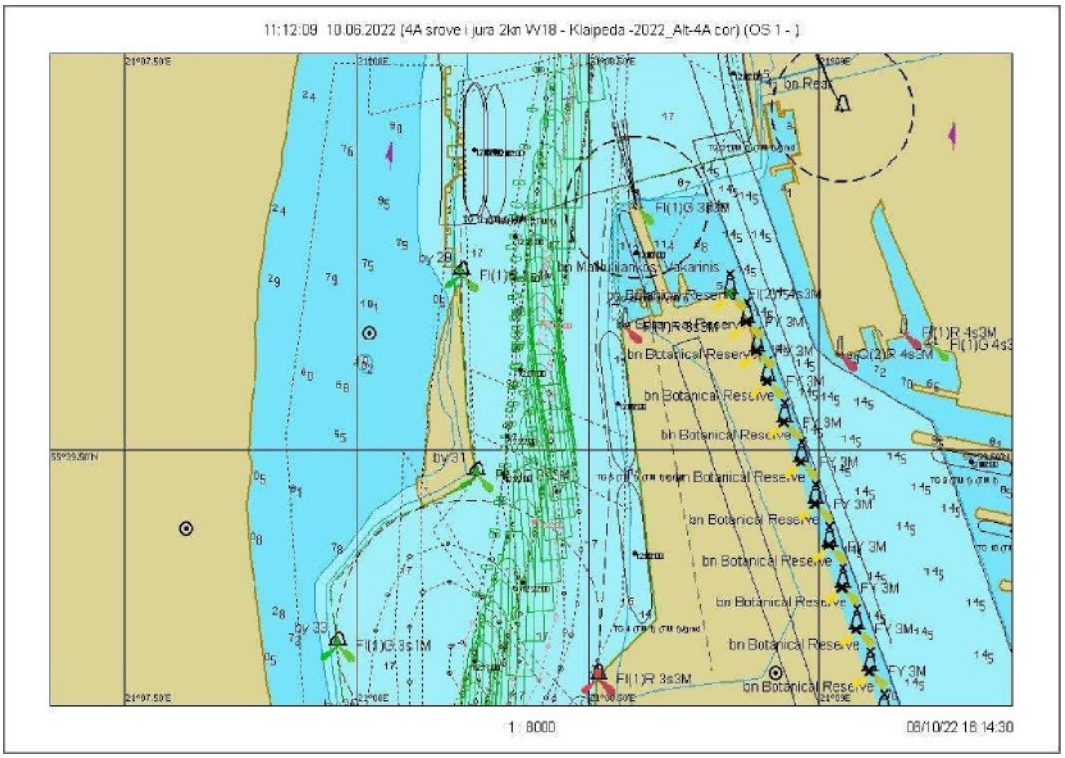


Fig. 7.3.237. Course 30.6 – Ship's turning trajectory

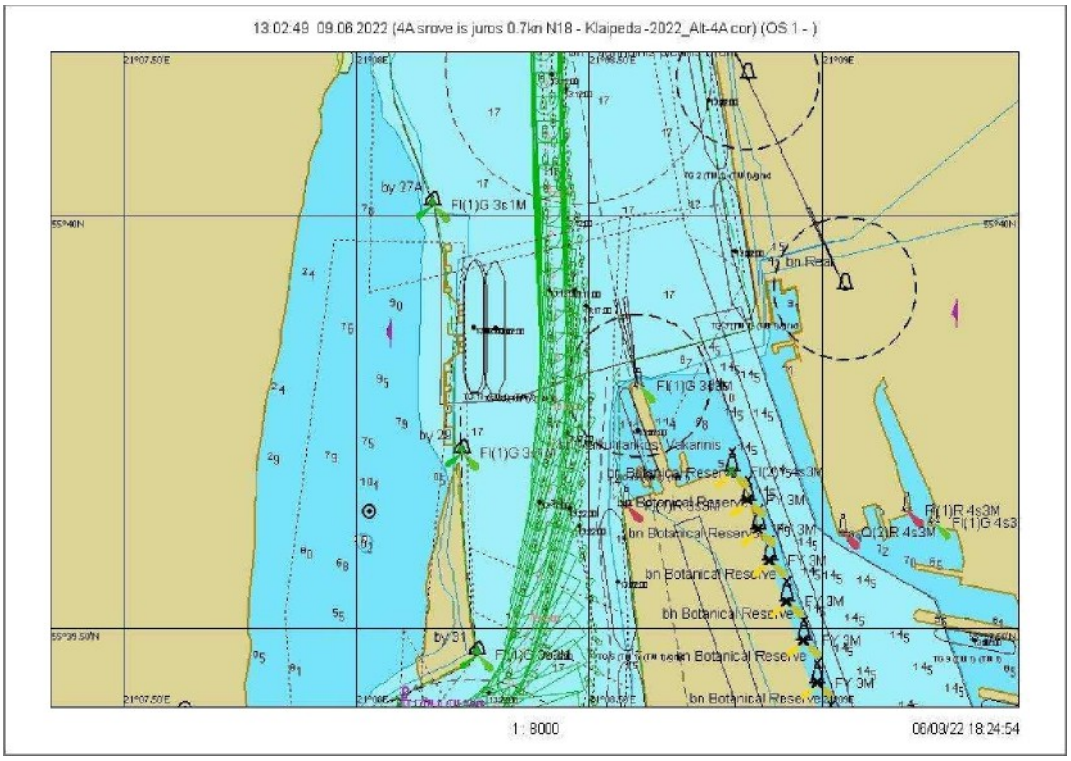


7.3.242 Fig. Course 30.7 — graphical representation of sailing from the quay



7.3.243 Fig. Voyage 30.7 – graphical representation of the voyage from buoy No. 31 to No. 27A

Scenario 31. Wind N/18 m/s, current from the shore 0.7 knots Voyage 31.1



7.3.244 Fig. Voyage 31.1 — graphical representation of the voyage from buoy No. 27A to No. 31

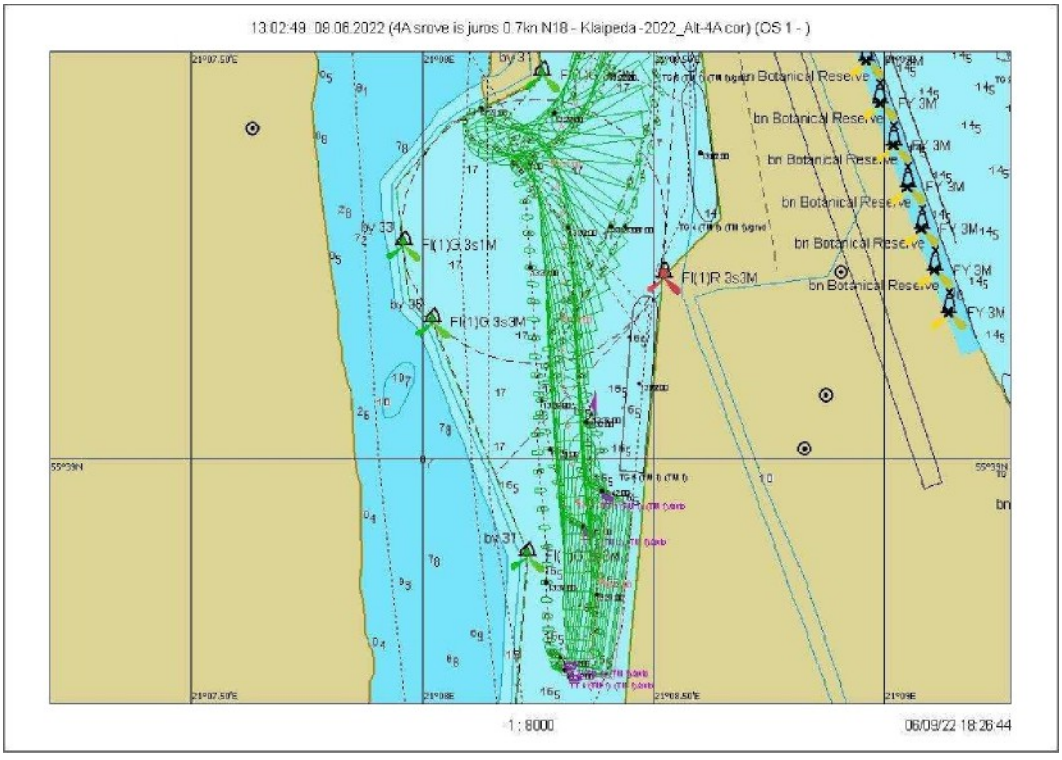
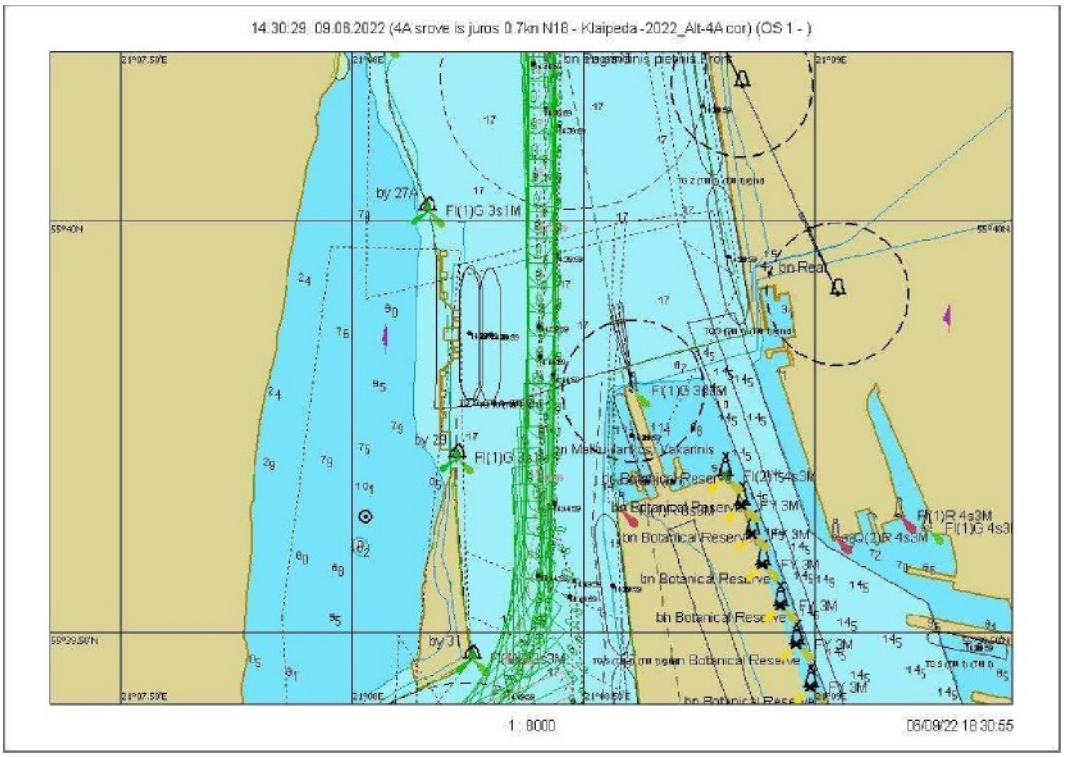
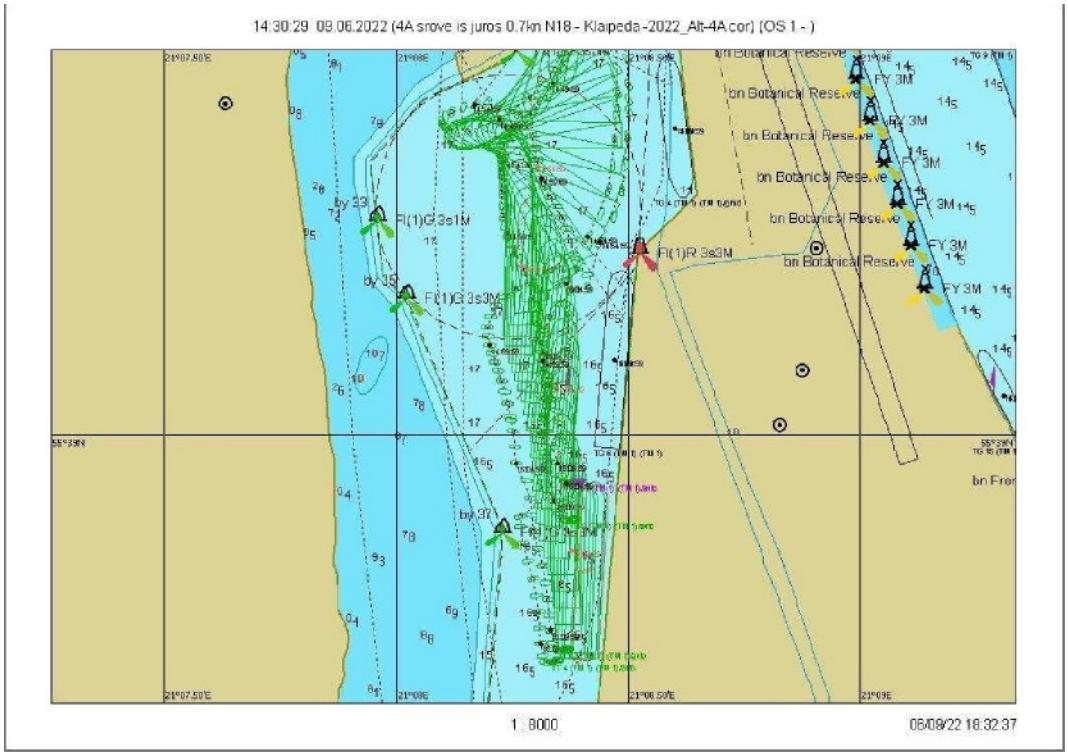


Fig. 7.3.245. Maneuver 31.1 – Ship's turning trajectory

Scenario 31. Wind N/18 m/s, current from the sea 0.7 knots Course 31.2



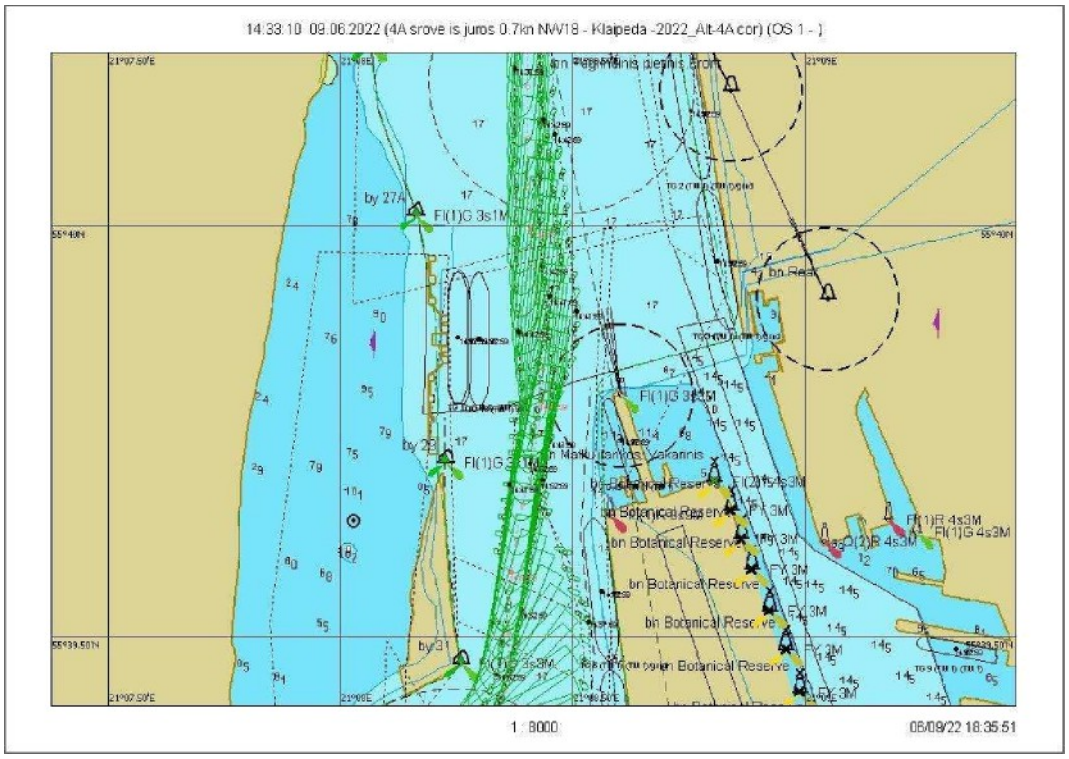
7.3.246 Fig. Voyage 31.2 – graphical representation of the voyage from buoy No. 27A to No. 31



7.3.247 Fig. Course 31.2 – Ship's turning trajectory

Scenario 32. Wind NW/18 m/s, current from the shore 0.7 knots

Voyage 32.1



7.3.248 Fig. Course 32.1 – graphical representation of the course from buoy No. 27A to No. 31

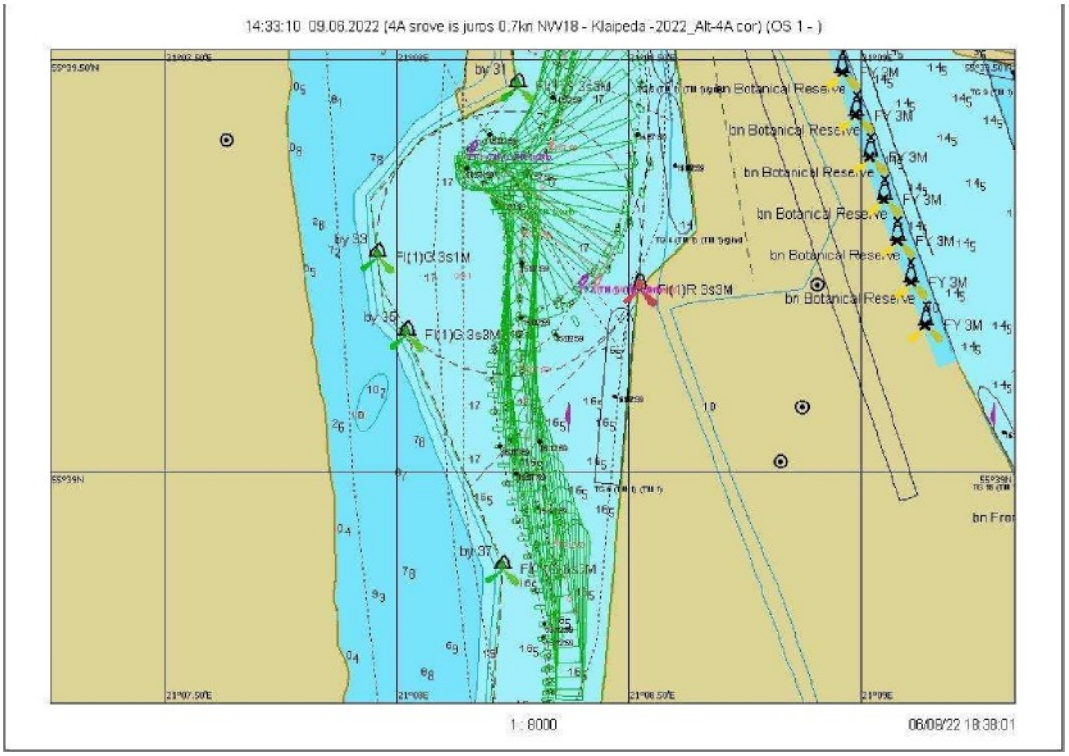
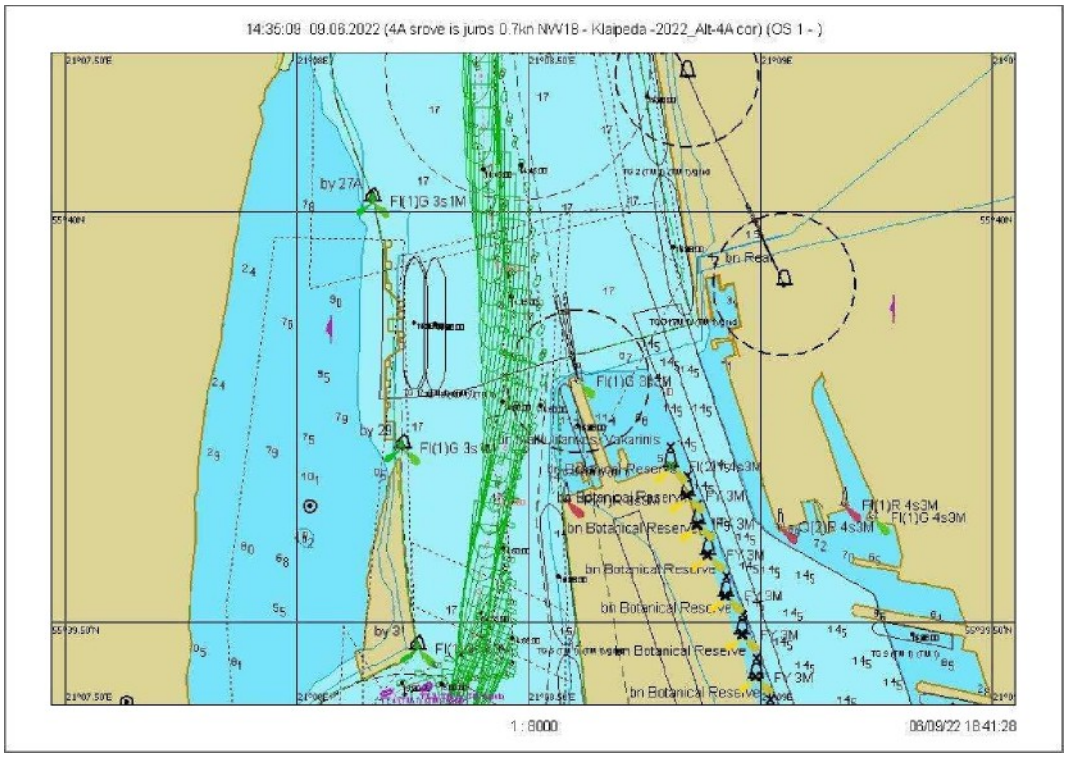


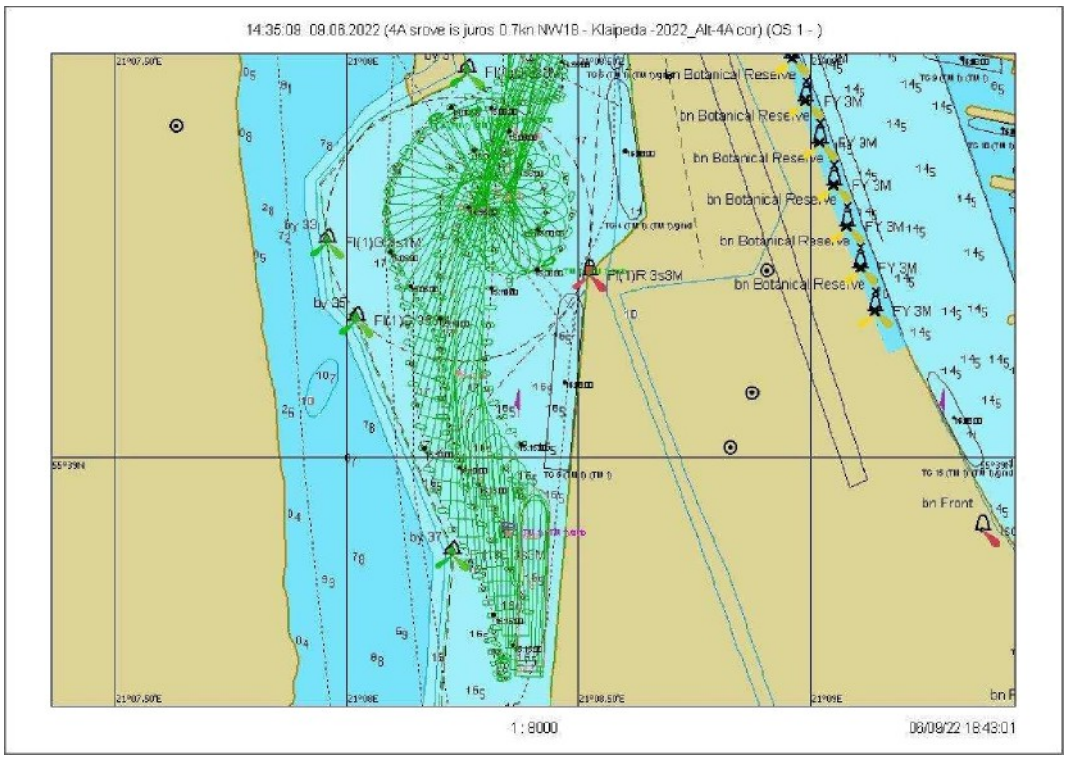
Fig. 7.3.249. Maneuver 32.1 – Ship's turning trajectory

Scenario 32. Wind NW/18 m/s, current from the shore 0.7 knots

Voyage 32.2

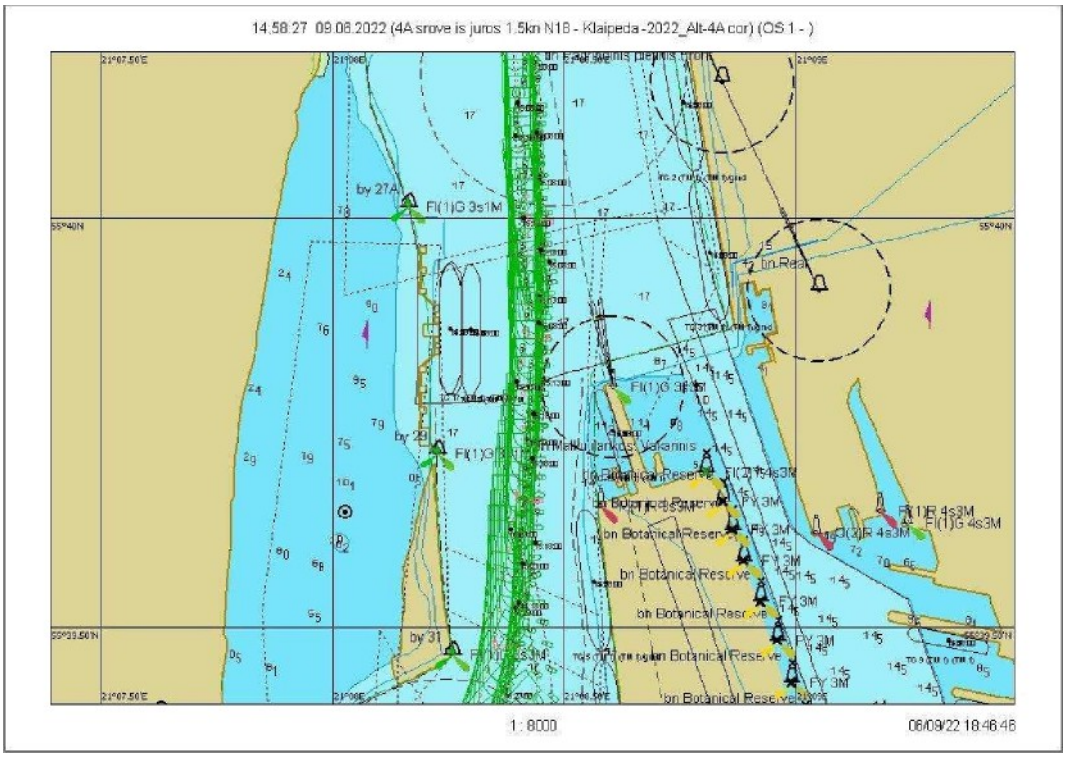


7.3.250 Fig. Course 32.2 – graphical representation of the course from buoy No. 27A to No. 31



7.3.251 Fig. Voyage 32.2 - Ship turning trajectory

Scenario 33. Wind N/18 m/s, current from the sea 1.5 knots Voyage 33.1



7.3.252 Fig. Course 33.1 – graphical representation of the course from buoy No. 27A to No. 31

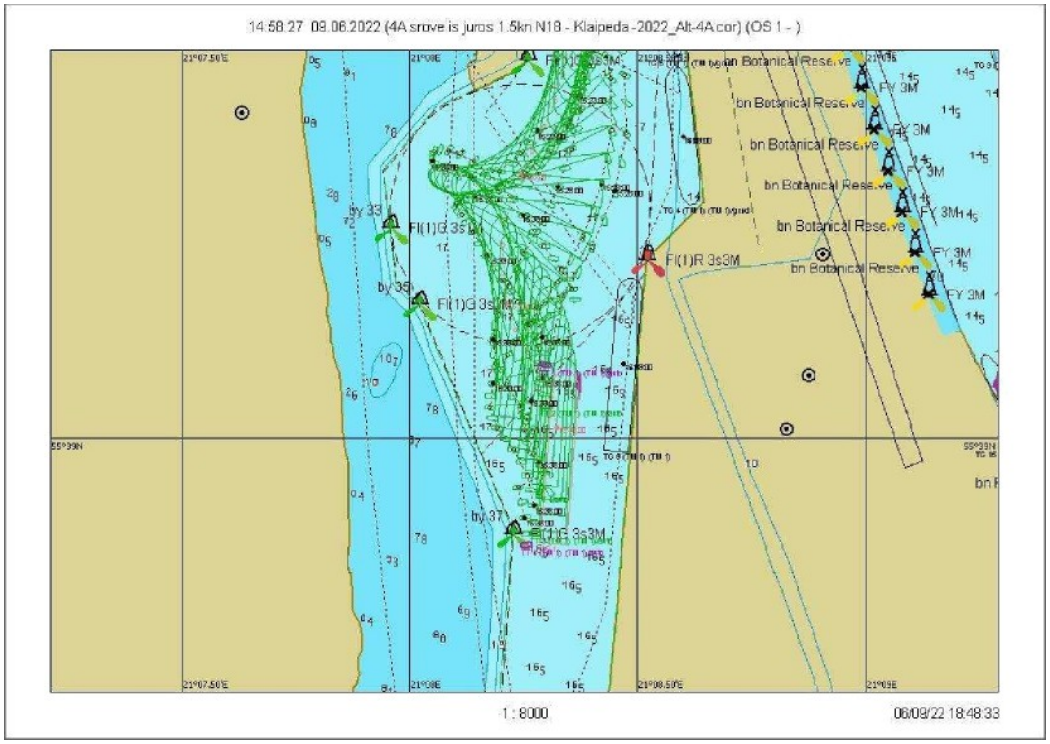
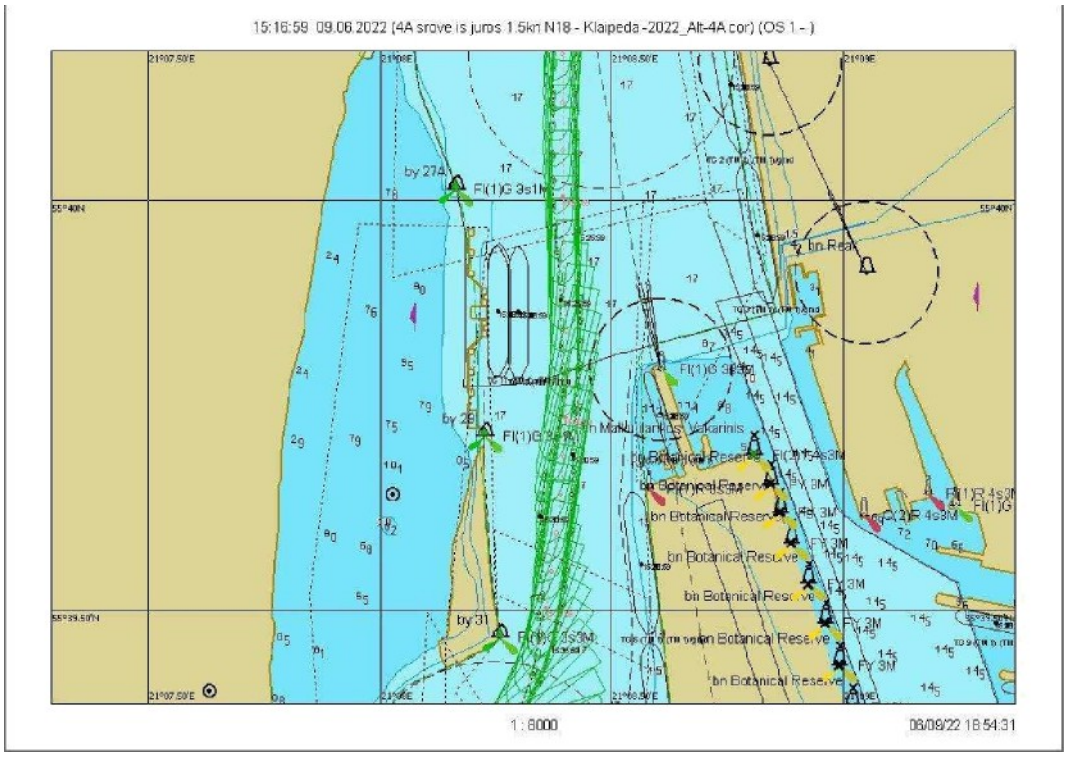
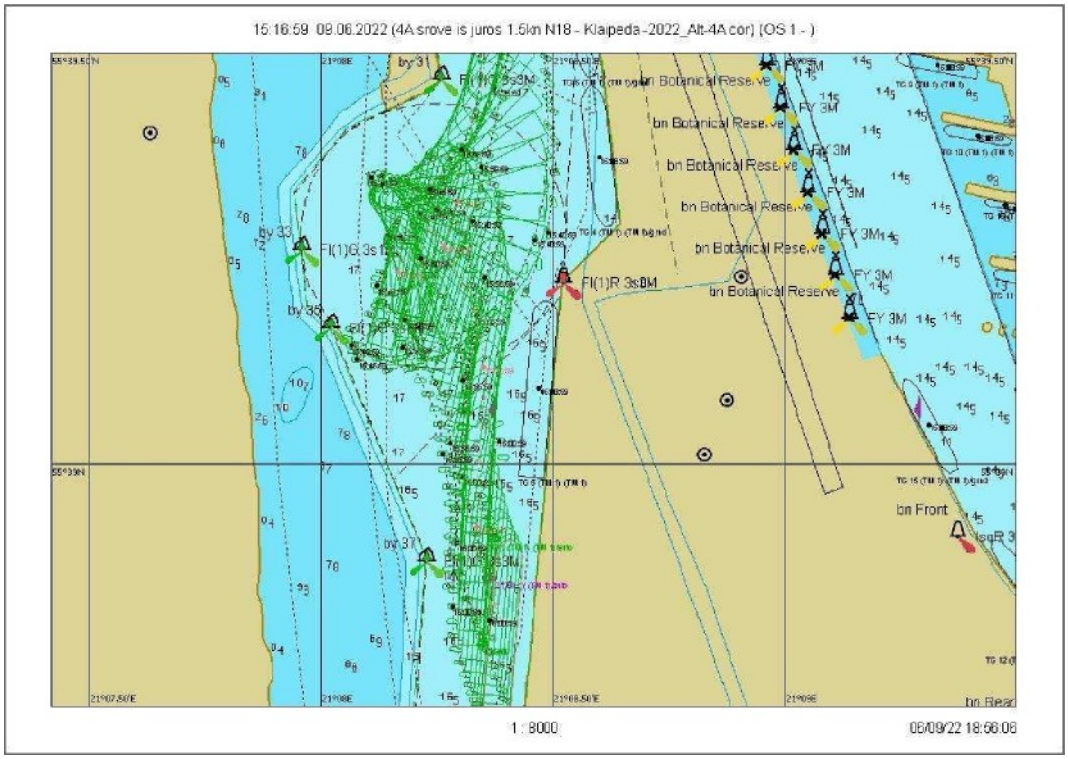


Fig. 7.3.253. Maneuver 33.1 – Ship's turning trajectory

Scenario 33. Wind N/18 m/s, current from the jetty at 1.5 knots Course 33.2

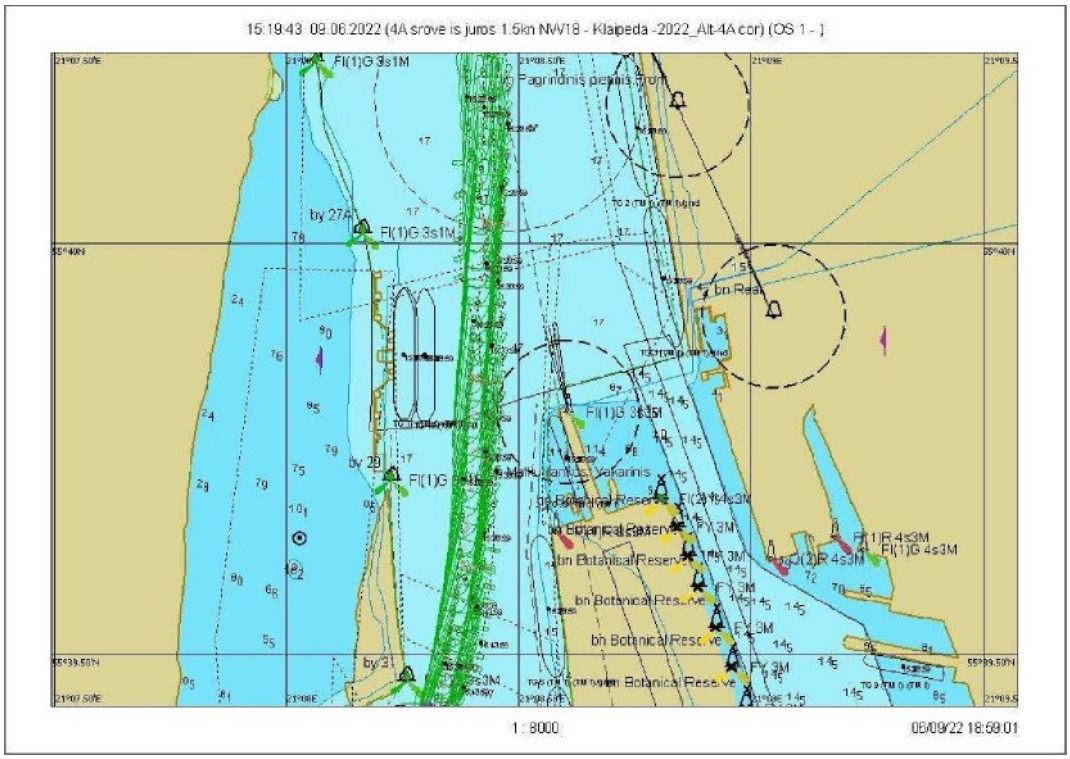


7.3.254 Fig. Course 33.2 – graphical representation of the course from buoy No. 27A to No. 31



7.3.255 Fig. Course 33.2 – Ship's turning trajectory

Scenario 34. Wind NW/18 m/s, current from the sea 1.5 knots Voyage 34.1



7.3.256 Fig. Course 34.1 – graphical representation of the course from buoy No. 27A to No. 31

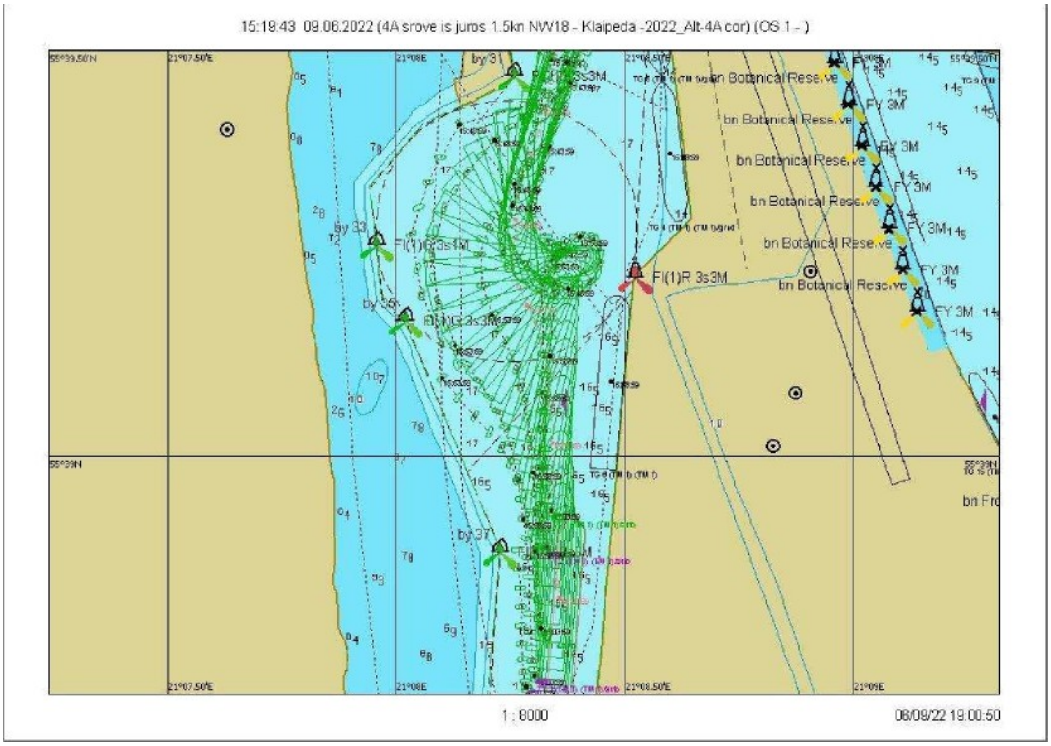
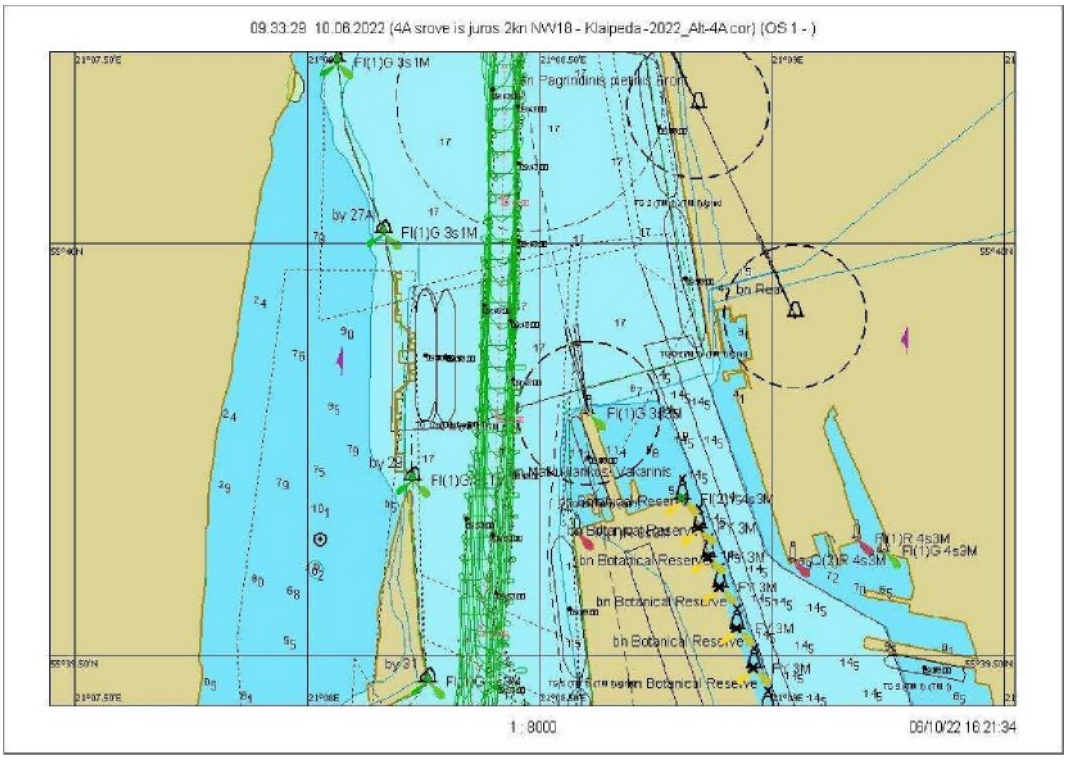


Fig. 7.3.257. Maneuver 34.1 – Ship's turning trajectory

Scenario 35. Wind NW/18 m/s, current from the sea 2 knots Voyage

35.1



7.3.258 Fig. Course 35.1 – graphical representation of the course from buoy No. 27A to No. 31

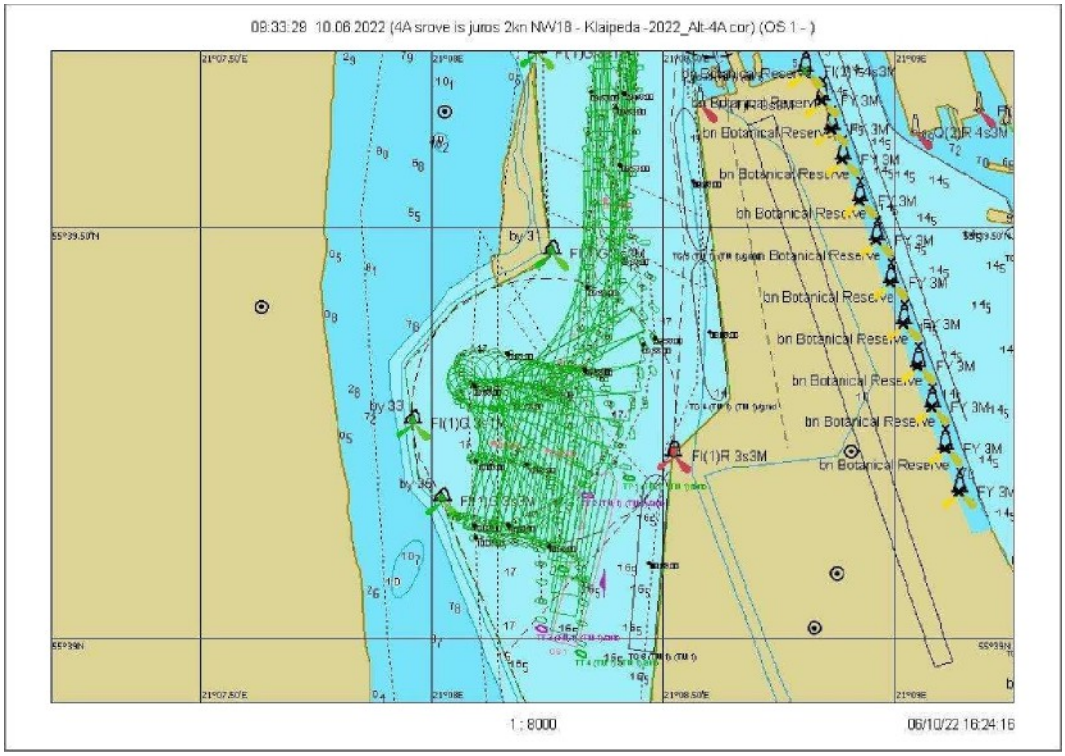


Fig. 7.3.259. Course 35.438 - Ship's turning trajectory

Scenario 35. Wind NW/18 m/s, current from the shore 2 knots Course 35.2

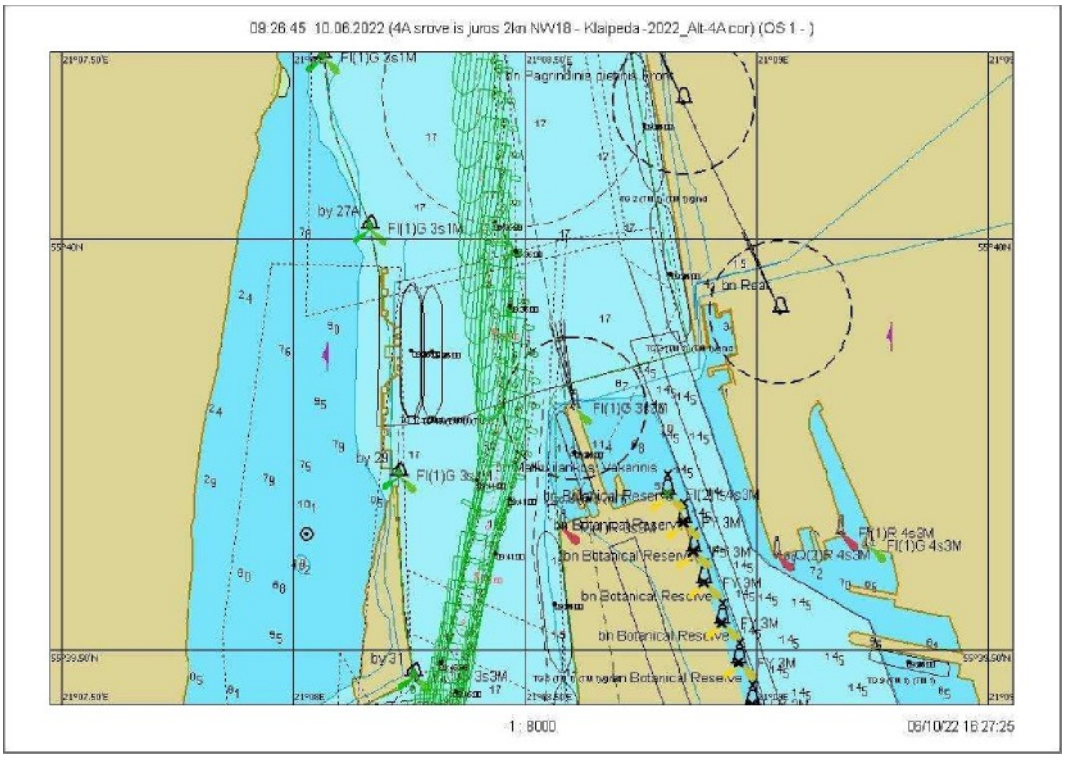


Fig. 7.3.260. Course 35.2 – graphical representation of the course from buoy No. 27A to No. 31

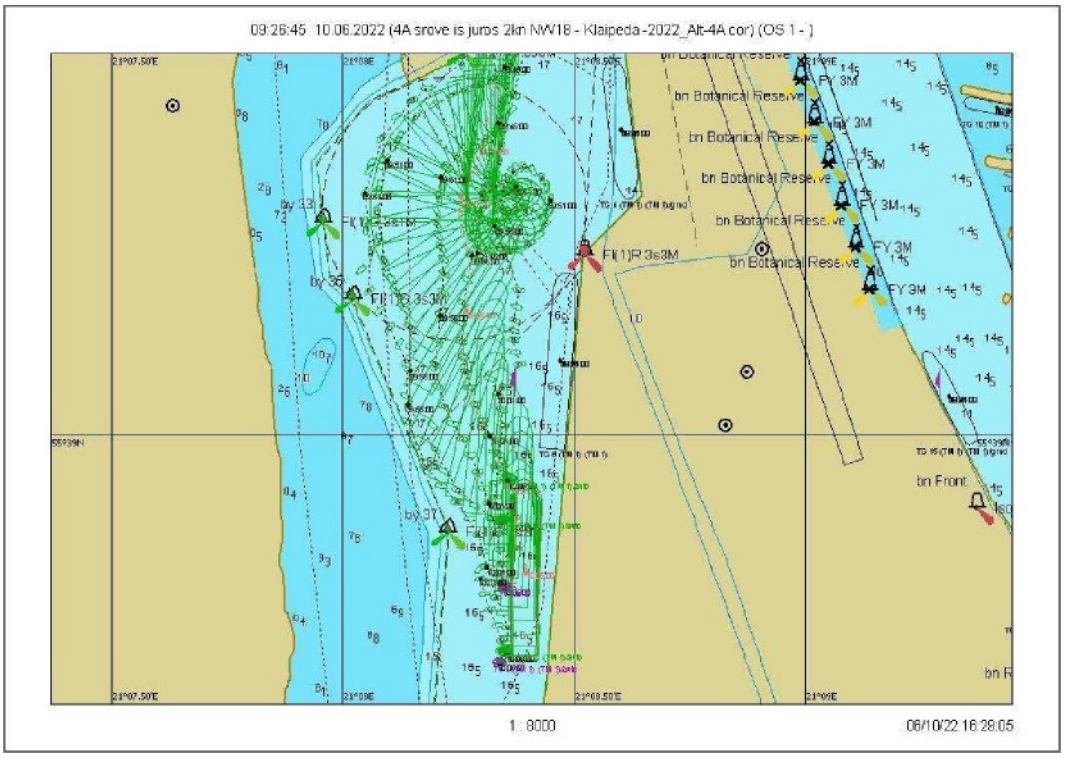


Fig. 7.3.261. Course 35.2 – Ship's turning trajectory

Scenario 35. Wind NW/18 m/s, current from the shore 2 knots Course 35.3

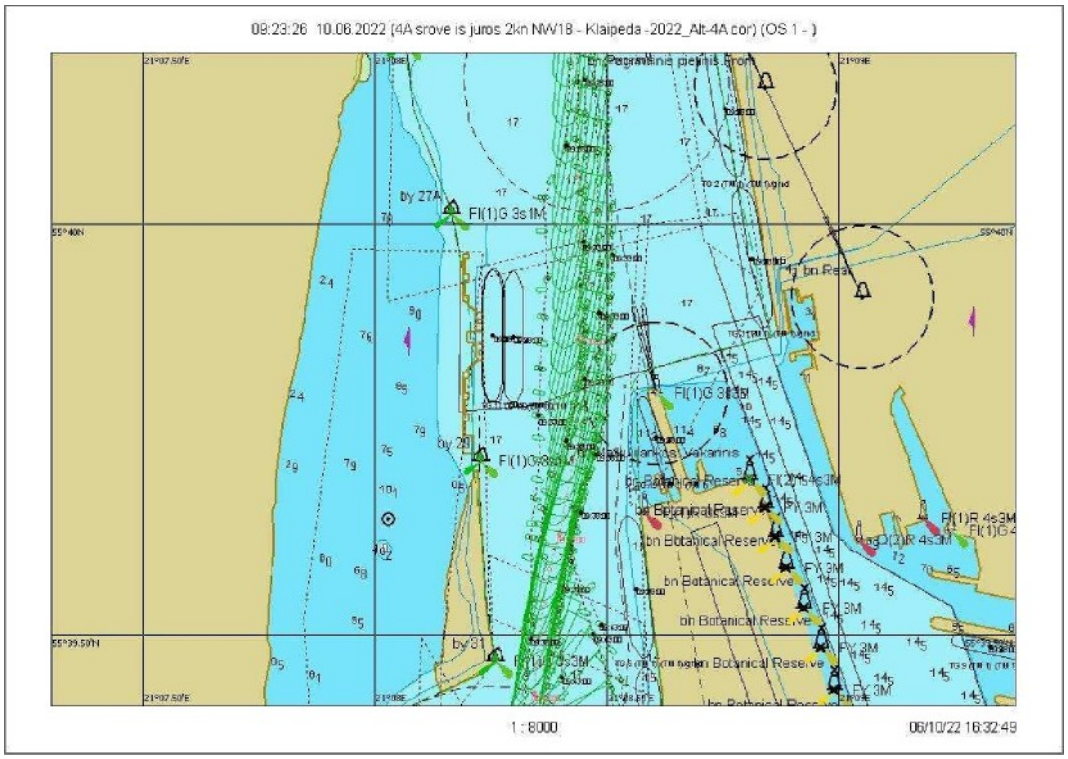


Fig. 7.3.262. Course 35.3 – graphical representation of the course from buoy No. 27A to No. 31

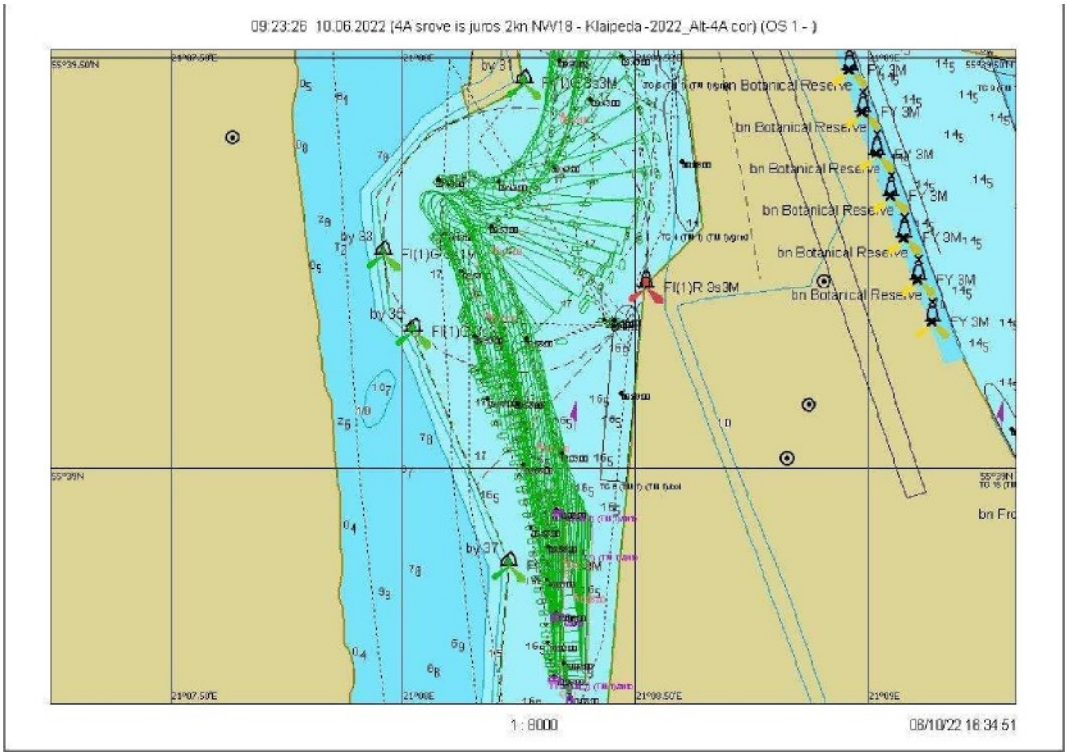


Fig. 7.3.263. Course 35.3 - Ship's turning trajectory

Scenario 36. Wind N/18 m/s, current from the sea 2 knots Course 36.1

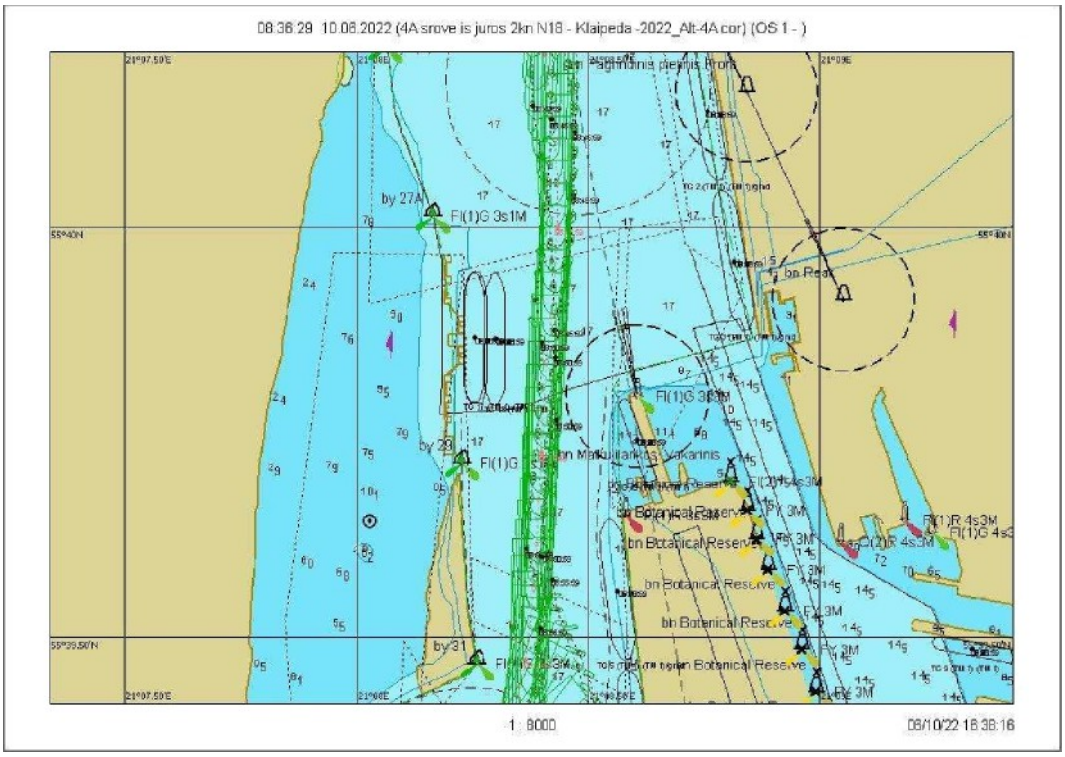


Fig. 7.3.264. Course 36.1 – graphical representation of the course from buoy No. 27A to No. 31

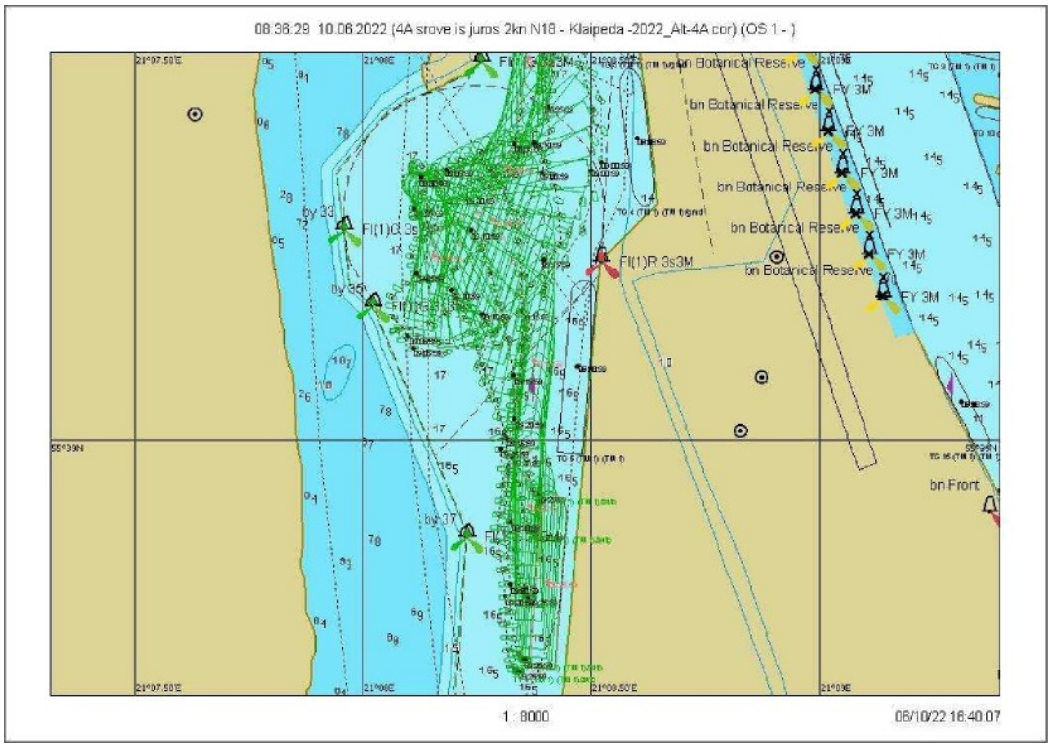


Fig. 7.3.265. Maneuver 36.1 – Ship's turning trajectory

Scenario 36. Wind N/18 m/s, current from the sea 2 knots Course 36.2

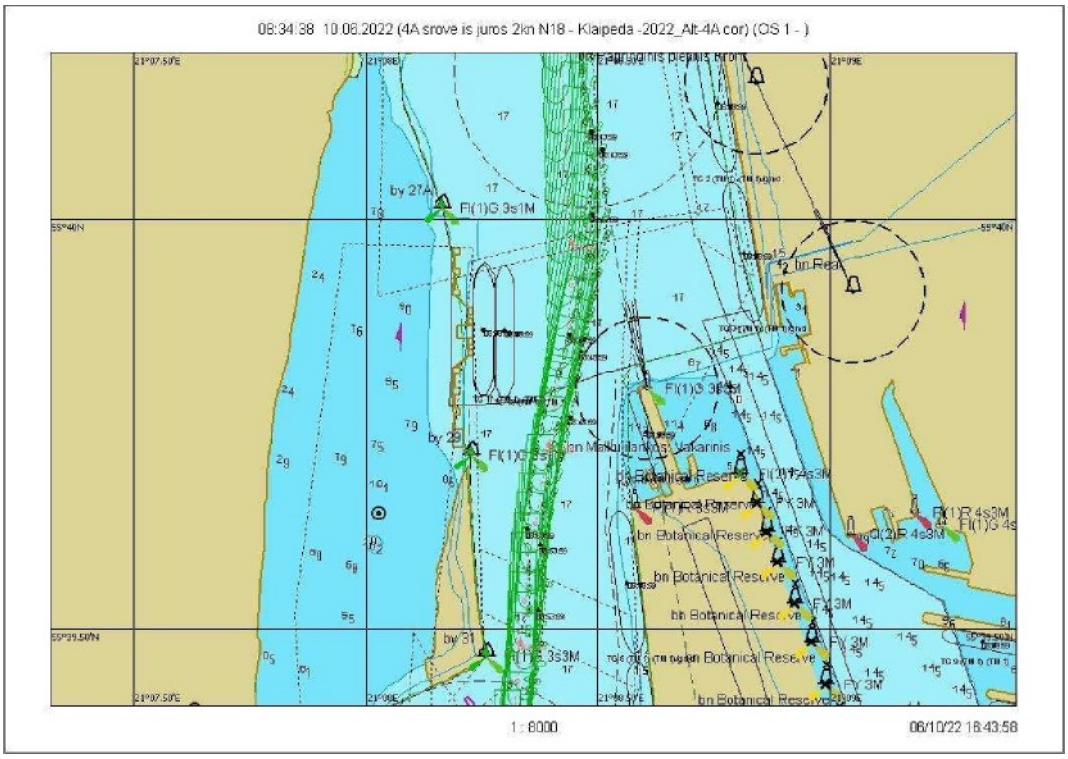


Fig. 7.3.266. Course 36.2 – graphical representation of the course from buoy No. 27A to No. 31

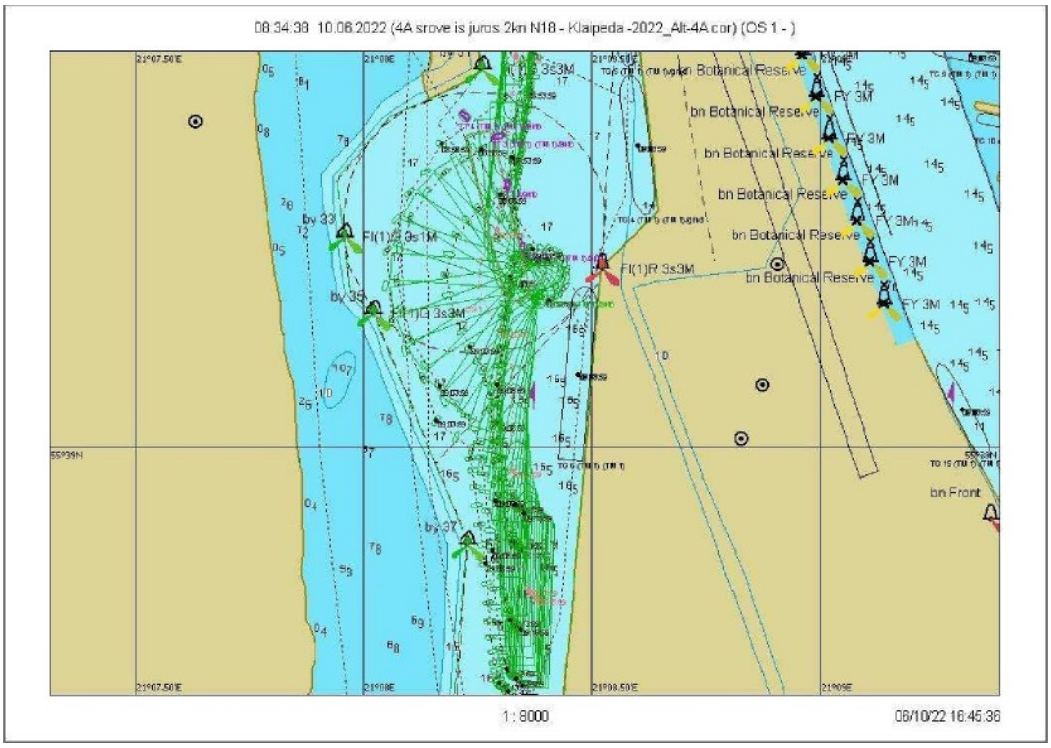


Fig. 7.3.267. Maneuver 36.2 – Ship's turning trajectory

Scenario 36. Wind N/18 m/s, current from the sea 2 knots Course 36.3

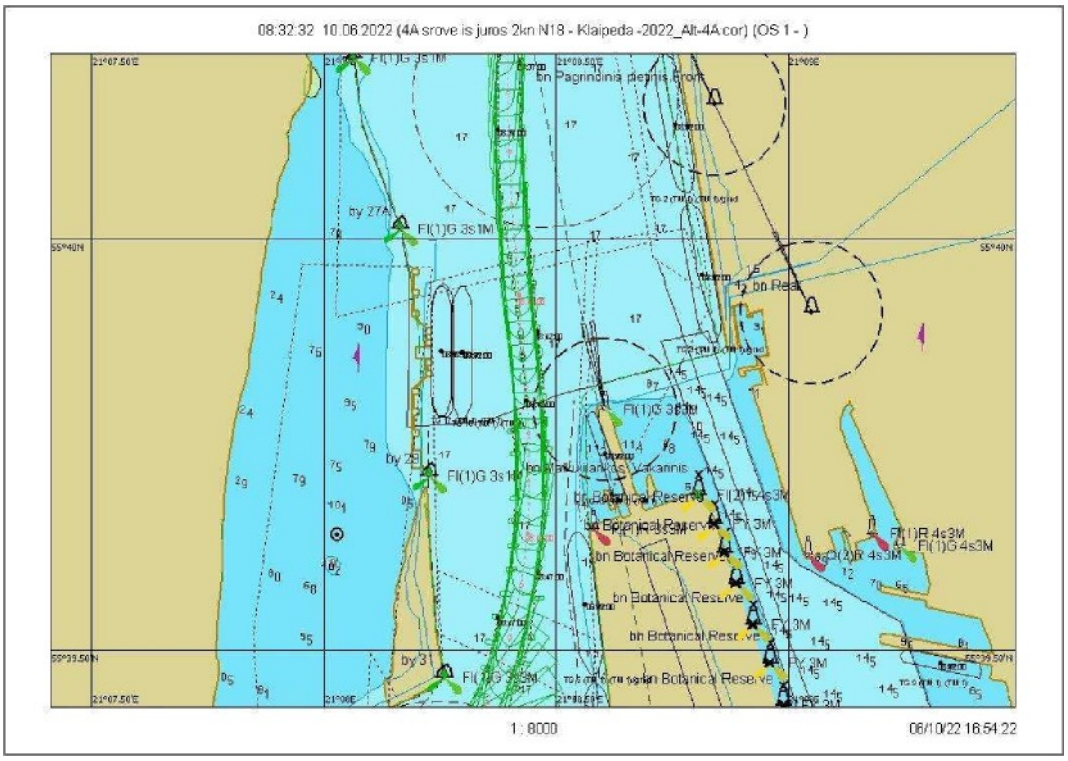


Fig. 7.3.268. Voyage 36.3 – graphical representation of the voyage from buoy No. 27A to No. 31

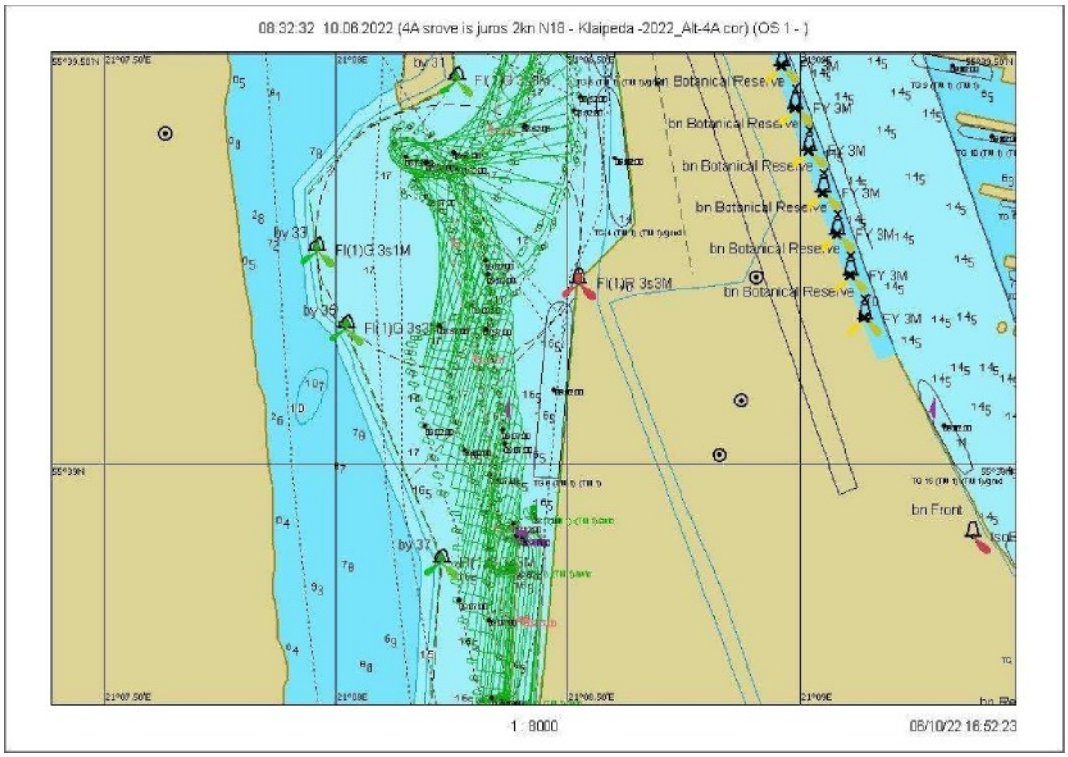
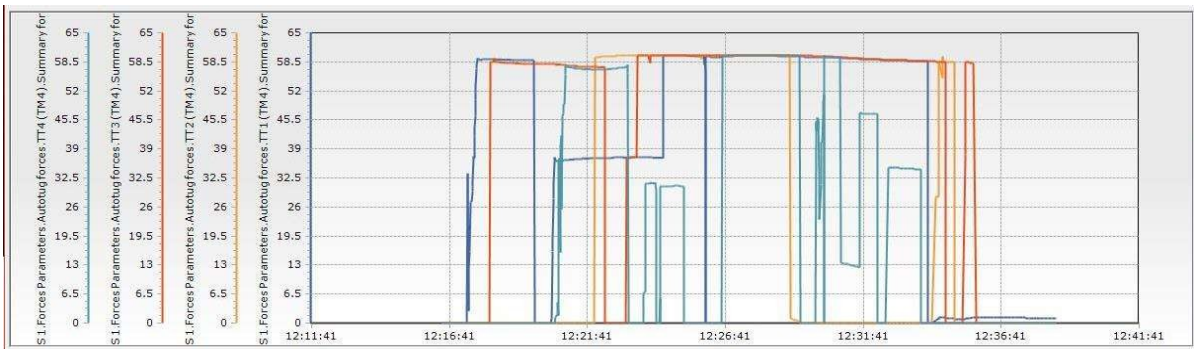


Fig. 7.3.269. Course 36.3 – Ship's turning trajectory

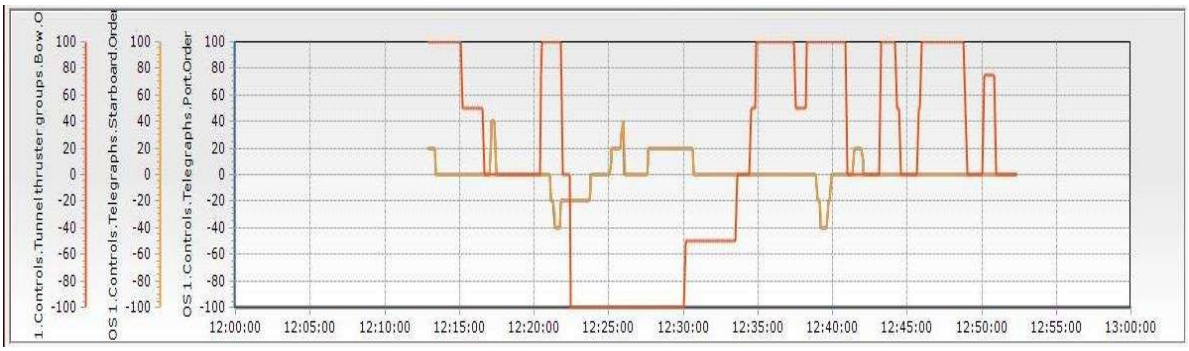
7.4. Empirical diagrams of tugboat and ship engine operation



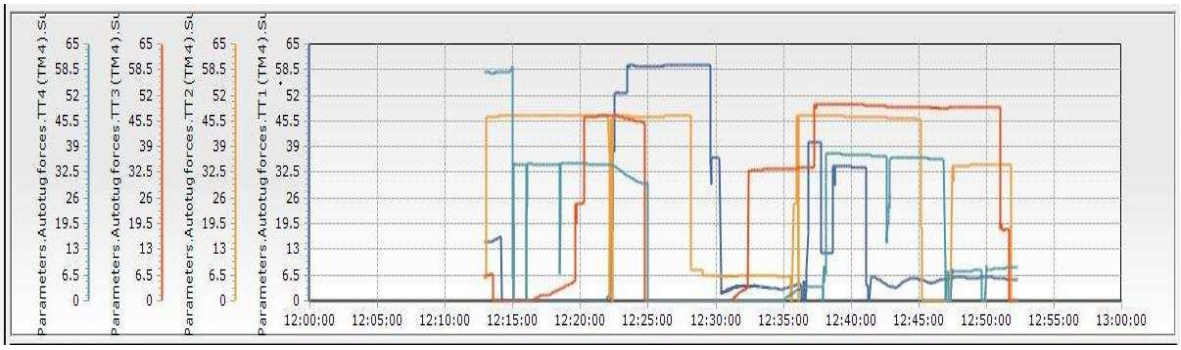
7.4.1 Fig. 2A Alternative—ship engine performance, voyage 7.2, wind N-10 m/s, current 0.7 knots from the shore



7.4.2 Fig. 2A Alternative – tugboat engine performance, sailing at 7.2 knots, wind N-10 m/s, current 0.7 knots from the shore

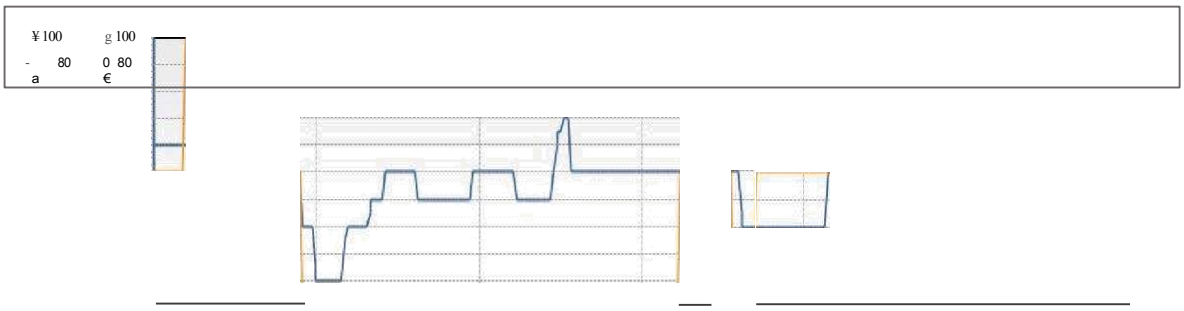


7.4.3 Fig. 2A Alternative – Ship engine operation, sailing at 9.1 knots with a wind of 10 m/s from the north and a current of 1.5 knots from the sea

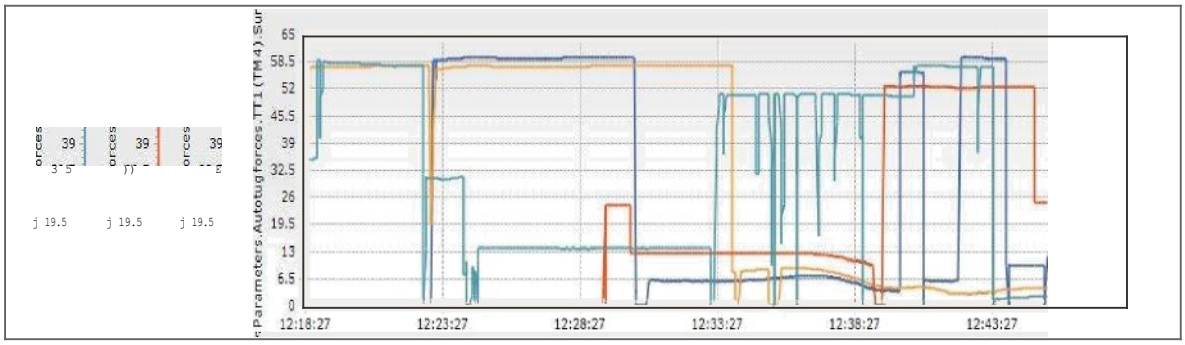


7.4.4 Fig. 2A Alternative – tugboat engine operation, sailing with a 9.1-knot wind from the north at 10 m/s, current 1.5 knots from the sea

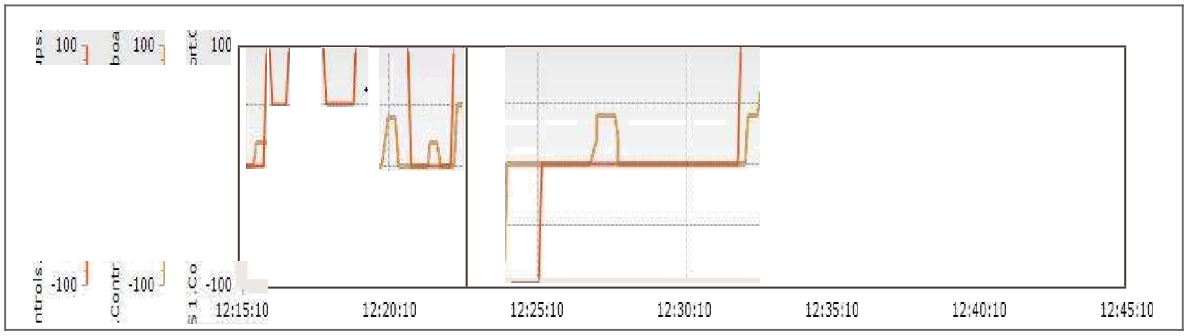
Fig. 7.3.269. Course 36.3 – Ship's turning trajectory



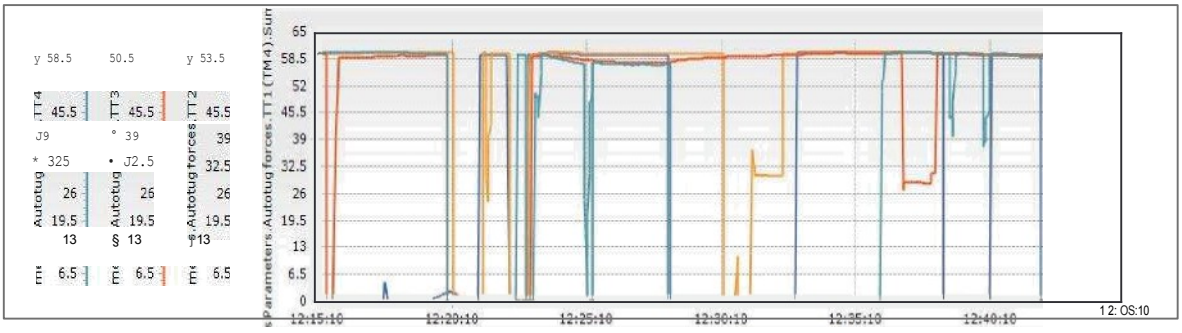
7.4.5 Fig. 2A Alternative—ship engine operation, sailing at 19.3 knots, wind N-14 m/s, current 0.7 knots from the sea



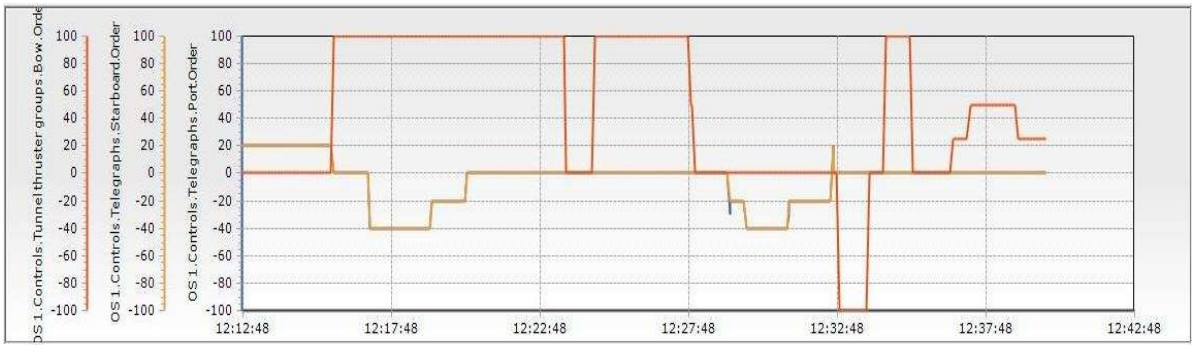
7.4.6 Fig. 2A Alternative—tugboat engine operation, sailing at 19.3 knots, wind N-14 m/s, current 0.7 knots from the sea



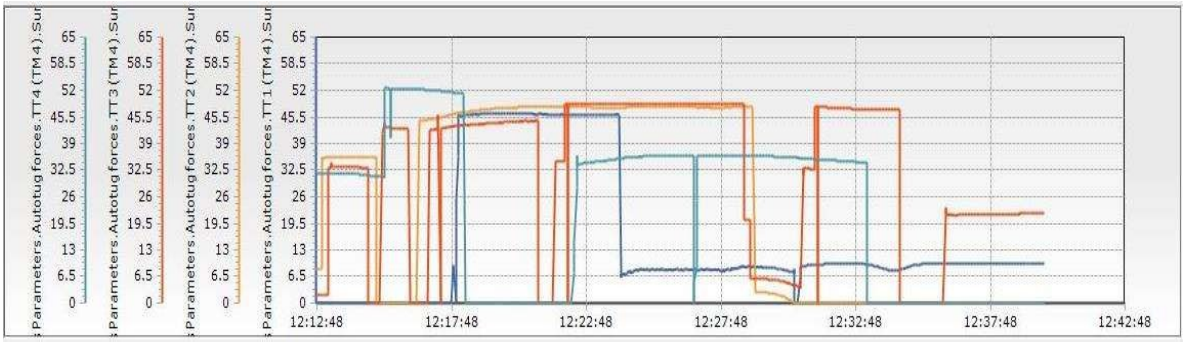
7.4.7 Fig. 2A Alternative—ship engine operation, sailing at 21.2 knots, wind N-14 m/s, current 1.5 knots from the sea



7.4.8 Fig. 2A Alternative—tugboat operation, sailing at 21.2 knots, wind N-14 m/s, current 1.5 knots from the sea



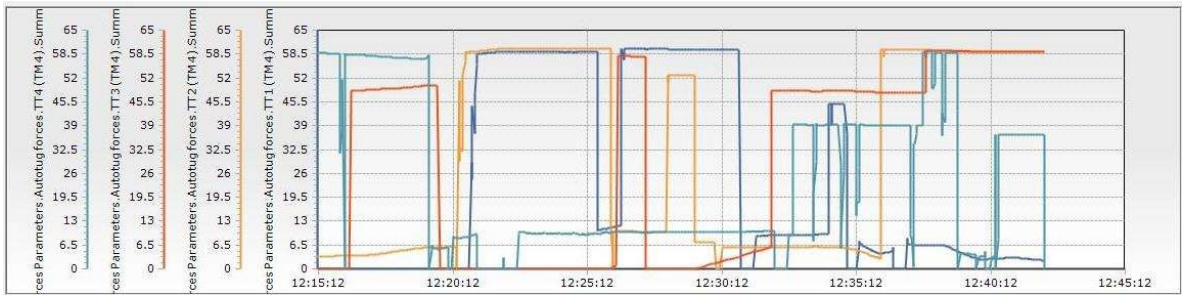
7.4.9 Fig. 2A Alternative – ship engine operation, sailing 8.1, wind NW-10 m/s, current 0.7 knots from the shore



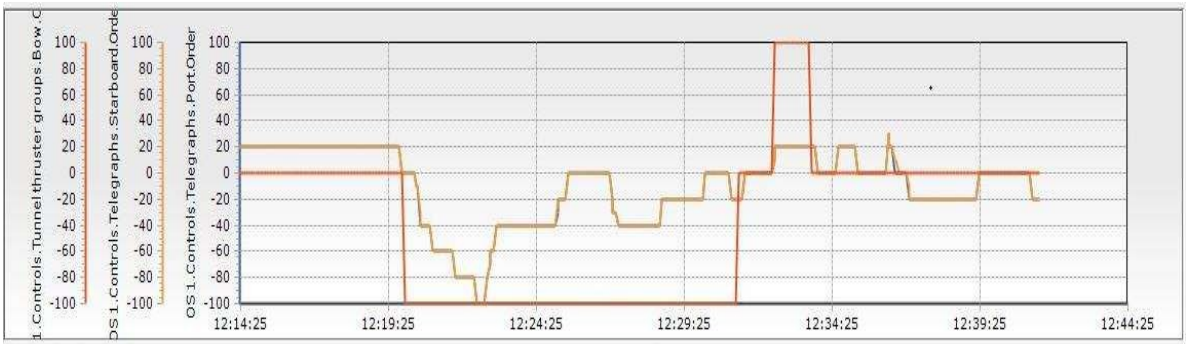
7.4.10 Fig. 2A Alternative – tugboat operation, sailing with a wind of 8.1 m/s from the northwest, current 0.7 knots from the shore



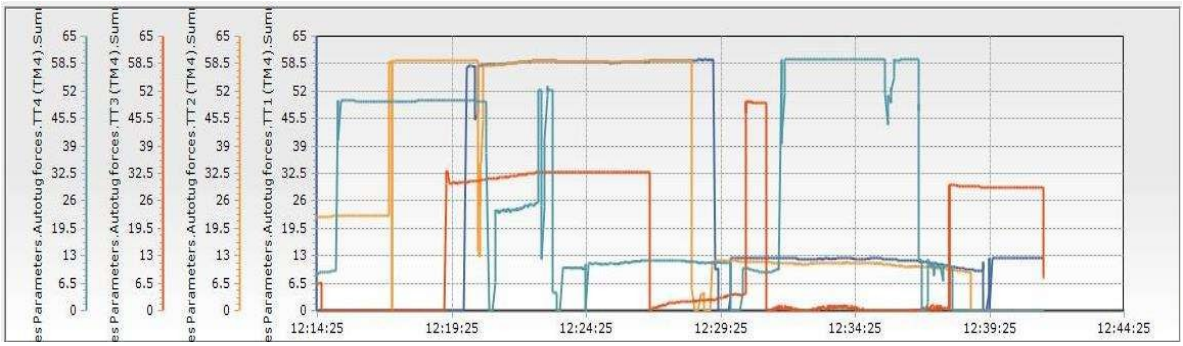
7.4.11 Fig. 2A Alternative – Ship engine operation, sailing at 10.3 knots, wind NW-10 m/s, current 1.5 knots from the sea



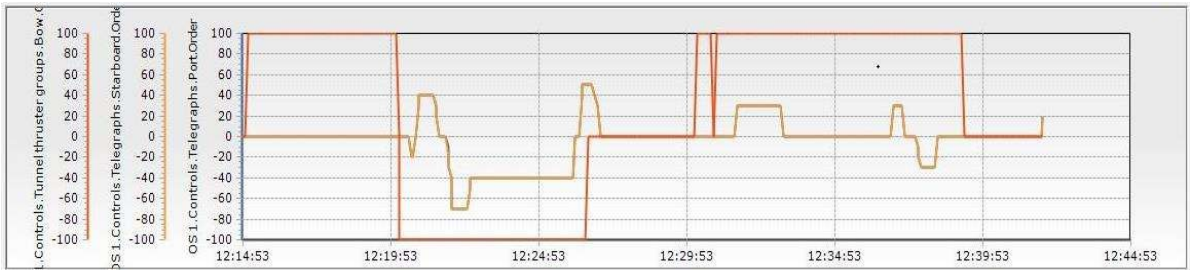
7.4.12 Fig. 2A Alternative – tugboat engine operation, sailing 10.3, wind NW-10 m/s, current 1.5 knots from the shore



7.4.13 Fig. 2A Alternative – ship engine operation, sailing at 20.1 knots, wind NW-14 m/s, current 0.7 knots from the sea



7.4.14 Fig. 2A Alternative – tugboat operation, sailing 20.1, wind NW-14 m/s, current 0.7 knots from Jfiros



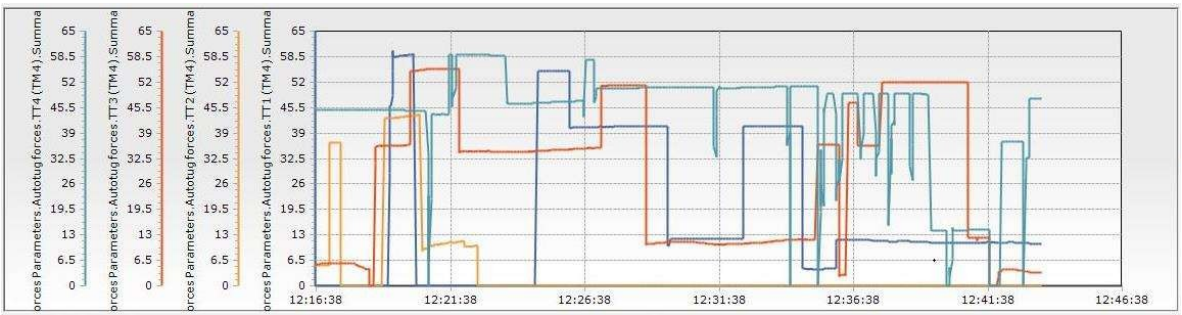
7.4.15 Fig. 2A Alternative – Ship engine operation, sailing at 22.2 knots, wind NW-14 m/s, current 1.5 knots from Jfiros



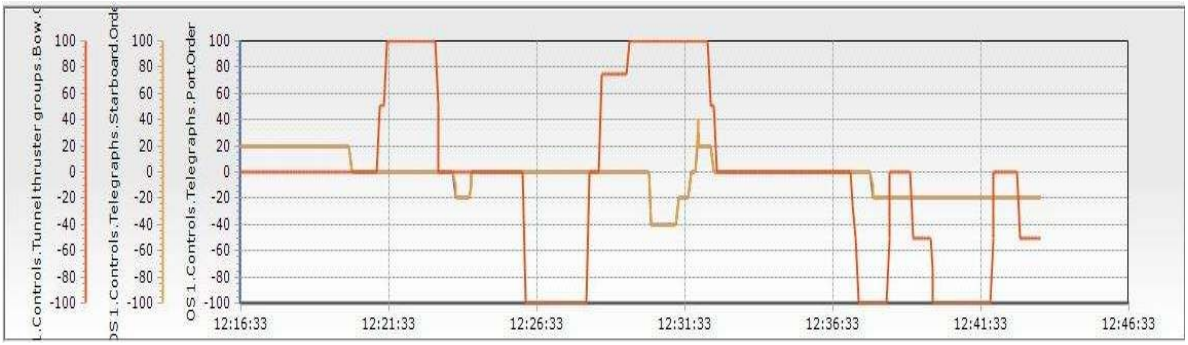
7.4.16 Fig. 2A Alternative – tugboat engine operation, sailing 22.2, wind NW-14 m/s, current 1.5 knots from the sea



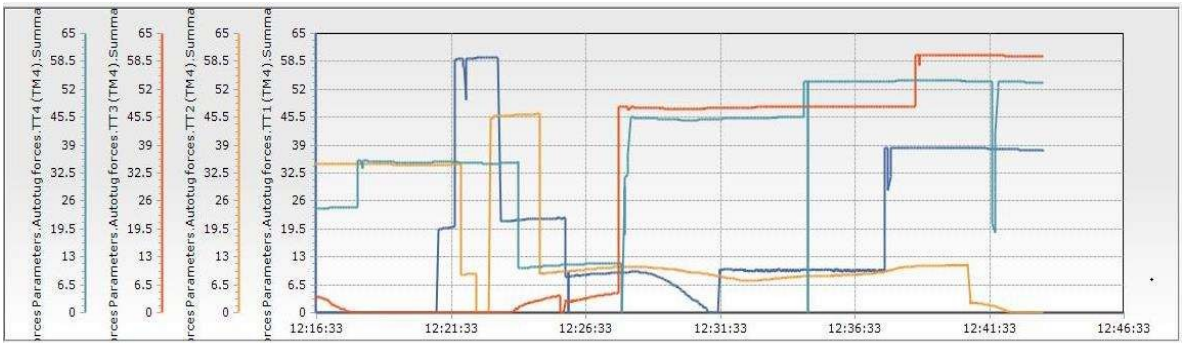
7.4.17 Fig. 2A Alternative – Ship engine operation, sailing at 1.3 knots, wind SW-10 m/s, current 0.7 knots from the shore



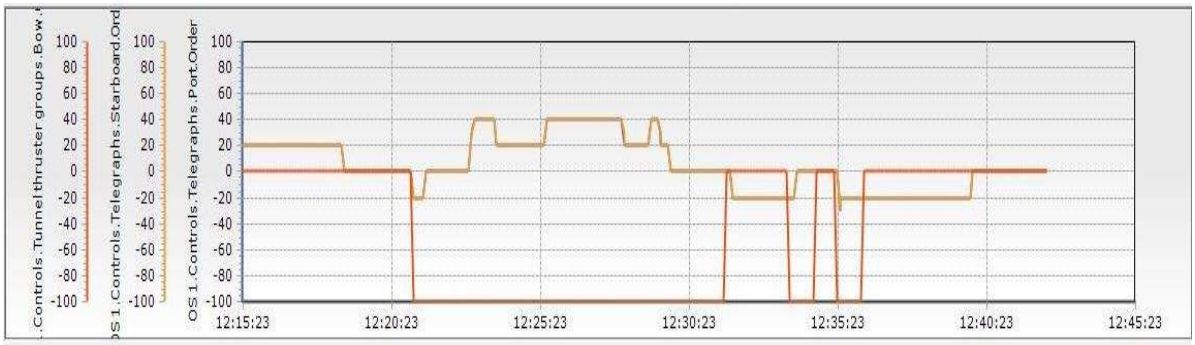
7.4.18 Fig. 2A Alternative – tugboat operation, sailing with a 1.3 m/s wind from the SW, current 0.7 knots from the sea



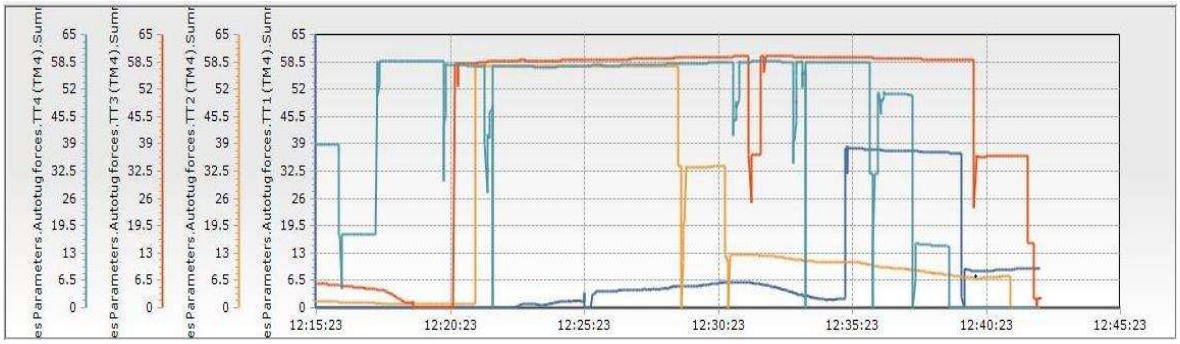
7.4.19 Fig. 2A Alternative – Ship engine operation, sailing 3.1, wind SW-10 knots, current 1.5 knots | jfirą



7.4.20 Fig. 2A Alternative – tugboat operation, sailing with a 3.1 m/s wind from the southwest (SW), current 1.5 knots in the sea



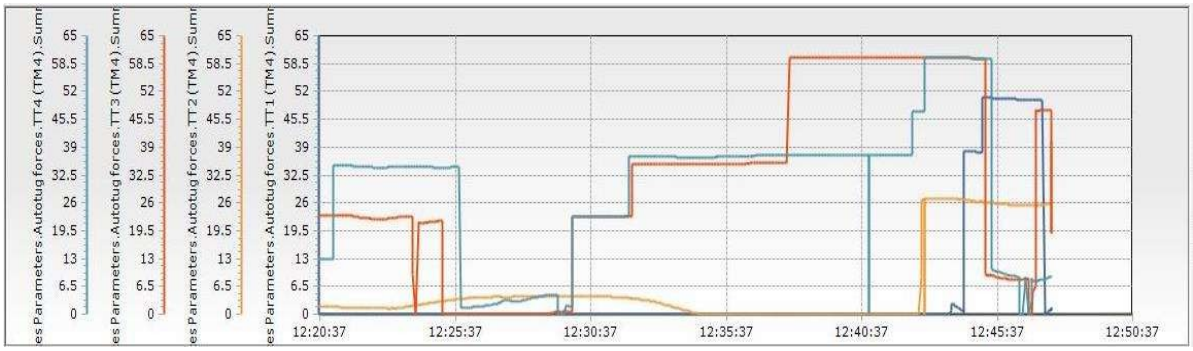
7.4.21 Fig. 2A Alternative – Ship engine operation, sailing 13.1, wind SW-14 knots, current 0.7 knots | at sea



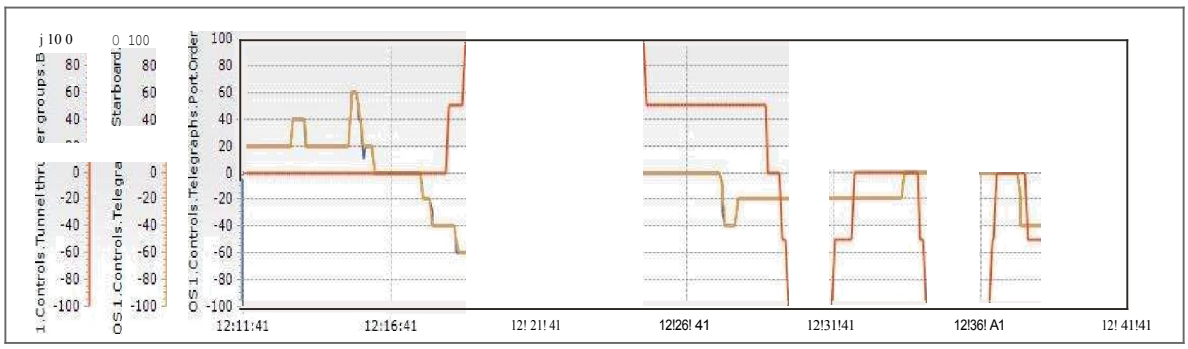
7.4.22 Fig. 2A Alternative – tugboat engine operation, sailing 13.1, wind SW-14 knots, current 0.7 knots at sea



7.4.23 Fig. 2A Alternative – ship engine operation, sailing 15.1, wind SW-14 knots, current 1.5 knots | at sea



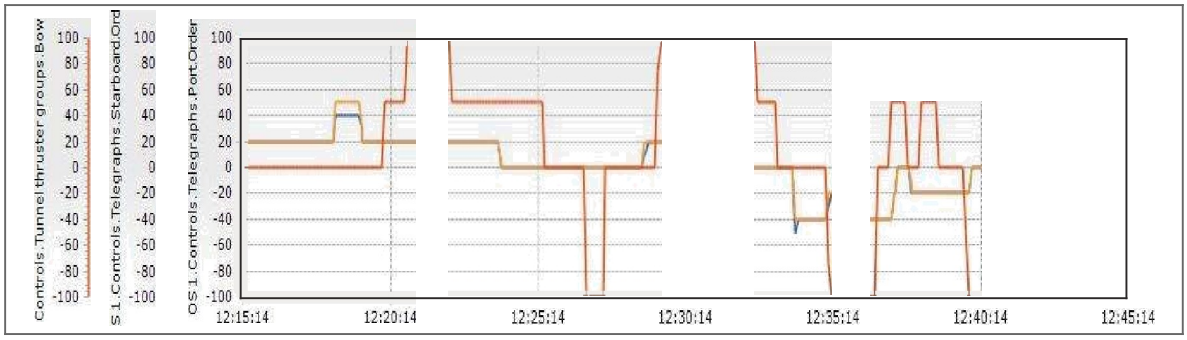
7.4.24 Fig. 2A Alternative – tugboat operation, sailing 15.1, wind SW-14 knots, current 1.5 knots | at sea



7.4.25 Fig. 2A Alternative—ship engine operation, sailing 2.1 wind W-10 m/s, current 0.7 knots



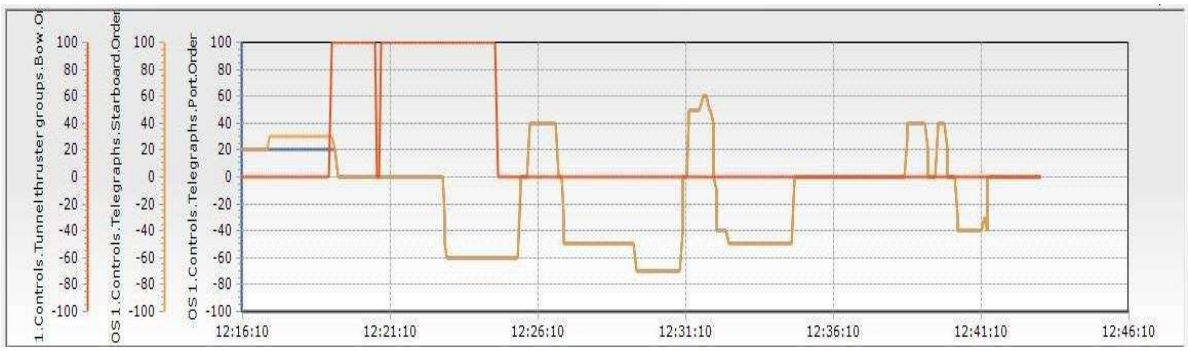
7.4.26 Fig. 2A Alternative—tugboat engine operation, sailing with a 2.1 m/s wind from the west (W), current 0.7 knots



7.4.27 Fig. 2A Alternative—ship engine operation, sailing 4.1, wind W-10 m/s, current 1.5 knots



7.4.28 Fig. 2A Alternative – tugboat engine operation, sailing 4.1 wind W-10 m/s, current 1.5 knots into the wind



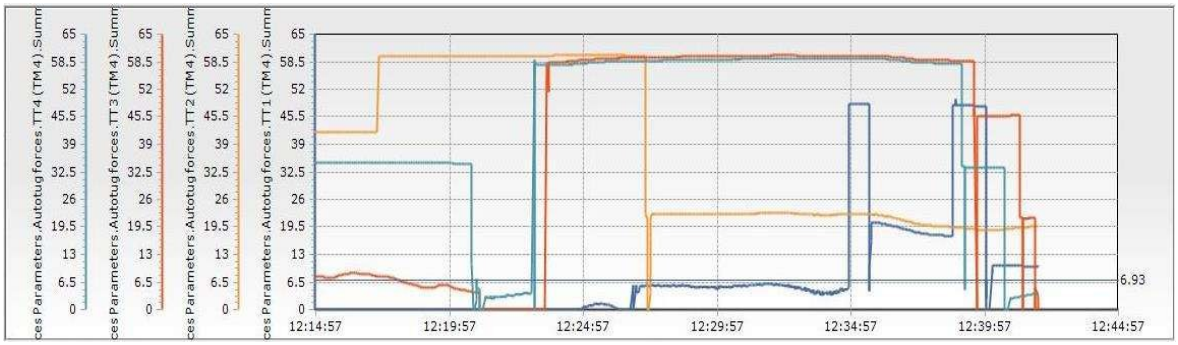
7.4.29 Fig. 2A Alternative – Ship engine operation, sailing in 14.2 m/s wind from the west, 0.7 knots current, at sea



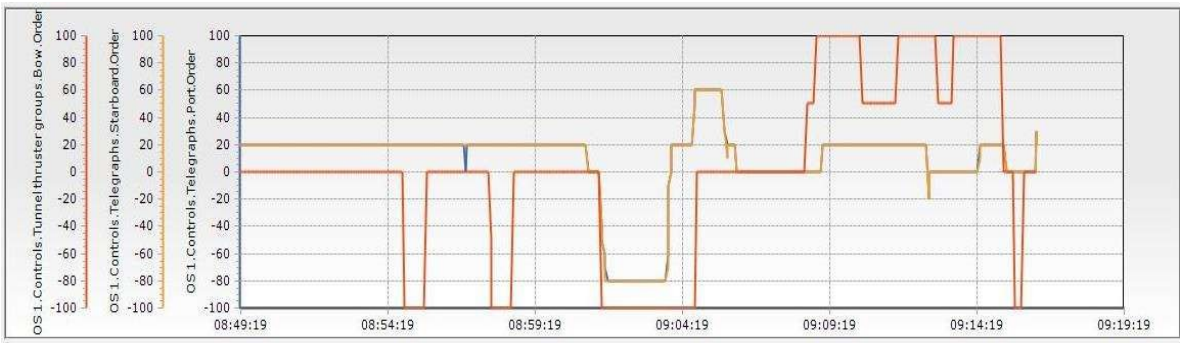
7.4.30 Fig. 2A Alternative – tugboat operation, sailing 14.2, wind W-14 knots, current 0.7 knots | jirą



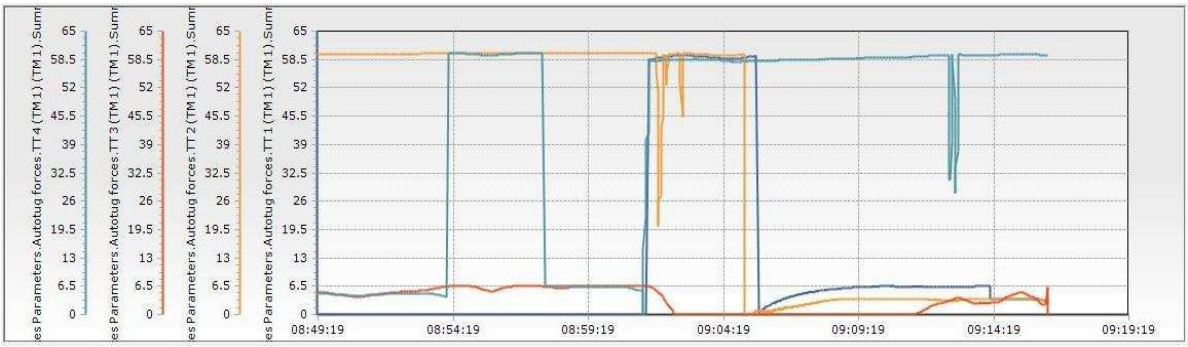
7.4.31 Fig. 2A Alternative – Ship engine operation, sailing at 16.3 knots, wind W-14 m/s, current 1.5 knots | jfirą



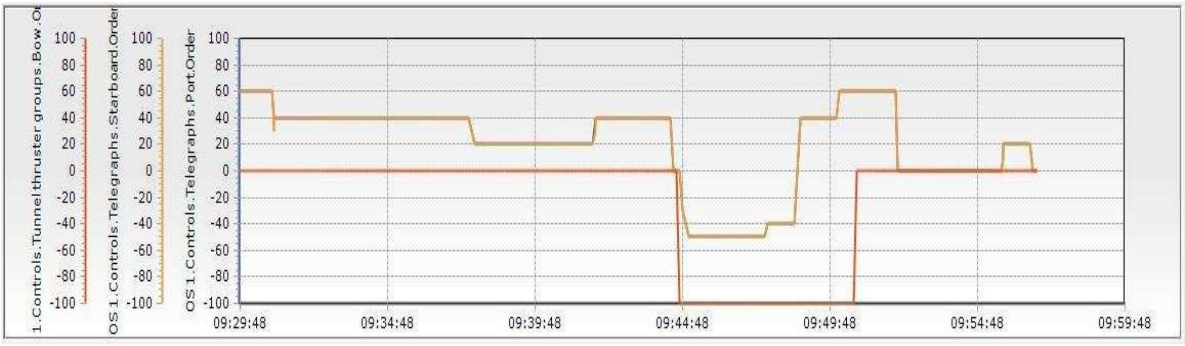
7.4.32 Fig. 2A Alternative – tugboat propulsion, sailing at 16.3 knots, wind W-14 m/s, current 1.5 knots, and sea state



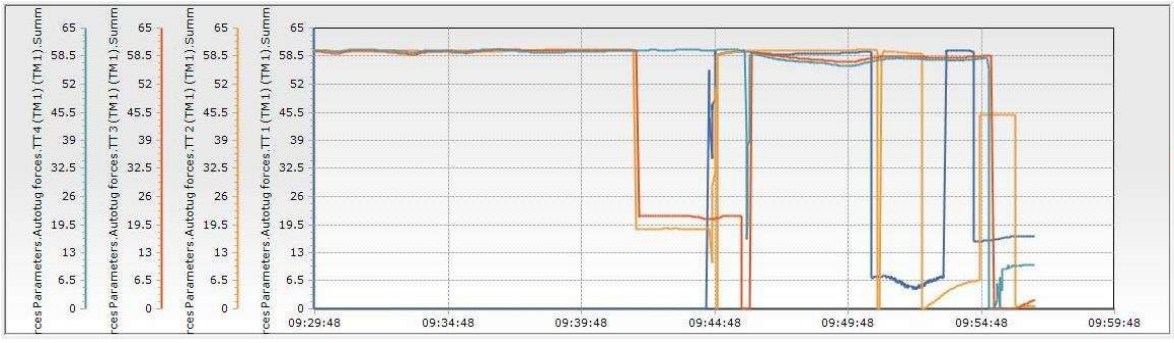
7.4.33 Fig. 3A Alternative – ship engine operation, sailing at 7.2 knots, wind N-10 m/s, current 0.7 knots from the sea



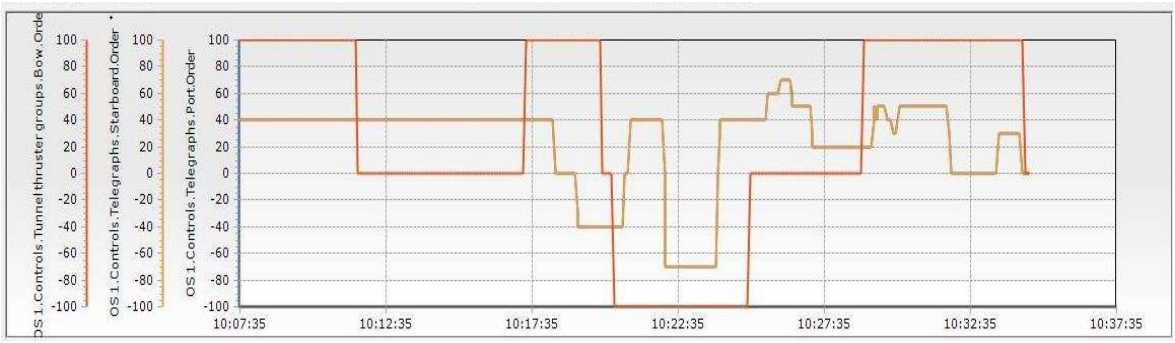
7.4.34 Fig. 3A Alternative – tugboat operation, sailing with a 7.2 m/s wind from the north (N), current 0.7 knots from the sea



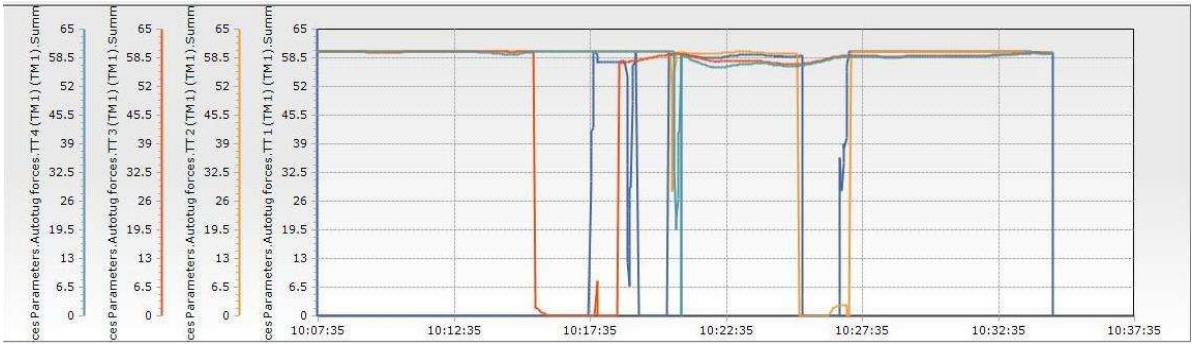
7.4.35 Fig. 3A Alternative – Ship engine operation, sailing in 9.3 m/s wind from the north, current 1.5 knots from the sea



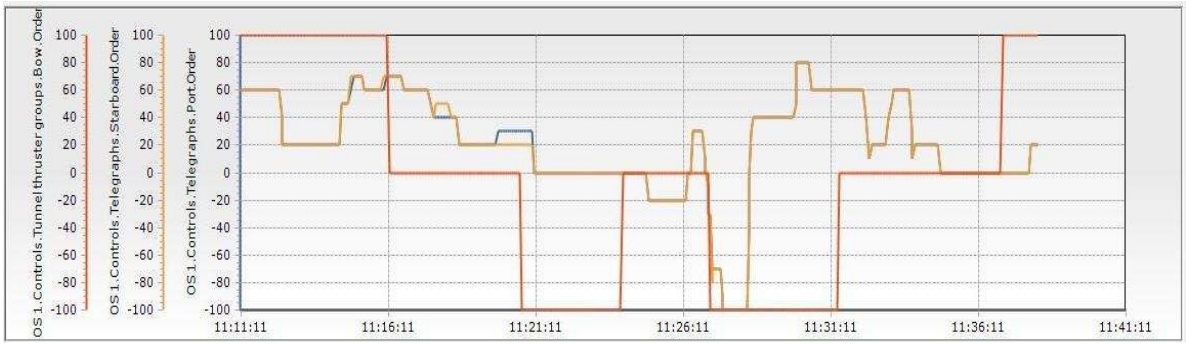
7.4.36 Fig. 3A Alternative – tugboat engine operation, sailing at 9.3 knots, wind N-10 m/s, current 1.5 knots from the shore



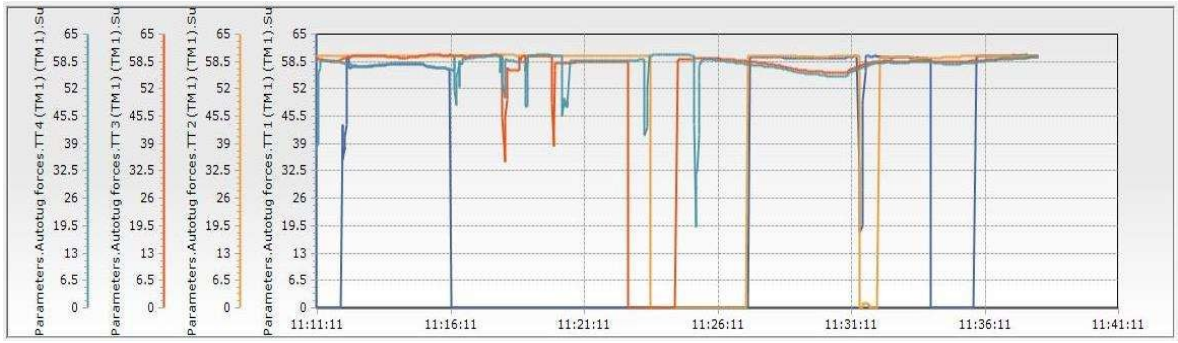
7.4.37 Fig. 3A Alternative – Ship engine operation, sailing at 19.1 knots, wind N-14 m/s, current 0.7 knots from the sea



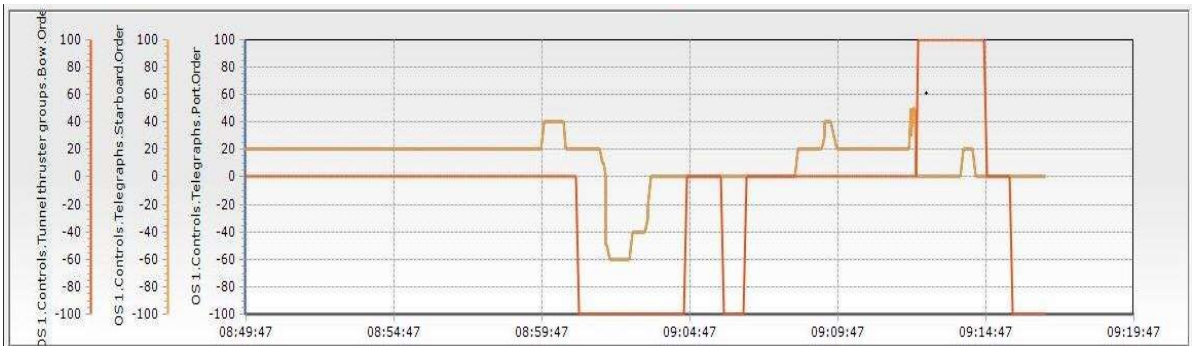
7.4.38 Fig. 3A Alternative – tugboat operation, sailing at 19.1 knots, wind N-14 m/s, current 0.7 knots from the shore



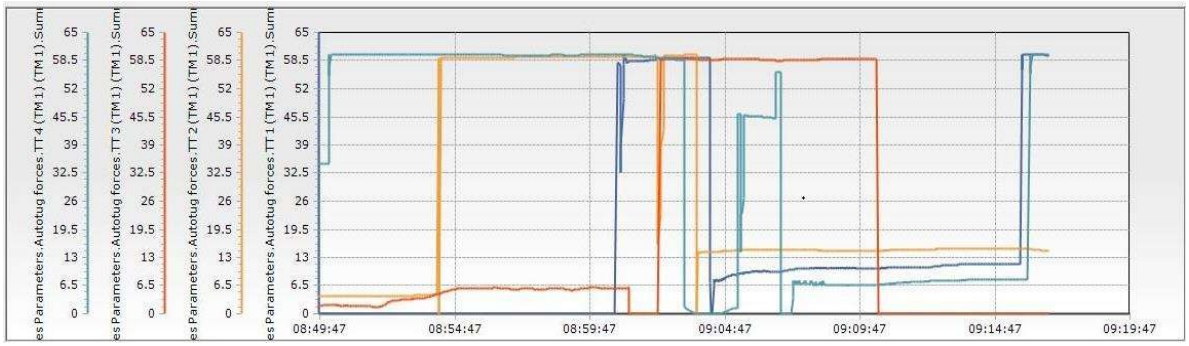
7.4.39 Fig. 3A Alternative – Ship engine operation, sailing at 21.1 knots, wind N-14 m/s, current 1.5 knots from the shore



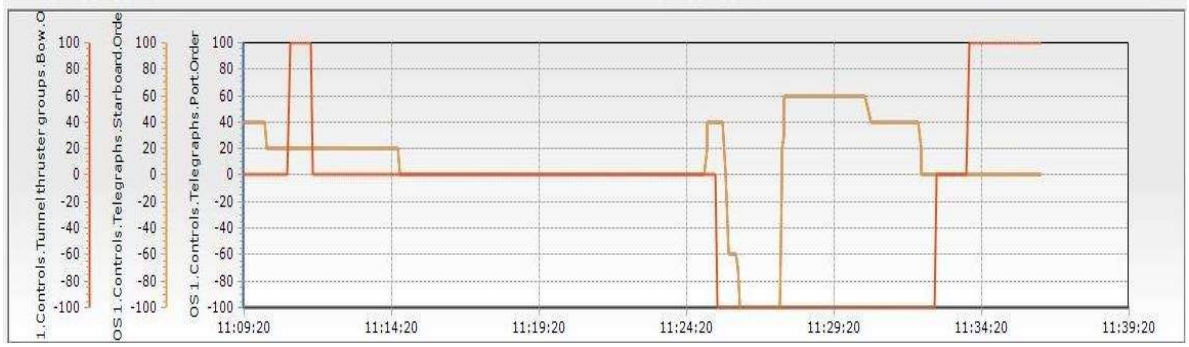
7.4.40 Fig. 3A Alternative – tugboat engine operation, sailing at 21.1 knots, wind N-14 m/s, current 1.5 knots from the shore



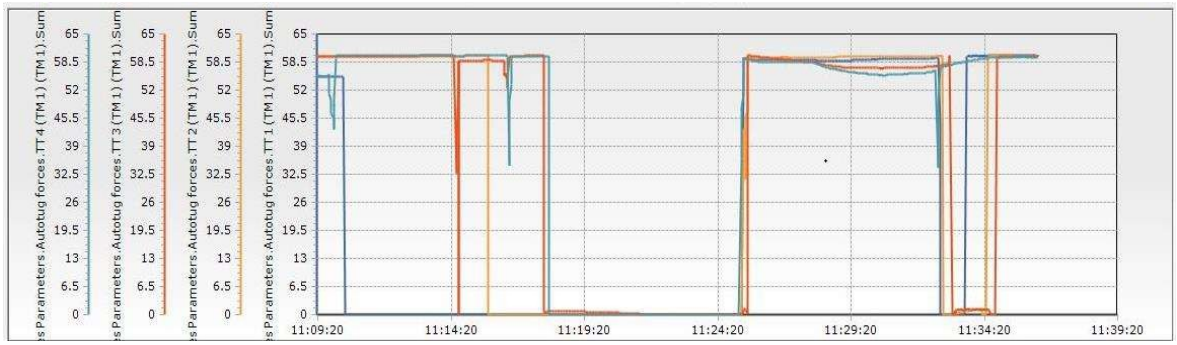
7.4.41 Fig. 3A Alternative – Ship engine operation, sailing at 8.1 knots, wind NW-10 m/s, current 0.7 knots from Jfiros



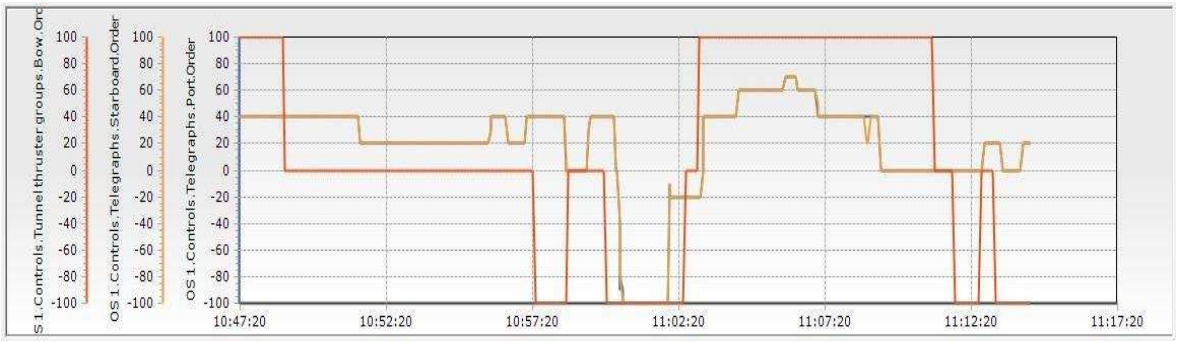
7.4.42 Fig. 3A Alternative – tugboat operation, sailing 8.1, wind NW-10 m/s, current 0.7 knots from the sea



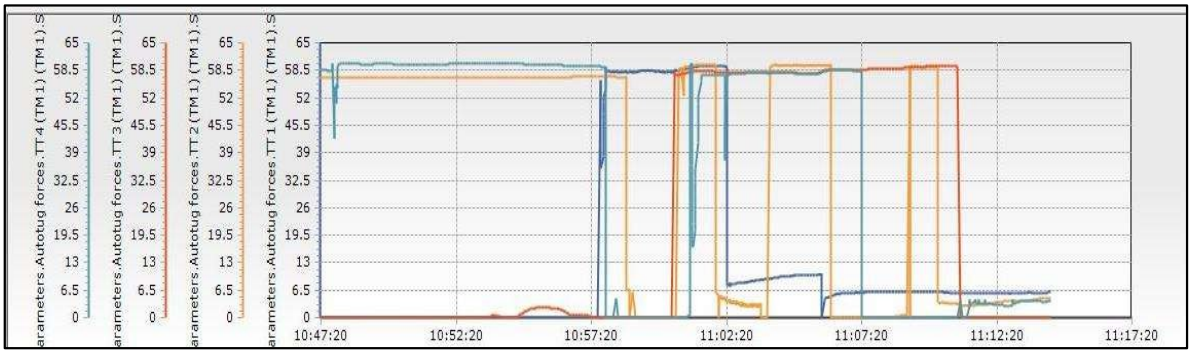
7.4.43 Fig. 3A Alternative – Ship engine operation, sailing at 11.1 knots, wind NW-10 m/s, current 1.5 knots from the sea



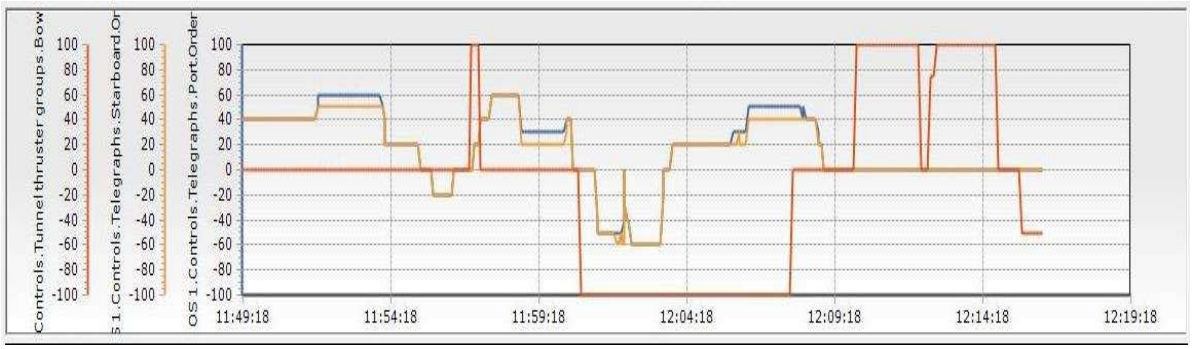
7.4.44 Fig. 3A Alternative – tugboat engine operation, sailing at 11.1 knots, wind NW-10 m/s, current 1.5 knots from the shore



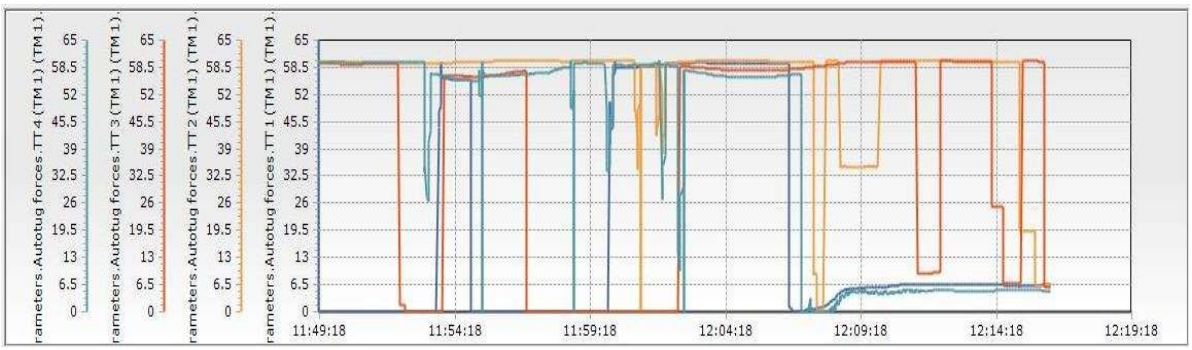
7.4.45 Fig. 3A Alternative – Ship engine operation, sailing at 20.2, wind NW-14 m/s, current 0.7 knots from the sea



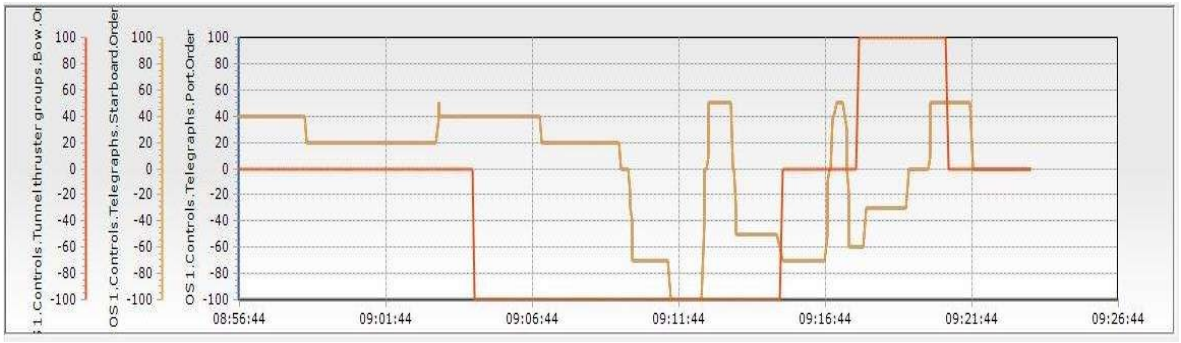
7.4.46 Fig. 3A Alternative – tugboat operation, sailing 20.2, wind NW-14 m/s, current 0.7 knots from Jfiros



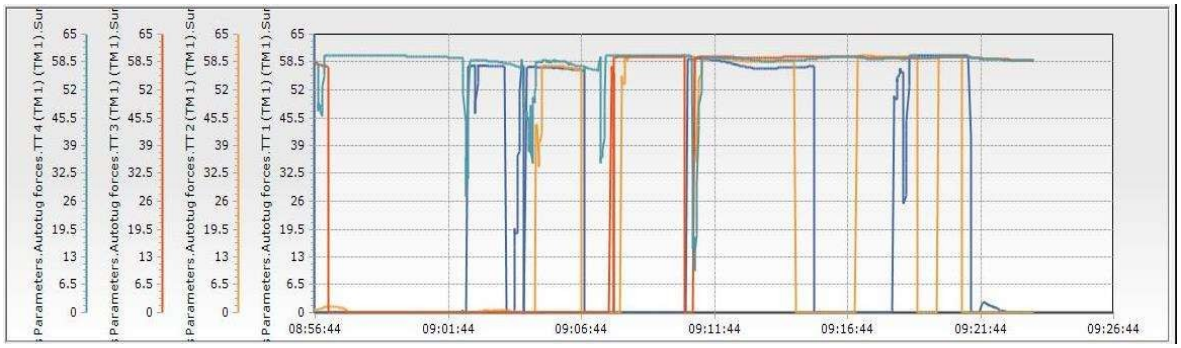
7.4.47 Fig. 3A Alternative – ship engine operation, sailing at 22.2 knots, wind NW-14 m/s, current 1.5 knots from the sea



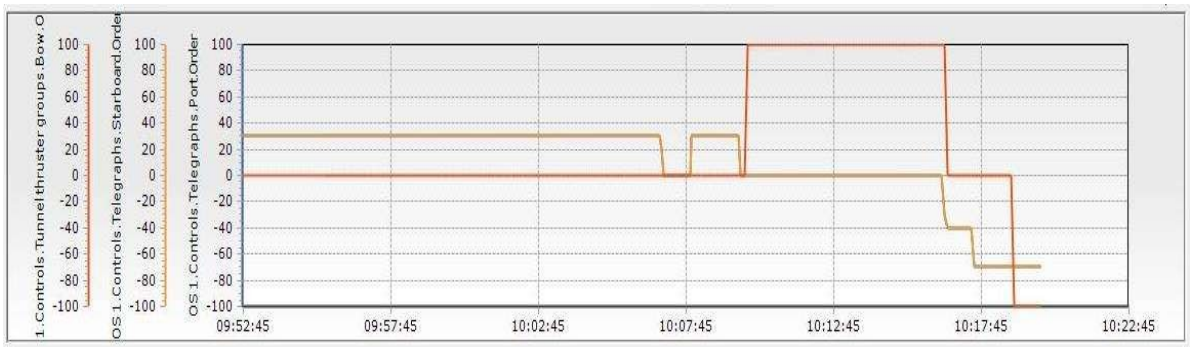
7.4.48 Fig. 3A Alternative – tugboat operation, sailing at 22.2 knots, wind NW-14 m/s, current 1.5 knots from the sea



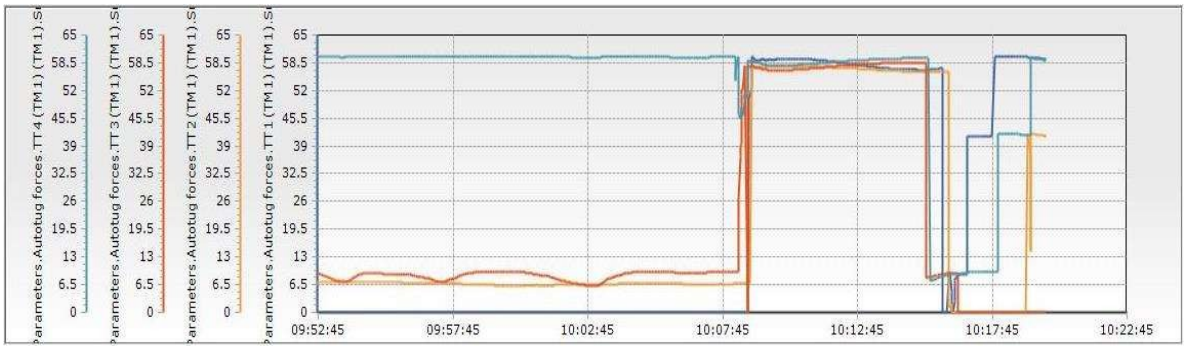
7.4.49 Fig. 3A Alternative – Ship engine operation, sailing 1.1, wind SW-10 m/s, current 0.7 knots | jÎirą



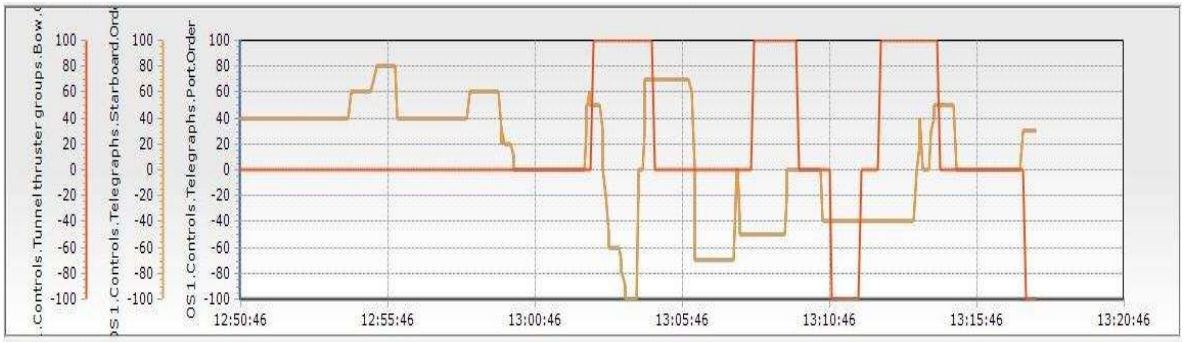
7.4.50 Fig. 3A Alternative – tugboat operation, sailing 1.1, wind SW-10 m/s, current 0.7 knots from the sea



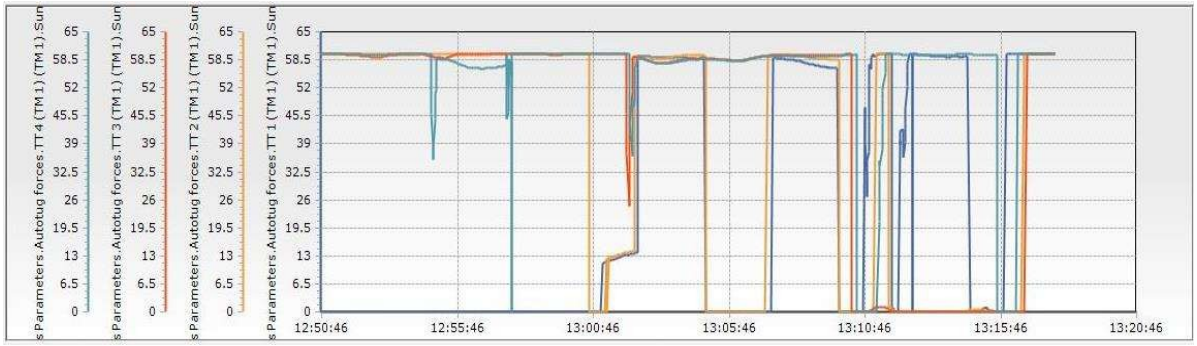
7.4.51 Fig. 3A Alternative: Ship engine operation, sailing at 1.1, wind SW-10 knots, current 0.7 knots | jfirą



7.4.52 Fig. 3A Alternative – tugboat engine operation, sailing 3.3 m/s wind SW-10 m/s, current 1.5 knots



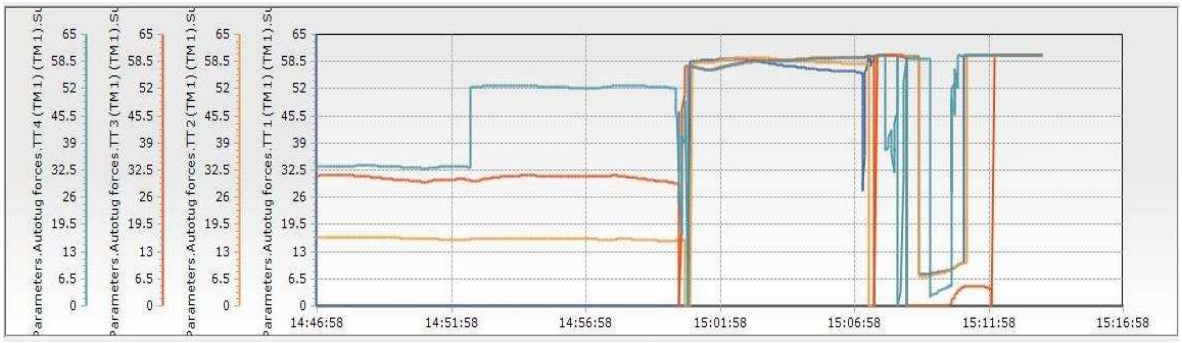
7.4.53 Fig. 3A Alternative: Ship engine operation, sailing at 13.3 knots, wind SW 14 knots, current 0.7 knots | jÌirą



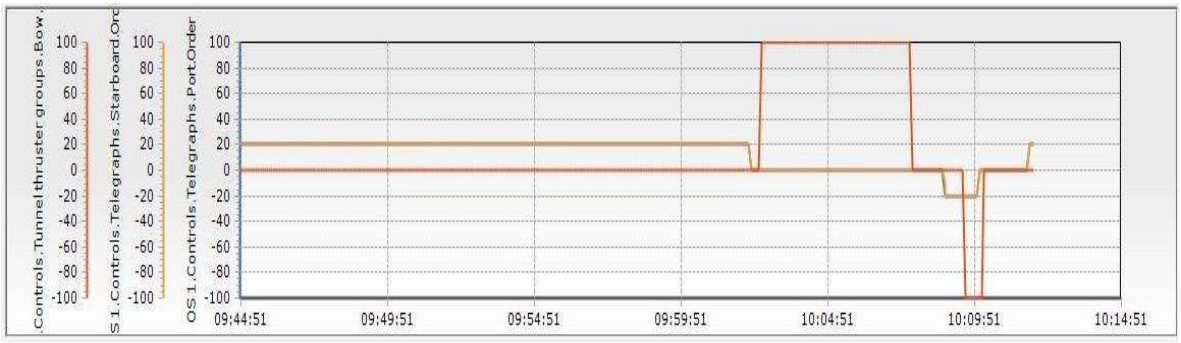
7.4.54 Fig. 3A Alternative – tugboat operation, sailing at 13.3 knots, wind SW-14 mph, current 0.7 knots | jÌirą



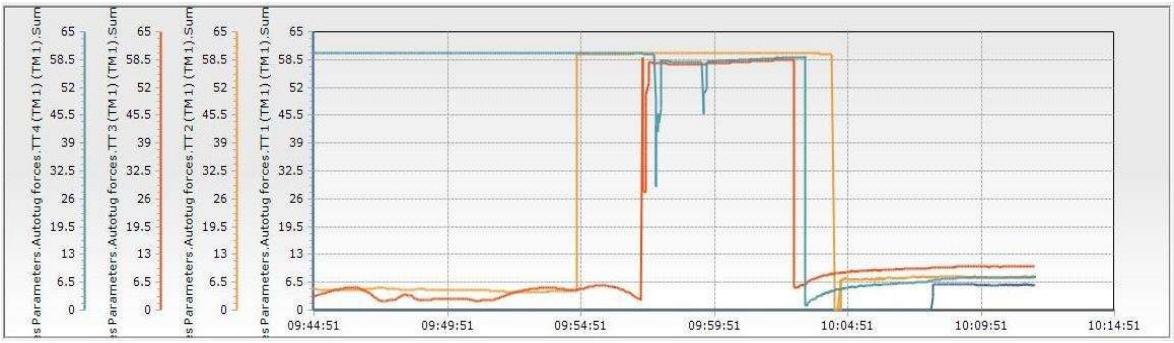
7.4.55 Fig. 3A Alternative – Ship engine operation, sailing at 15.2 knots, wind SW-14 knots, current 1.5 knots | jÌirą



7.4.56 Fig. 3A Alternative: tugboat engine operation, sailing at 15.2 knots, wind SW-14 knots, current 1.5 knots



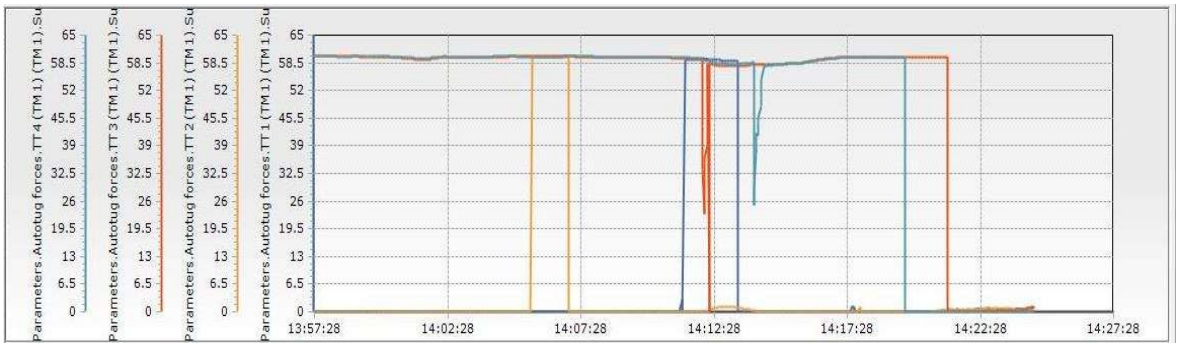
7.4.57 Fig. 3A Alternative – Ship engine operation, sailing at 2.2 knots, wind W-10 mph, current 0.7 knots | sea



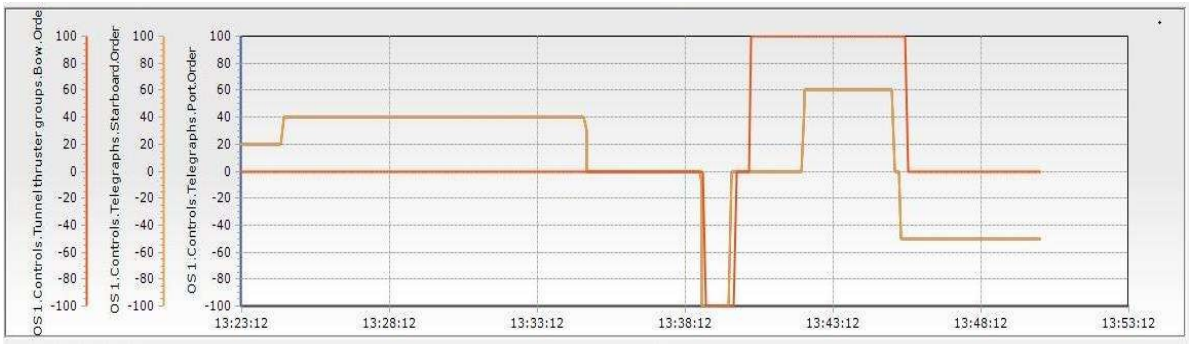
7.4.58 Fig. 3A Alternative – tugboat operation, sailing 2.2, wind W-10 knots, current 0.7 knots } sea



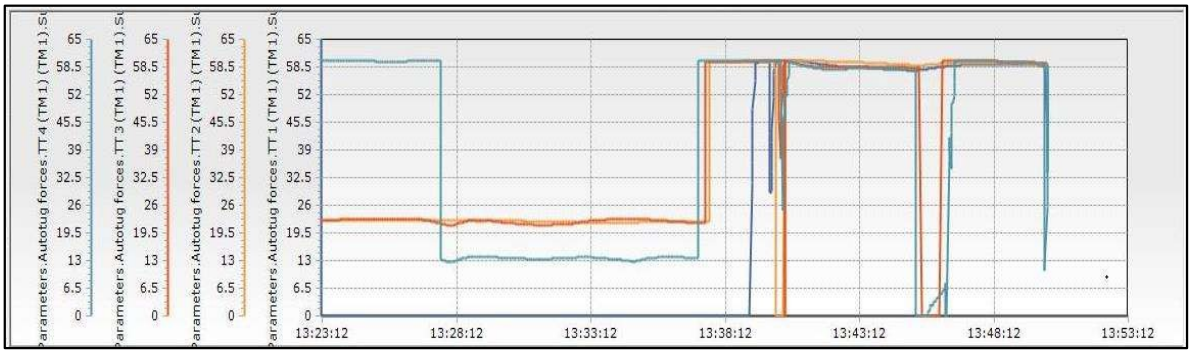
7.4.59 Fig. 3A Alternative – Ship engine operation, sailing with a 4.3 m/s wind from the west, current 1.5 knots | jfirą



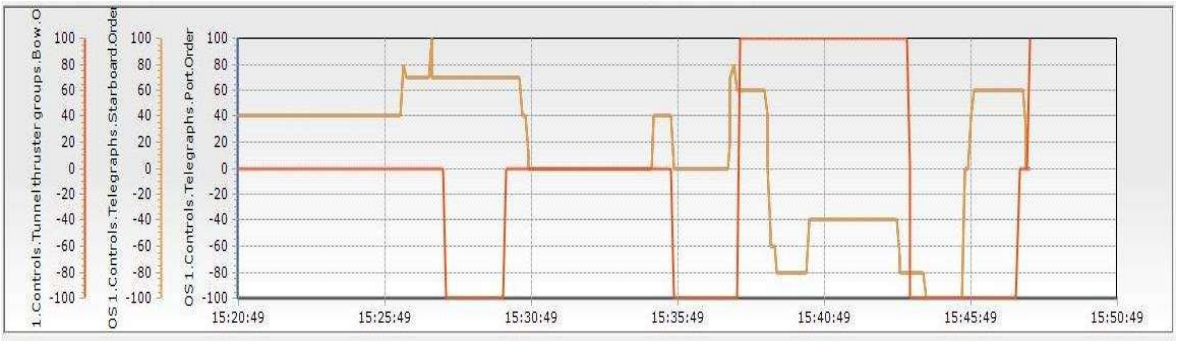
7.4.60 Fig. 3A Alternative: tugboat operation, sailing at 4.3 knots, wind W-10 m/s, current 1.5 knots



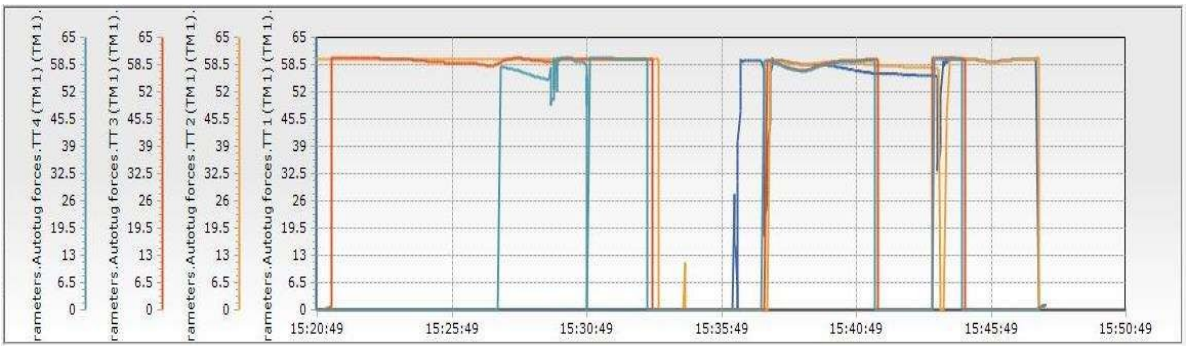
7.4.61 Fig. 3A Alternative: Ship engine operation, sailing with a 14.1 m/s wind from the west, current 0.7 knots



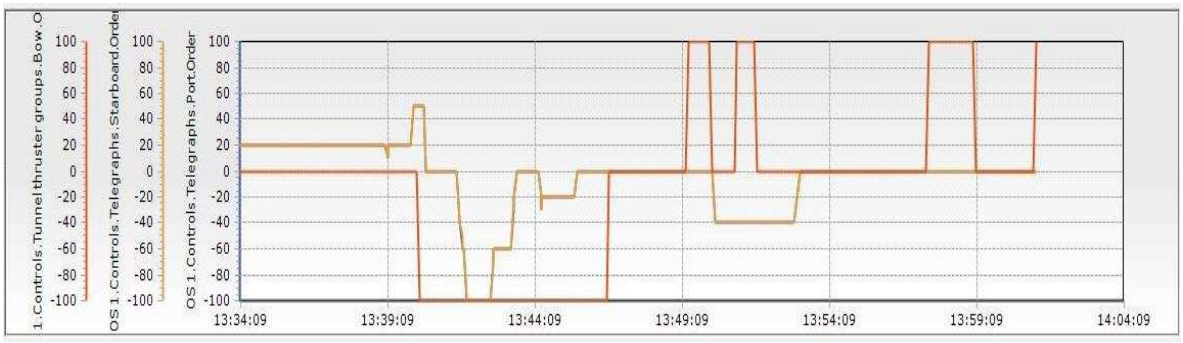
7.4.62 Fig. 3A Alternative – tugboat engine operation, sailing 14.1, wind W-14 knots, current 0.7 knots in the sea



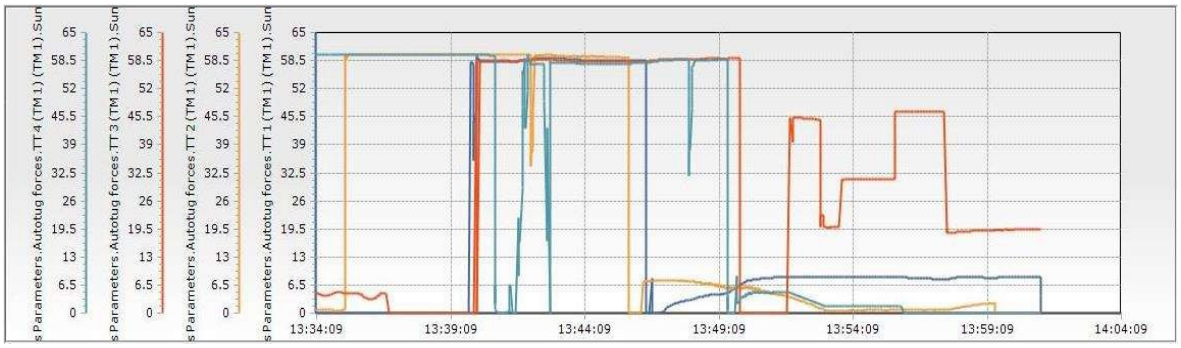
7.4.63 Fig. 3A Alternative – Ship engine operation, sailing at 16.2 knots, wind W-14 m/s, current 1.5 knots | jfirą



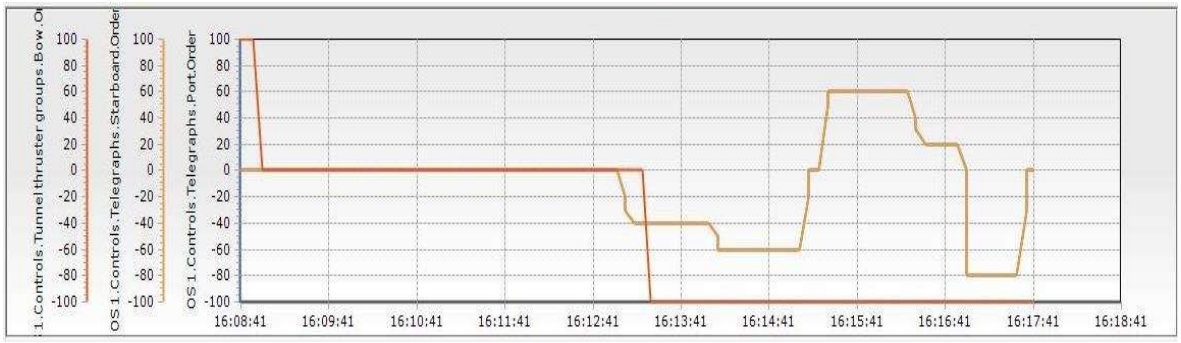
7.4.64 Fig. 3A Alternative – tugboat operation, sailing at 16.2 knots, wind W-14 m/s, current 1.5 knots | jfirą



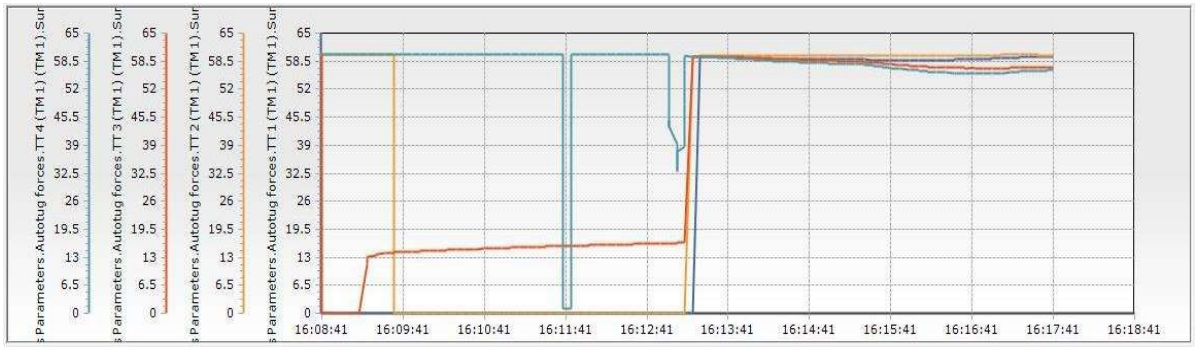
7.4.65 Fig. 4A Alternative – Ship engine operation, sailing at 7.1 knots, wind W-10 m/s, current 0.7 knots from jfirą



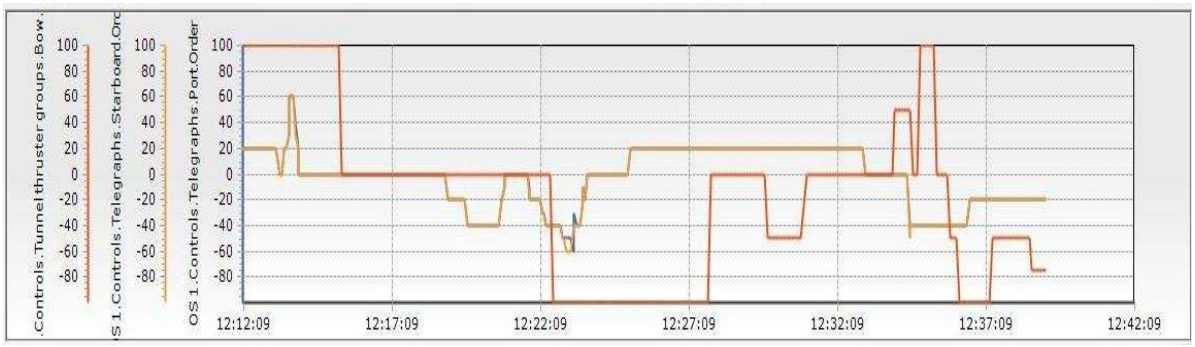
7.4.66 Fig. 4A Alternative – tugboat engine operation, sailing at 7.1 knots, wind N-10 m/s, current 0.7 knots from jfira



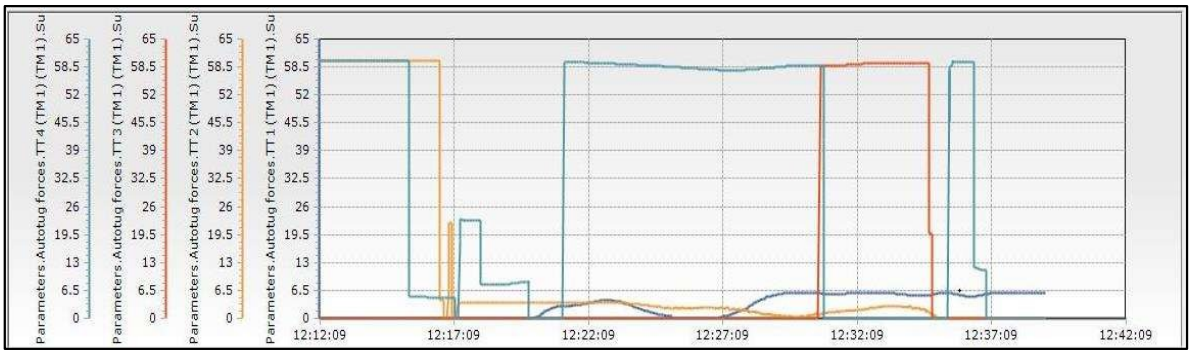
7.4.67 Fig. 4A Alternative – Ship engine operation, sailing in 8.2 m/s wind from the north, current 1.5 knots from the shore



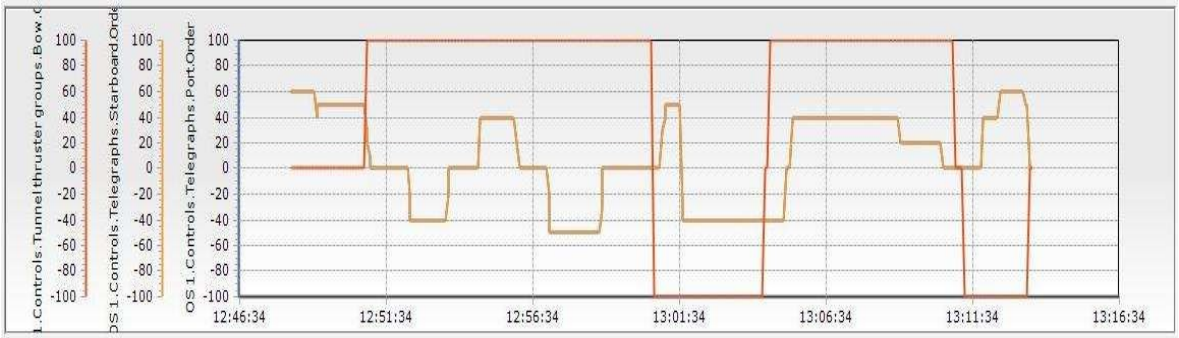
7.4.68 Fig. 4A Alternative – tugboat engine operation, sailing at 8.2 knots, wind N-10 m/s, current 1.5 knots from the shore



7.4.69 Fig. 4A Alternative – Ship engine operation, sailing at 19.3 knots, wind N-14 m/s, current 0.7 knots from the shore



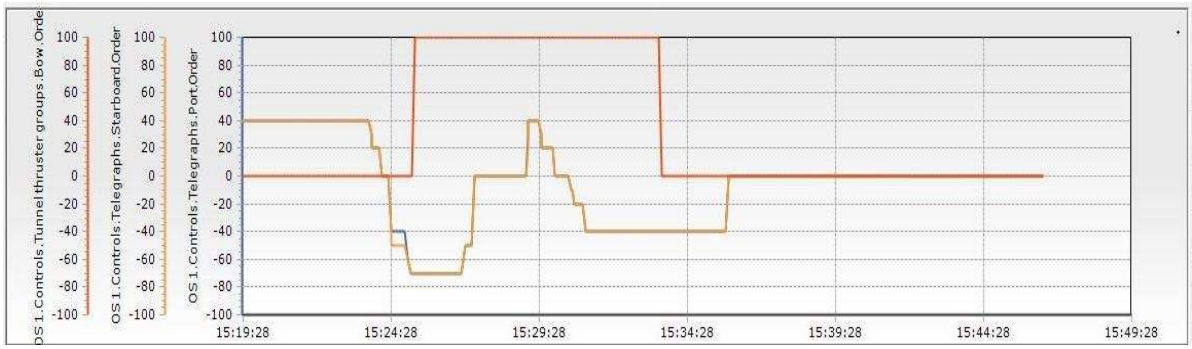
7.4.70 Fig. 4A Alternative – tugboat operation, sailing at 19.3 knots, wind N-14 m/s, current 0.7 knots from the shore



7.4.71 Fig. 4A Alternative – Ship engine operation, sailing at 21.2 knots, wind N-14 m/s, current 1.5 knots from Jfiros



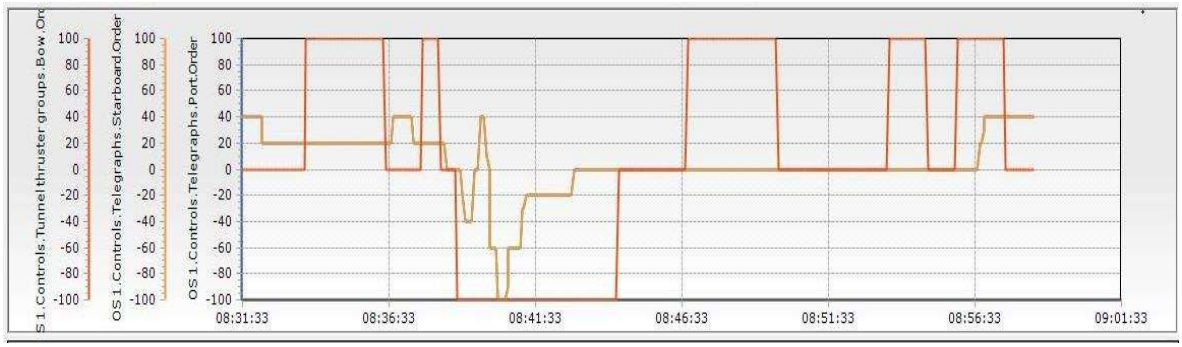
7.4.72 Fig. 4A Alternative – tugboat operation, sailing at 21.2 knots, wind N-14 m/s, current 1.5 knots from the sea



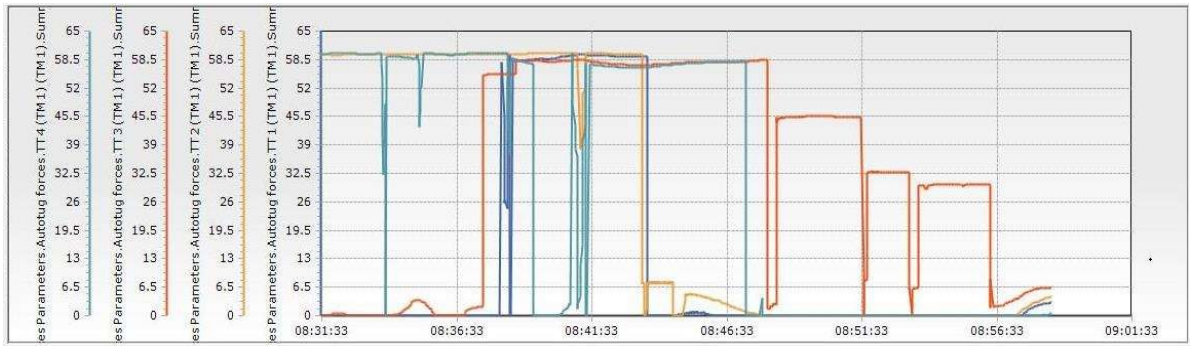
7.4.73 Fig. 4A Alternative – Ship engine operation, sailing at 9.1 knots, wind NW-10 m/s, current 0.7 knots from the shore



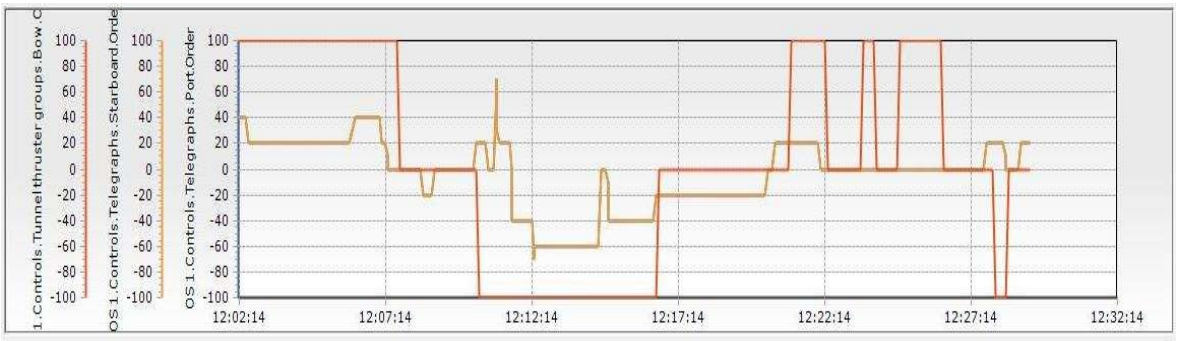
7.4.74 Fig. 4A Alternative – tugboat operation, sailing at 9.1 knots, wind NW-10 m/s, current 0.7 knots from the shore



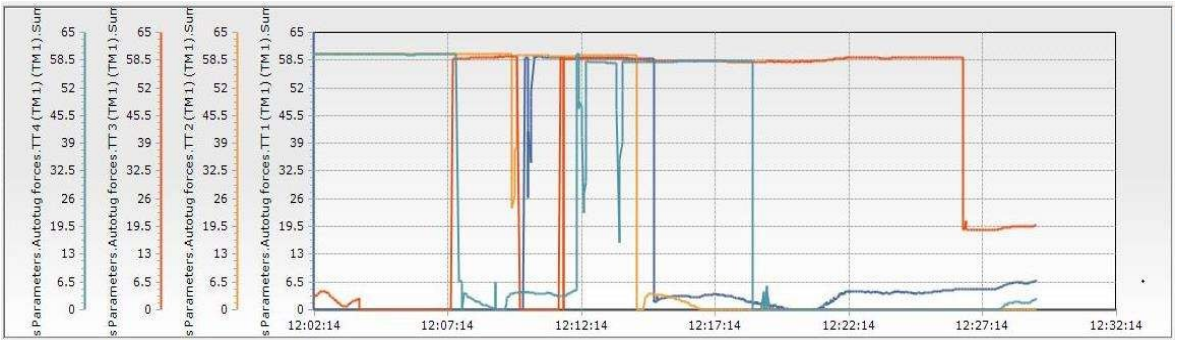
7.4.75 Fig. 4A Alternative – Ship engine operation, sailing at 10.2 knots, wind NW-10 m/s, current 1.5 knots from the sea



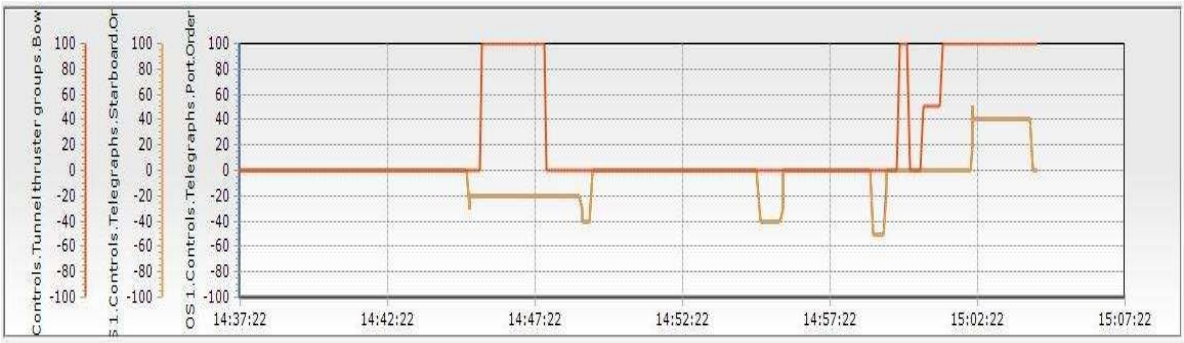
7.4.76 Fig. 4A Alternative – tugboat operation, sailing 10.2, wind NW-10 m/s, current 1.5 knots from the shore



7.4.77 Fig. 4A Alternative – Ship engine operation, sailing at 20.1 knots, wind NW-14 m/s, current 0.7 knots from the shore



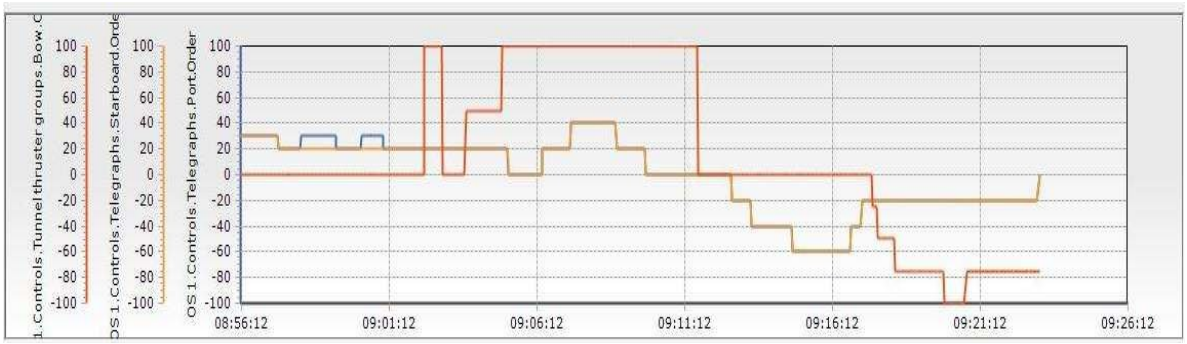
7.4.78 Fig. 4A Alternative – tugboat operation, sailing 20.1, wind NW-14 m/s, current 0.7 knots from Jfiros



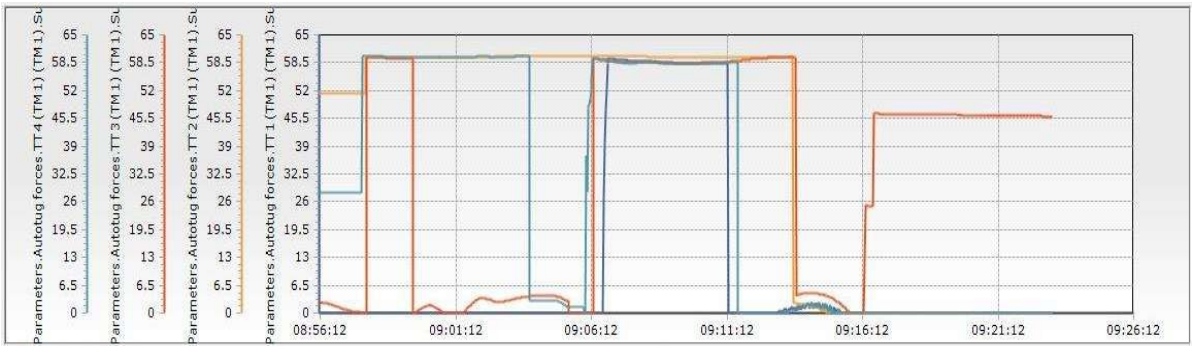
7.4.79 Fig. 4A Alternative – Ship engine operation, sailing at 22.2 knots, wind NW-14 m/s, current 1.5 knots from Jfiros



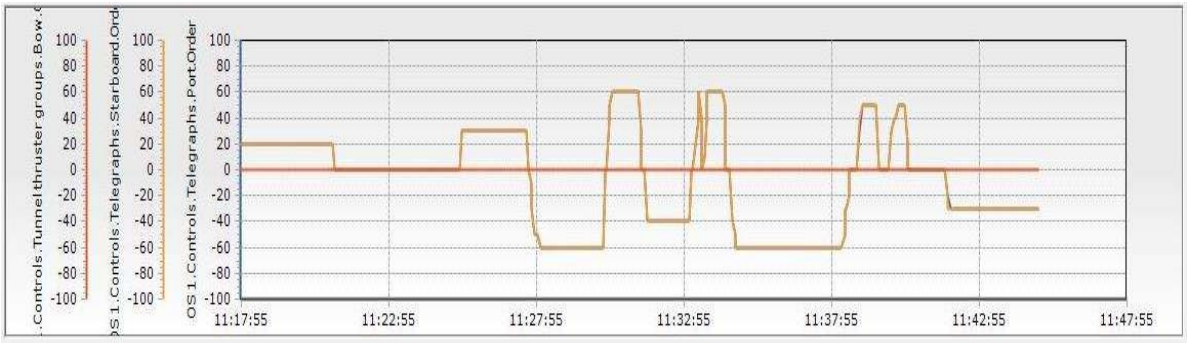
7.4.80 Fig. 4A Alternative – tugboat operation, sailing 22.2, wind NW-14 m/s, current 1.5 knots from the sea



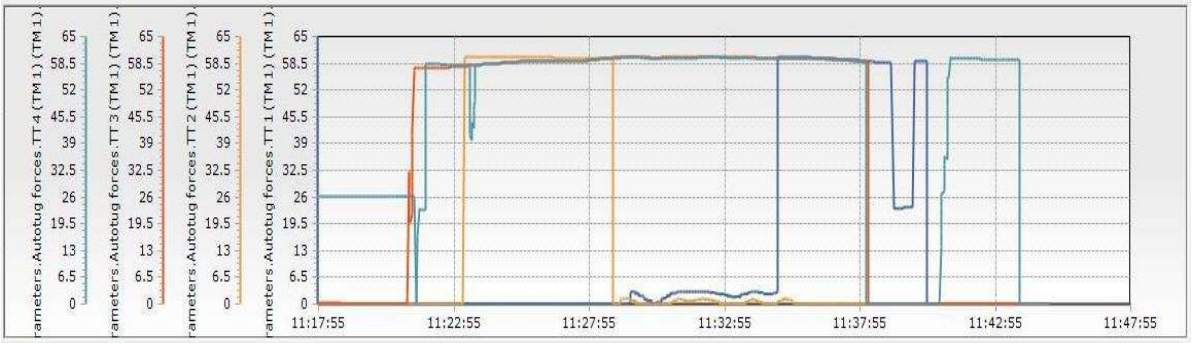
7.4.81 Fig. 4A Alternative – Ship engine operation, sailing at 1.3 knots, wind SW-10 m/s, current 0.7 knots | sea



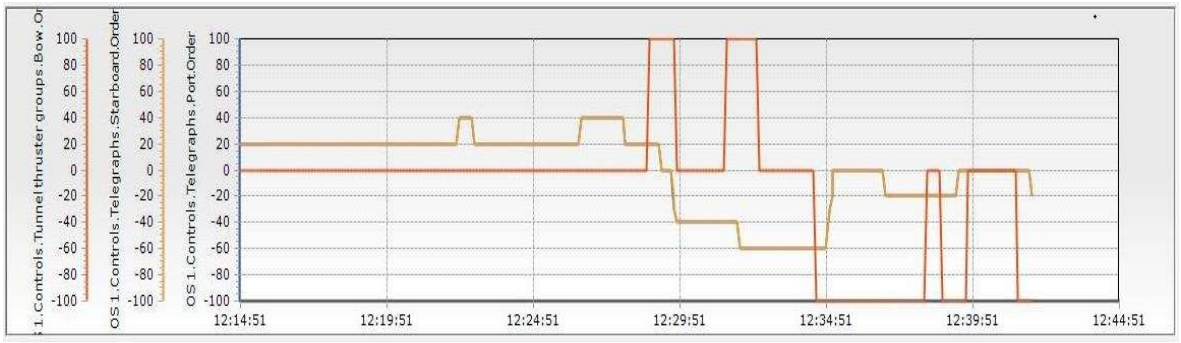
7.4.82 Fig. 4A Alternative – tugboat operation, sailing 1.3, wind SW-10 m/s, current 0.7 knots from the sea



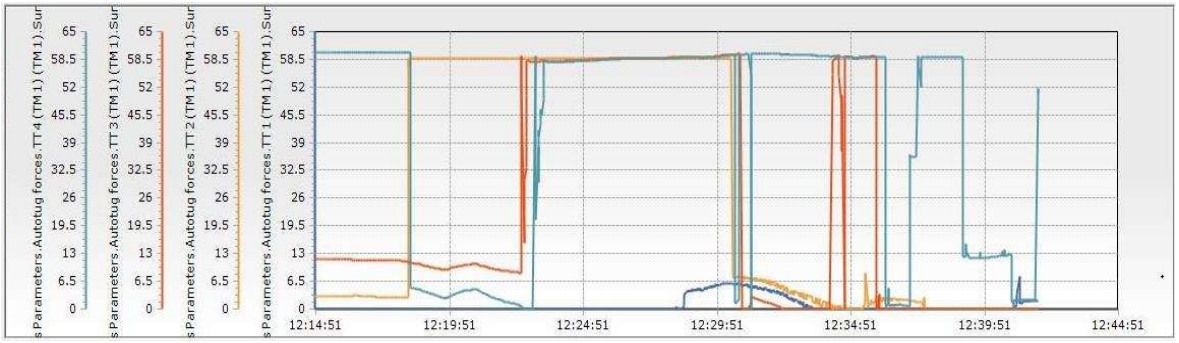
7.4.83 Fig. 4A Alternative – Ship engine operation, sailing with a 3.3 m/s wind from the southwest (SW), current 1.5 knots | sea



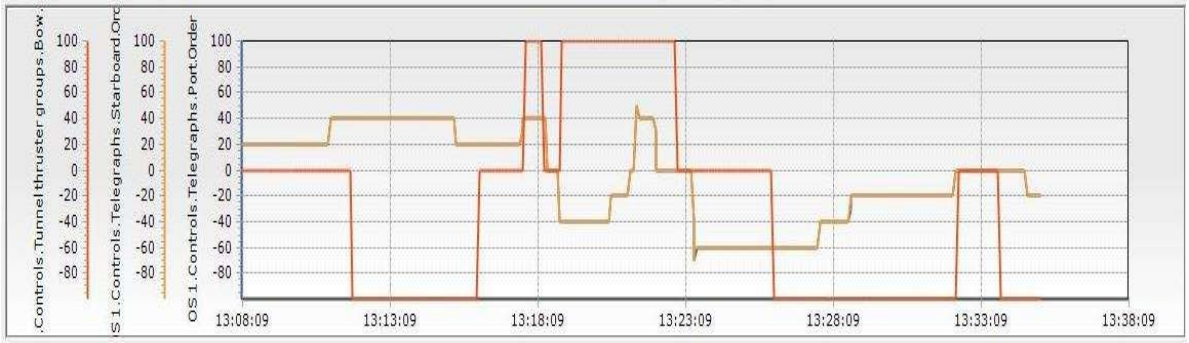
7.4.84 Fig. 4A Alternative – tugboat operation, sailing with a 3.3 m/s wind from the southwest (SW), current 1.5 knots, and sea



7.4.85 Fig**.** 4A Alternative – Ship engine operation, sailing with a 13.3 m/s wind from the southwest (SW) and a current of 0.7 knots



7.4.86 Fig. 4A Alternative – tugboat engine operation, sailing 13.3, wind SW-14 knots, current 0.7 knots | jfirą



7.4.87 Fig. 4A Alternative – ship engine operation, sailing at 15.1 knots, wind SW-14 knots, current 1.5 knots | jfirą

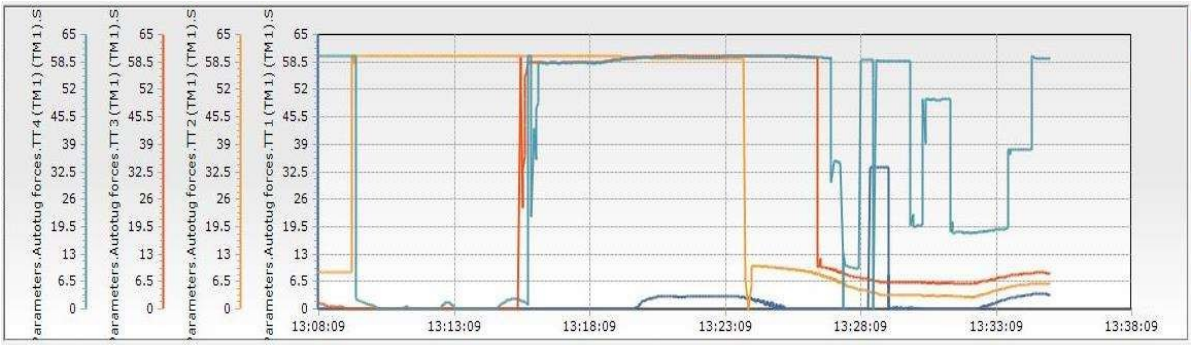


Fig. 4A Alternative – tugboat operation, sailing 15.1, wind SW-14 knots, current 1.5 knots

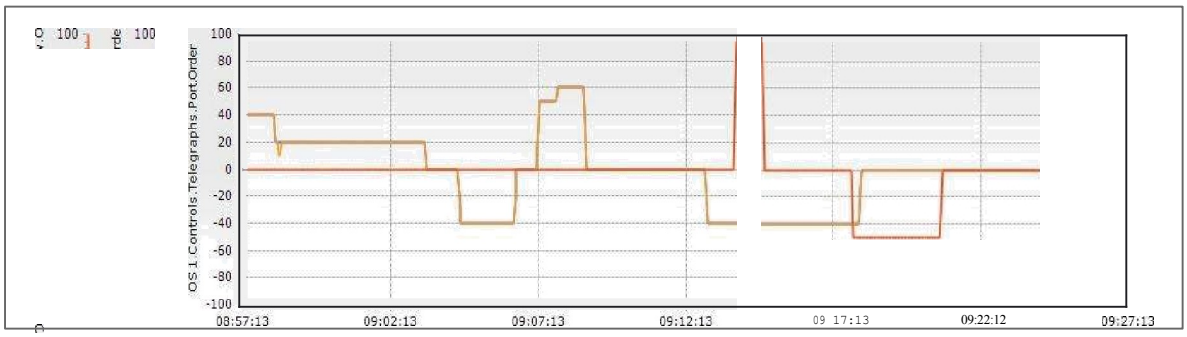
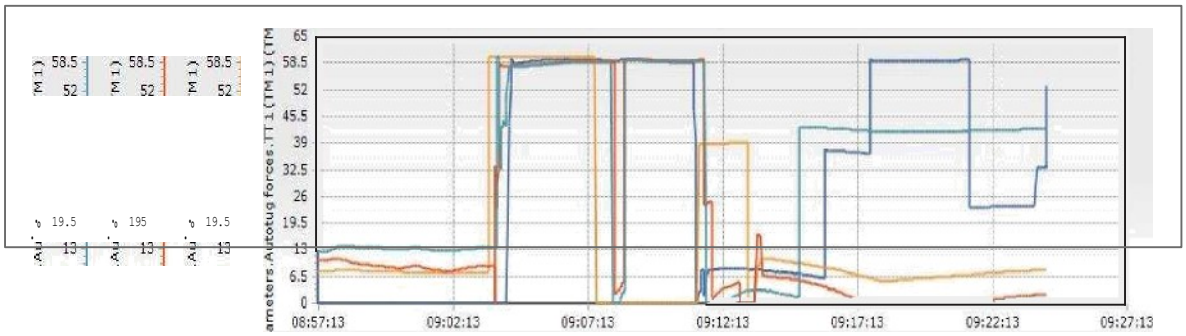


Fig. 7.4.88. Alternative 4A – ship's engine operation, sailing at 2.1 knots, wind W-10 m/s, current 0.7 knots



7.4.89 Fig. 4A Alternative—tractor engine operation, sailing 2.1 wind W-10 m/s, current 0.7 knots

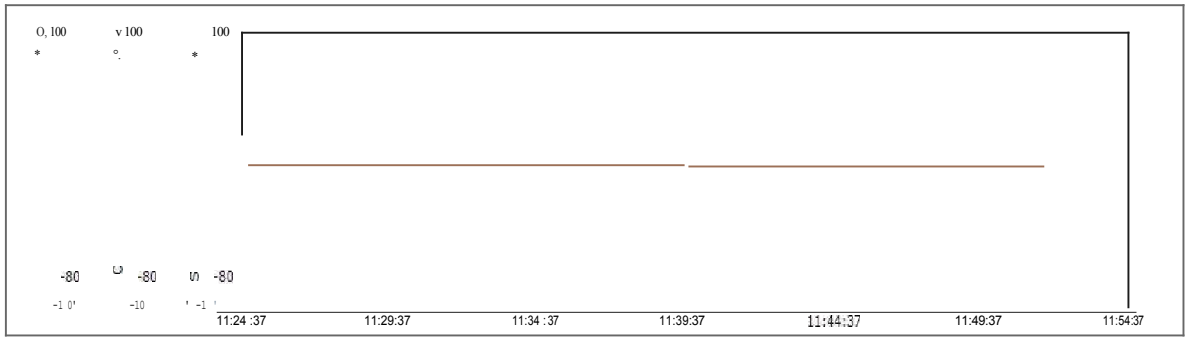
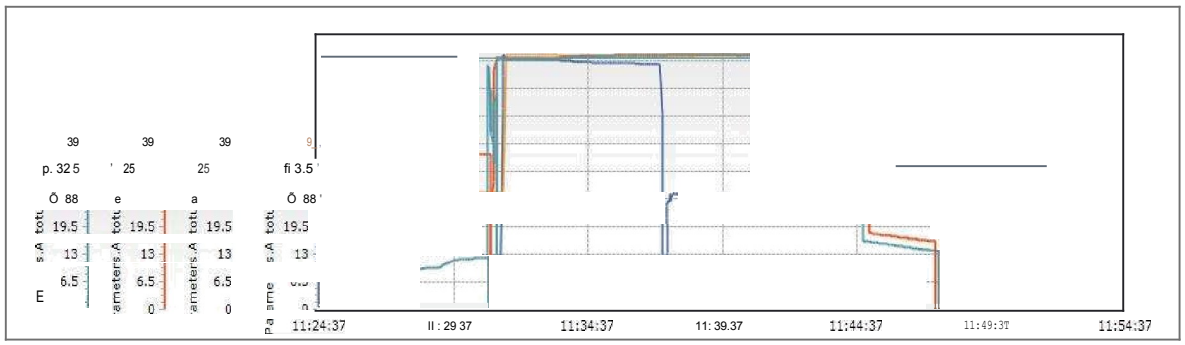
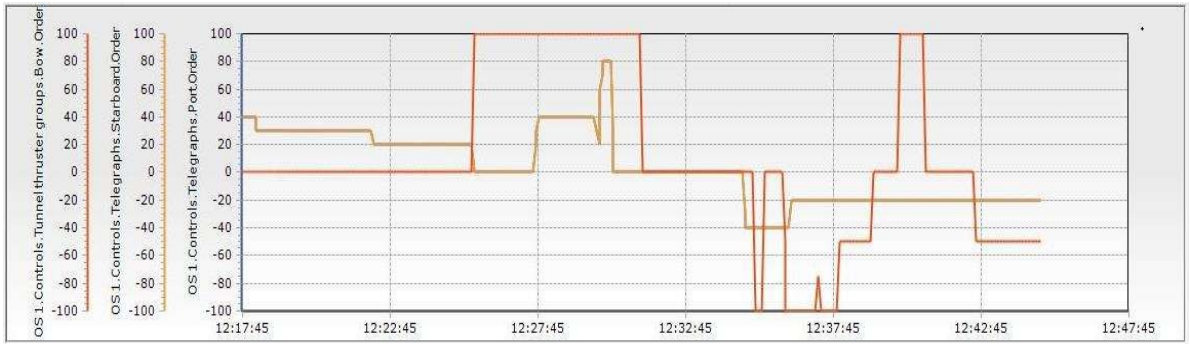


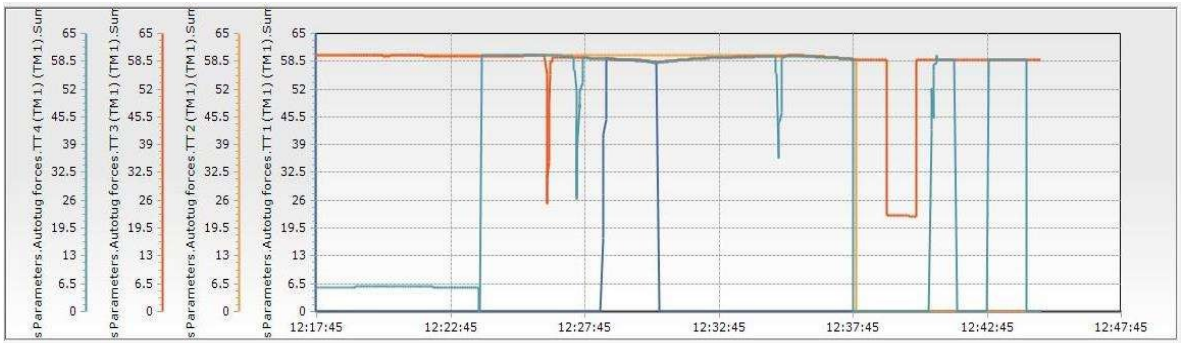
Fig. 7.4.9. Alternative 4A—ship engine operation, sailing with a 4.3-knot wind (W-10 m/s) and a 1.5-knot current



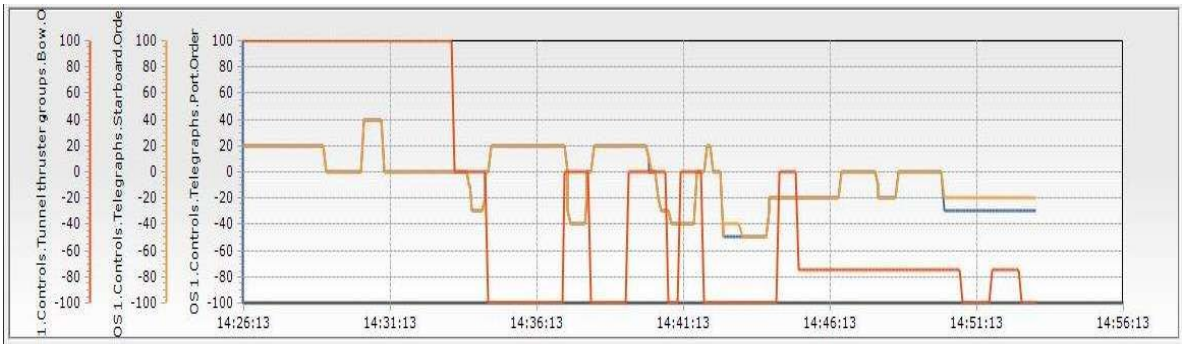
7.4.90 Fig. 4A Alternative—tugboat ëgainiq operation, sailing 4.3 wind W-10 knots, current 1.5 knots J sea



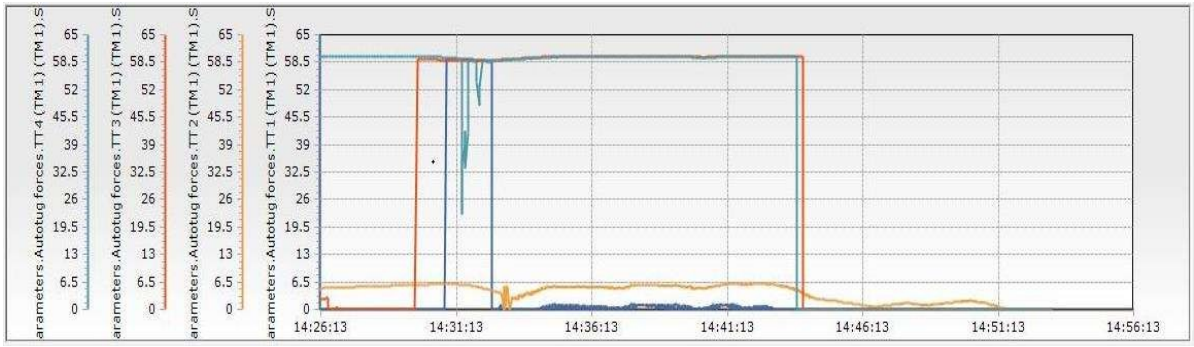
7.4.91 Fig. 4A Alternative—ship engine operation, sailing at 14.1 knots, wind W-14 m/s, current 0.7 knots | jÌirą



7.4.92 Fig. 4A Alternative – tugboat operation, sailing 14.1, wind W-14 mph, current 0.7 knots



7.4.93 Fig. 4A Alternative – ship engine operation, sailing at 16.2 knots, wind W-14 m/s, current 1.5 knots | jÌirą



7.4.94 Fig. 4A Alternative – tugboat propulsion, sailing at 16.2 knots, wind W-14 m/s, current 1.5 knots

8. OVERVIEW OF MEASUREMENT RESULTS

Key controlled stages of the ship handling tests:

- Stage 1 — safe approach, passing the LNG terminal, and sailing through the channel;
- Stage 2 — turning the vessel;
- Stage 3 — maneuvering the vessel to the mooring quay.

Taking into account each alternative, in order to achieve the set objective, the following navigational criteria were adopted and monitored based on selected critical points:

- hazardous (red):
    - o distance to the vessel at the berth— 0–30 meters;
    - o distance to buoy No. 31—0–25 meters;
    - o turning radius greater than 600 meters;
    - o 17-meter depth limit — 0–15 meters;
    - o Corners of Terminal Quays No. 1 and 2 — 0–25 meters;
    - o Buoys No. 33, 35, 37 — 0–15 meters;
- increased risk (yellow):
    - o Distance to the vessel at the quay — 35–55 meters;
    - o Distance to buoys No. 31–30 — 55 meters;
    - o Turning radius 600 meters and more;
    - o 17-meter depth limit — 20–30 meters;
    - o Angle of terminal berths No. 1 and 2—30–40 meters;
    - o Berths No. 33, 35, 37—20–30 meters;
- — safety (not specified).

1 At this stage, it is very important to evaluate the width of the designed navigation channel based on the anticipated largest vessel and to conduct navigation control. Taking into account the channel design recommendations in PIANC Report No. 121-2014, the width of the navigation channel is calculated using the formula:

$$W = WBM + ZWi + WBr + \quad Bg$$

In the formula:

WBM — basic maneuvering width;

We — additional straight channel margin;

Br reserve on the left side of the channel (shallow waters, shoal effect);

Bg — margin on the right side of the channel (moored LNG carrier).

A container ship is classified as a vessel with average maneuverability. According to PIANC recommendations, WBM should be 1.5 times the ship's width (1.5B).

On the left side of the channel, the shallow water margin at the sloping channel edge, when sailing at low speed, should be 0.3B, i.e., 18 meters. When passing a vessel moored at the quay, maintain a minimum of 1B, i.e., 60 m.

The additional straight channel clearance (W;) is 1.9B, the components of which, when sailing very slowly, are:

- vessel speed — 0B (very slow speed, less than 4 knots);
- crosswind — 1.1B (wind 33–48 knots, according to the scenario up to 18 m/s = 36 knots);
- longitudinal current — 0.2B (current speed up to 2.0 knots);
- marking with navigational aids — 0.2B (well marked);
- depth margin — 0.4B (depth-to-draft ratio less than 1.25T).

Adding up all the components for determining the width of the navigable channel yields 3.2B. Given the width of the vessel being towed is 60 meters, we get 192 meters. Comparing this to the narrowest operational channel width of 190 meters in Alternative 2A, when two gas carriers are moored, we can conclude that the channel width meets the requirements for towing a vessel with a tugboat.

Methods for recording navigational criteria:

- Passing distances — measurement results obtained by analyzing ship navigation charts;
- Turning radius — measured by analyzing the ship's navigation charts;
- Vessel maneuvering width — a measurement method based on the analysis of vessel navigation charts.

According to the pilot's practical experience, the critical points to which particular attention should be paid are:

- When navigating:
    - O Alternatives 2A and 4A—passing the SGD vessel and checking the channel depth limit on the port side (at berth No. 147);
    - O Alternative 3A – Buoy No. 31, the edge of the 17-meter-deep channel between buoys No. 31–35, the corner of Terminal Quay No. 1;

- turning basin:
    - Alternatives 2A and 4A – Pier No. 31, the 17-meter-deep boundary of the turning basin, distance to the ship at Berths No. 151, 152, corner of Terminal Berth No. 1;
    - Alternative 3A – buoy No. 35, the 17-meter depth limit of the turning basin between buoys No. 35–39, distance to the ship at berths No. 1 and 2, corner of terminal berth No. 1;
- when approaching the wharf:
    - Option 2A—distances to the ship moored at the terminal berths
    - Option 3A—distance to a vessel moored at the terminal berths, 11-meter depth limit;
    - Option 4A—distance to the vessel moored at the terminal berth, buoy No. 37;
- Upon departure—distance to the vessel moored at the terminal quay, passing by the LNG vessel and checking the channel depth limit on the starboard side (at quay No. 147).

Taking into account the width of the navigation channel and the objective of maintaining a safe distance of 60 meters from the LNG vessel, efforts are made to stay as close as possible to the left edge of the navigation channel, maintaining a speed of less than 4 knots. Data on the measured distance during the passage are presented in Tables 8.1–8.12.

An analysis of the passage distance to the LNG vessel during all tests revealed that a safe 60-meter distance was maintained 53% of the time, while passages with increased risk accounted for 40.4% and those with high risk for 6.6%.

When navigating and hugging the left bank of the channel, the lack of marking poses a risk of drifting out of the channel limits. In 17% of all trials, vessels came dangerously close to the 17-meter-deep edge or drifted beyond it. Consequently, there were also instances of grounding on shoals. The highest risk was observed with N, NW, and W winds. The majority of hazardous incidents, as many as 12.1%, occurred in Alternative 2A, due to the narrower width of the navigation channel and the pilot's lack of experience in navigating the vessel in an unfamiliar area.

Tables 8.13–8.16 present information on the results of ship track width measurements recorded during the ship model tests, comparing them by scenario and weather conditions. Taking into account the desired maintenance of a 0.3B shallow water margin on the left side of the channel and a distance of 1B from the second LNG ship, a 2B ship maneuvering lane width must be maintained. Analysis of

the navigation data, it is evident that the 2B limit was exceeded 38.4% of the total voyage. A significant increase in the width of the ship's maneuvering lane is recorded during navigation at an angle of approximately 10°.

2 A key element in this stage is the assessment of the area with a sufficient turning circle diameter and control of the vessel's turning, compared to the established turning circle of 600 meters. According to the recommendations of PIANC Report No. 121-2014, the minimum turning basin diameter in which a vessel can turn while sailing astern without using bow thrusters and/or tug assistance should be approximately 4 times greater than the vessel's length (4L). If the vessel is turned with the assistance of a tugboat, the turning radius may be 2L. Under very favorable conditions, this radius may be reduced to 1.6L. When using the main propeller and bow thrusters, as well as with the assistance of a tugboat, the turning basin diameter may be reduced to 1.5L. In the presence of currents in the harbor or in areas with strong winds, the turning circle area must be extended to allow the ship to drift while turning. A detailed assessment of the planned turning basin size was conducted by simulating the ship's maneuvering during trial runs in complex situations—strong currents, strong crosswinds, and a combination of both. In the preliminary design alternatives, the turning circle diameter is set at 600 meters, which corresponds to 1.5L, based on the largest vessel to be towed, which is 400 meters in length. The results of the turning basin diameter recorded during the tests are presented in Tables 8.17, 8.18, 8.19, and 8.20.

Analysis of the results shows that the 600-meter turning circle limit was exceeded in 43.3% of all turns. The results indicate that when winds exceed 10 m/s, a turning basin diameter of **600** meters is insufficient in most cases. The turning basin is most severely stretched when north winds of up to 1,000 meters per second are blowing.

3 In the approach phase, when reversing toward the berth, the key factor in Alternatives 2A and 4A was maneuvering in a confined space due to the berth configuration and maintaining a safe distance from vessels moored at the berth. In Alternative 2A, while moving within the terminal basin, it was nearly impossible to maintain a safe distance from vessels due to the very limited space when working with tugs. In Alternative 3A, there is sufficient space for maneuvering, and this did not pose significant problems. The main spatial constraint in Alternative 3A is the 11-meter depth limit; deepening this would improve the situation. In Alternative 4A, near buoy No. 37, there is insufficient space for working with tugboats in strong winds and currents. The results of distance measurements while approaching the wharf are presented in Tables 8.1–8.12.

Lentelė 8.1

Alternatyva 2A. Atstumų lentelė (metrais) – įplaukimas/ išplaukimas, nuo SGD iki krantinės, pučiant šiaurės krypčių vėjui

Plauk. Nr.	SGD laivas	Kr. Nr. 147 17 m gylio riba	Kr. Nr. 147 pirsas	Buja Nr. 31	Apsisuk. rato 17 m riba	Term. krant. Nr. 1 kampas	Term. krant. Nr. 4 kampas	Apsisuk. skersmuo	Kr. 149-152 17 m gylio riba	Laivai prie term. kr. Nr. 1 ir 4
7.1	75	25	120	65	105	110	315	410	95	
7.2	65	55	140	90	105	110	205	410	40	
7.3	60	40	135		145	50	110		75	
9.1	90		85		75	135	145	470	125	
9.2	80		95			150	140		155	
9.3	75		90		50	100	160	440	85	
11.1	110		50	-	-	-	-	-	-	-
11.2	100		85			200			135	
11.3			85			55	60			
11.4		60	145			110	100		90	
11.5	60		105			100			90	
19.1		85	170	80	40	75	80		90	
19.2	90		95			120	65			
19.3	70		110		45	60	190	460		
19.4	105		60	65	70	110	70	650	80	35
21.1	105		55					610	80	15
21.2			115		40	95	40			
21.3			105		30	80	75	605	80	25
23.1			120	35	35	85	35	660	65	0
23.2	95		75	35		135	75	635	105	20
23.3	70	35	120					670	60	30
31.1	70		115	65	70	70	50			
31.2	80		125		90	55	105			
31.3	65	25	125	65		155	50		105	35
33.1	65		95	45	50	60	60	705	45	35
33.2		40	135			90	50	690	100	20
33.3	75		85	75	40	95	105		115	
35.1	70	40	130			150	115		160	
35.3	60		80		35	60	55		65	

Lentelė 8.2

Alternatyva 2A. Atstumų lentelė (metrais) – įplaukimas/ išplaukimas, nuo SGD iki krantinės, pučiant šiaurės vakarų krypčių vėjui

Plauk. Nr.	SGD laivas	Kr. Nr. 147 17 m gylio riba	Kr. Nr. 147 pirsas	Buja Nr. 31	Apsisuk. rato 17 m riba	Term. krant. Nr. 1 kampas	Term. krant. Nr. 4 kampas	Apsisuk. skersmuo	Kr. 149-152 17 m gylio riba	Laivai prie term. kr. Nr. 1 ir 4
8.1	115		55	70	65	125	260	430	80	35
8.2	80		115	65	100	95	265	460	95	20
8.3	75		95		80	110	270	430	85	40
10.1	85		75	70		195			130	0
10.2	85		85	60	90	100	100		0	
10.3	60		90		50		80	430		
10.4	95		55	60	85	95	90	420	65	30
12.1		60	150	5		70				
12.2	85		45			90				
12.3	70		75	20		100				
20.1	60		80	20	55	60				
20.2	95		60		35	140				
22.1	95		95	90	50	100				
22.2	70		65	100	70	115				
22.3	65		95	45	35	60				
24.1	80		75	55	40	90				
24.2	60		120		40	50				
24.3	125		55	-	-	-	-	-	-	-
24.4	130		50	-	-	-	-	-	-	-
24.5	120		55	-	-	-	-	-	-	-
24.6	75		85	50	55	60	60		40	50
32.1	80		95						140	
32.2	65		105	45	80	70	105	560	45	
32.3	65		80	120	50	40				
34.1			100	70	155	55	65			
34.2	75		90	55	110	85	130			-
34.3	65		125		50	70	70			50
36.1	70		85	90		80			60	
36.2	80		90			105	65		90	
36.3	75	0	75	40	15	80	65	575	105	30

Alternatyva 2A. Atstumų lentelė (metrais) – įplaukimas/ išplaukimas, nuo SGD iki krantinės, pučiant pietvakarių krypčių vėjui

Plauk. Nr.	SGD laivas	Kr. Nr. 147 17 m gylio riba	Kr. Nr. 147 pirsas	Buja Nr. 31	Apsisuk. rato 17 m riba	Term. krant. Nr. 1 kampas	Term. krant. Nr. 4 kampas	Apsisuk. skersmuo	Kr. 149-152 17 m gylio riba	Laivai prie term. kr. Nr. 1 ir 4
1.1	60	35	130	50	125	80	240	410	90	
1.2		35	130	50	50	190	180	490	100	
1.3		80	175	75	100	80	300	455		
3.1		50	145	75	70	100	230		100	
3.2	65	40	135	100		120	370		75	
3.3		60	150	50	75	110	275	490	80	
5.1	60	50	140	80	140	50	150			
5.2		50	145	100	35	130	260		60	
5.3		75	160	50	115	120	295		85	
13.1			125		55	80	80		75	
13.2			125	50	65	95	90			
13.3			160		145	90	130		90	
15.1			115	80	80	110	200		65	
15.2			150	115		130	170			
15.3			155		60	125	330	480	125	
17.1		55	150			-	85	460	120	
17.2	80		120	70	35	85	185		85	
17.3		55	150			50	320			
17.4		90	180	80	55	90	230			
25.1	60	45	135	55	45	85	170		85	
25.2	70		125		125	80	300	420	90	
27.1		65	150	75	75	60	260			
27.2		75	165	45	55	120	315		95	
27.3		65	155	60	90	65	230		85	
29.1		65	160	85	35		190			
29.2	65	45	135		235	70	320	-		-
29.3		65	150	55		45	300			

Lentelė 8.4

Alternatyva 2A. Atstumų lentelė (metrais) – įplaukimas/ išplaukimas, nuo SGD iki krantinės, pučiant vakarų krypčių vėjui

Plauk. Nr.	SGD laivas	Kr. Nr. 147 17 m gylio riba	Kr. Nr. 147 pirsas	Buja Nr. 31	Apsisuk. rato 17 m riba	Term. krant. Nr. 1 kampas	Term. krant. Nr. 4 kampas	Apsisuk. skersmuo	Kr. 149-152 17 m gylio riba	Laivai prie term. kr. Nr. 1 ir 4
2.1			140	55	100	65	195	450	70	
2.2			110	60	105	100	240	430	100	
2.3			145	105	60	100	195		75	
4.1			140	75	55	45	170	490	50	
4.2			140	90	60	105	190			
4.3		50	140		120	80	220	435	65	
6.1		50	140	75	130		130		50	
6.2		55	140	115		60	140	480	60	
6.3		50	140	50	40	80	245	485	75	
14.1	65	40	125			55	210	430	75	
14.2			150	50	110	55	85		65	
14.3			150		90		95	480	55	
16.1			125	60		55	160	440	115	
16.2		70	160	70		100	165	450	80	
16.3		55	150		115	100	280	410	95	30
16.4	70	35	125	100	85	60	235		0	-
18.1		50	150	75	50	60	175	590	80	20
18.2	60	60	145	60	50	95	50			
18.3	70	45	135		70	80	250		70	15
26.1	85		95	65	45		155	-	55	-
26.2	70		105	45	60	75	230	450	90	
26.3		90	180			145	250	480	95	-
26.4			115	60		115	420	470		-
26.5			125	75	125	55	80		30	
28.1			150	70	40	75	235		65	
28.2			145	50	95	90	295		85	
28.3			125	70	60	80	200		85	
30.1			150	65	45	85	200		75	
30.2			165	85	55	30	200			
30.3		60	160	90	45	85	200		70	

Alternatyva 3A. Atstumų lentelė (metrais) – įplaukimas/ išplaukimas, nuo SGD iki krantinės, pučiant šiaurės krypčių vėjui

Plauk. Nr.	SGD laiv,	Kr. Nr. 147 17 m riba	Kr. Nr. 147 pirsas	Buja Nr. 31	Kr. 149-152 17 m riba	Term. krant Nr. 1 kampas	Buja Nr. 33	Buja Nr. 35	Apsis. rato 17 m riba	Laiv. prie term. kr. Nr. 1	Apsis. skersmuo
7.1	90		85		70	165		40	55	155	445
7.2	70	35	90		70	145	55	55	100	125	
7.3	90	45	90	75	75	95	130	45	80	75	
7.3*	60	100	150	65	75	135	90	50	-	115	-
9.1	85		55			125	45	35	95	110	
9.2	60		75			135	60	30	100	125	
9.2*	105		65	55	75	75	65	100	-		-
9.3		40	100	90		75	120	30		70	
9.3*	130	35	65	70	90	115	100	40	-	100	-
10.1	60		70			115	55			115	
10.2			75			100	35	30	55	85	
10.3	80		65			115	90	75	60		
19.1	80	75	130			105	95	55		85	
19.2	65	35	100			145	65	45	50	130	
19.3	65	40	90	50		150	50	80	67	160	
21.1			65			105	85	35		100	
21.2			95		105	150	35	35		145	
21.3			90	55		115	80	60	75	130	
23.1			85	55	90	90	100	55		90	
23.2	65	80	135		100	110	65	50	75	80	
23.3	60	85	140		125	105	50	80		115	
30.1		90	135	60		115	65	35	40	115	
30.2			120		80	140			35	155	
30.3		80	130	60	70	135	70	40	60	125	
30.4	60	65	130	70	70	90	85	80	55	90	
33.1		50	95	70		90	100			85	
33.2		100	150	80		85	100			60	
33.3	70	45	95	50	90	105	65	35	80	90	
33.3*	60	50	100	65	80	100	110	105	-	75	-
35.1	70	55	115	50		100	60	45	65	90	
35.2		70	125	45	80	90	50	50	55	80	
35.3	60	85	140			70	45			115	

Alternatyva 3A. Atstumų lentelė (metrais) – įplaukimas/ išplaukimas, nuo SGD iki krantinės, pučiant šiaurės vakarų krypčių vėjui

Plauk. Nr.	SGD laiv,	Kr. Nr. 147 17 m riba	Kr. Nr. 147 pirsas	Buja Nr. 31	Kr. 149-152 17 m riba	Term. krant Nr. 1 kampas	Buja Nr. 33	Buja Nr. 35	Apsis. rato 17 m riba	Laiv. prie term. kr. Nr. 1	Apsis. skersmuo
8.1	90		80	45	60	135	65		100	125	
8.1*	100	55	100		85	95	125	140	-	60	-
8.2	80		65	110		85	115	55	70	80	
11.1	65	40	95		90	130	90	50	65	120	
11.2		100	150		110	95	70	45	125	65	
11.3	85		60		70	130	80	55	85	110	
12.1			70	80		-	-	-	-	-	-
12.2		90	145		135	90	100	35	95	60	
12.3		65	115	80	80	110	100		75	90	
12.4		75	130		100	150				120	
20.1	60	35	90		90	135	90	55	90	105	
20.2	65	35	80	45	70	115	85	35	80	100	
22.1	65	90	135		85	100	85		65	105	
22.2		60	115	80		70	70	45	125	60	
24.1	90		65	80		65	35	105		60	-
24.2	65	85	140	55	100	115	50	55	90	90	
24.3	60	65	115		60	125	60	60	60	105	
32.1			60			70	145	135	165		
34.1		35	90		120	90	65		45	85	
34.2	60		60	65	70	100	55	85	155		
34.3		35	100		85	155				200	
34.3*	90	40	90	60	90	120	125	160	-	85	-
36.1		55	110		65	50	65	85	90		
36.1*	100		85	65	60	120	90		-	140	-
36.2		100	150		135	115	85	95	-	100	-
36.3	60	0	70	75	60	90	95	45	90	75	815

Alternatyva 3A. Atstumų lentelė (metrais) – įplaukimas/ išplaukimas, nuo SGD iki krantinės, pučiant pietvakarių krypčių vėjui

Plauk. Nr.	SGD laiv,	Kr. Nr. 147 17 m riba	Kr. Nr. 147 pirsas	Buja Nr. 31	Kr. 149-152 17 m riba	Term. krant Nr. 1 kampas	Buja Nr. 33	Buja Nr. 35	Apsis. rato 17 m riba	Laiv. prie term. kr. Nr. 1	Apsis. skersmuo
1.1		100	155	85	85	120	70	40	80		490
1.2	100	40	95		100	135	90	95	115	75	460
1.3	85	65	120	45	135	95	130	130	95	70	400
3.1	85	75	120	80	100	70	145	135	60		440
3.2		85	140	50	120	120	90	70	95	120	430
3.3	60	90	145	50	100	70	105	75	90		
3.3*	80	60	105		100	110	115		-	70	-
5.1		110	160	70	110	105	100	155	45		
5.1*	75	50	100	50	90	115	70	35	-	115	-`
5.2	80	75	130	55	105	110	105		90		470
5.3		110	170	50	110	125	105	80	105		450
5.4	65	85	140	50	105	110	110				
13.1	80	60	110	60	95	120	85	95	105	80	
13.2	75	70	125	50	110	100	115	40	95	100	
13.3	60	75	130	75	85	75	150	125	115	70	
15.1	80	75	130	60	110	90	135	125			
15.2	60	70	105	65	100	90	120	75	80	100	415
15.2*	85	45	95		115	140	15	115	-	120	-
15.3		105	160	50	115	130	100			120	
17.1		110	160	60	95	130	105	75		60	
17.2	70	75	135	65	100	90	130	90	60	80	490
17.2*	95	65	125	55	90	100	100	175	-	65	-
17.3	60	100	145	60	90	100	95	130	35	65	
17.3*	60	93	150	50		140	65	95	-	115	-
25.1	65	65	120	45	90	105	105	110	50		
25.2		115	170		115						
27.1	60	90	140	50	105	70	110	105	65		
27.2	65	75	125	60	90	100	80	90		95	
27.3	60	65	115		110	115	95	70	80	125	
27.3*	130		55		90	175		120	-	130	-
29.1	65	80	135	75	70	100	130	85	70	85	480
29.2	60	90	145	55	105	115	110	105	35	90	
29.3		100	155	70	90	120	105	115		90	
29.3*	30	105	160	60	50	145	35	80	-	130	-

Alternatyva 3A. Atstumų lentelė (metrais) – įplaukimas/ išplaukimas, nuo SGD iki krantinės, pučiant vakarų krypčių vėjui

Plauk. Nr.	SGD laiv,	Kr. Nr. 147 17 m riba	Kr. Nr. 147 pirsas	Buja Nr. 31	Kr. 149-152 17 m riba	Term. krant Nr. 1 kampas	Buja Nr. 33	Buja Nr. 35	Apsis. rato 17 m riba	Laiv. prie term. kr. Nr. 1	Apsis. skersmuo
2.1	90		65		105	135	85	160	65	60	
2.1*		100	150	80		110	95	65	-	85	-
2.2	95	45	100			120	100	90	60	100	480
2.2*	80	75	125			115	90	155	-	80	-
2.3	120		70			75	125	120	80		460
4.1	80	65	115			125	95	55	75	115	430
4.2		85	140		110	125	100	95	160		410
4.3	80	65	125	70	100	75	140	150	55		
4.3*	65	80	130	85	60	135	65	65	-	130	-
6.1	80	70	130	65	125	90	120	110	60		
6.1*	100		75		85	145	45	115	-	115	-
6.2		105	160		105	145	70		40		
6.2*	95		105	75		135	70	50	-	125	-
6.3	75	65	125		105	100	75	60	90		
6.3*	75	85	135	60	70	90	130	155	-	50	-
14.1	110		55		100	70	135	120	65	55	450
14.2	60	65	120	60	110	65	125	125	60		
14.2*	90	60	95		100	105	95	180	-	80	-
14.3		90	140		125	120	105	150	60	60	485
16.1	65	70	130		105	85	135	125	100	70	460
16.2	60	85	140	60	110	105	70	60	10	155	
16.3		95	155		125	110	100	45	35	110	490
18.1		100	150		125	120	100	35	105	125	490
18.1*	70	65	120		125	120	105	150	-	85	-
18.2		100	150	65	90	110	115	115	75	70	470
18.3	60	90	140		90	90	105	120	40	65	
26.1	65	60	110		85	110	75	100	25	90	
26.2			75	60	105	130	75	95	70	125	
26.3			85	60	100	135	90	90	75	120	
28.1			160		120	100	85	70	95	95	
31.1			135		100	110	65	85		75	
31.1*			115			155	60	85	-	160	-
31.2	65	55	105		80		105	60	65	65	
31.3		95	150	65	80	80	120	90	55		
31.3*	65	75	140	45	65	100	100	160	-	90	-

Lentelė 8.9

Alternatyva 4A. Atstumų lentelė (metrais) – įplaukimas/ išplaukimas, nuo SGD iki krantinės, pučiant šiaurės krypčių vėjui

Plauk. Nr.	SGD laivas	Kr. Nr. 147 17 m riba	Kr. Nr. 147 pirsas	Buja Nr. 31	Kr. 149-152 17 m riba	Terminalo krantinės Nr. 1 kampas	Apsisuk. rato 17 m riba	Buja Nr. 37	Laivas prie term. kr. Nr. 1	Apsisuk. skersmuo
7.1		85	140	50	100		160	100		
7.2		85	130		60	65	60	55		
7.3	70	55	105	60		130	60	75	95	
8.1		90	140		100	-	130	-	-	-
8.2	65	60	105		60	90	50	-	-	-
19.1		80	120	75	100		120	60	70	
19.2	80	35	85	100		105	55	55	60	
19.3		70	120		75	95	75	80		
21.1		70	115	55		75	80	60	60	
21.2		50	100	80		125	35			
21.3		110	160	50	110	80	55	70		
23.1		110	160		110	90	75	70		
23.2		75	135	50	70	110	75	60	70	
23.3		35	80	55		75	125			
31.1	80	50	105	50		90		80		
31.2		95	150		65	85	70	75		
33.1	70	85	135	45	90	135	75	65	70	
33.2		70	125	45		77	55	65	60	
36.1		95	150	65		80	50	90		
36.2	60	80	140	45	125	70	40	60		
36.3	75	50	115	80		115	55	45		

Lentelė 8.10

Alternatyva 4A. Atstumų lentelė (metrais) – įplaukimas/ išplaukimas, nuo SGD iki krantinės, pučiant šiaurės vakarų krypčių vėjui

Plauk. Nr.	SGD laivas	Kr. Nr. 147 17 m riba	Kr. Nr. 147 pirsas	Buja Nr. 31	Kr. 149-152 17 m riba	Terminalo krantinės Nr. 1 kampas	Apsisuk. rato 17 m riba	Buja Nr. 37	Laivas prie term. kr. Nr. 1	Apsisuk. skersmuo
9.1	80		60					0	80	410
9.2	60	35	85				60	80	30	
10.1		40	85	50	60	145		30	85	
10.2		50	95				75	75	55	
10.3		100	150	30	125	60	115	80	35	
12.1		115	165		105	90	15	75	30	
12.2		95	140		70	65	120	95	60	660
12.2*	90	65	115	60	60	175	-	55	70	-
12.3	65	80	120	80	70	90	35	60	115	
12.3*			155		120	325	70		115	-
20.1			110				165	75		
20.2			80				70			
20.3			85				85	50		
22.1	85		45				85	-		
22.2		45	90			80	110	95		
22.3	70		65	65		65	65	60		
24.1		100	145		85		65	40		
24.2		85	140		100	85	35	80		
24.2*	-	-	-	75	140	160	-		95	-
24.3	65	65	130	60	65	110	90	65	75	
24.3*	-	-	-	70	95	200	-	35	80	-
32.1		60	115			90	75	70		
32.2	70		75	65	75	80	55			
34.1			130		90	65	70	75		
35.1			145	60	100	110		-	60	
35.2			80		75	105	45	35		
35.3			85	50		90	70	65		

Lentelė 8.11

Alternatyva 4A. Atstumų lentelė (metrais) – įplaukimas/ išplaukimas, nuo SGD iki krantinės, pučiant pietvakarių krypčių vėjui

Plauk. Nr.	SGD laivas	Kr. Nr. 147 17 m riba	Kr. Nr. 147 pirsas	Buja Nr. 31	Kr. 149-152 17 m riba	Terminalo krantinės Nr. 1 kampas	Apsisuk. rato 17 m riba	Buja Nr. 37	Laivas prie term. kr. Nr. 1	Apsisuk. skersmuo
1.1	70	70	130	90	60	110		55	70	455
1.2	80	70	115	70	75	125	60	90		450
1.3		95	150	65	115	75		85		450
3.1	40	85	140	70	90	140		65		
3.1*	-	-	-	95	125	145	-	70	75	-
3.2		105	155	75	85	105		60	60	460
3.2*	-	-	-	-	-	225	-	55	90	-
3.3	70	75	125	50	105	75	40	60	45	490
5.1		95	150	65	90	110		60		
5.2		110	160	50	95	110	40	70		
5.3	60	90	145	75	85	120		95		
5.3*			80	75	40	190	-	60	95	-
13.1			135	60	95	115		90	95	480
13.2			75	45	135	65	70	70		
13.3			160	60	90	110	65	80		
15.1			160	70	80	125		95		
15.1*	70	85	135	75	75	170	-	65		-
15.2		110	165	70	115	125	35	100		
15.3		75	130	60	90	75	55	100		
17.1		100	160	85		75	95	65	60	
17.1*	65	90	145	50	85	195	-	35	120	-
17.2		100	155	60	80	105		55	65	
17.3		110	165	70	75	130	45	80		
17.4		80	135	70	90	100	45	85		
17.5		105	160	75	70	110		100		
17.6	40	85	145	55	100	140		110		
25.1	70	45	90	115		80		100		
25.2	65	70	120	50	45	90	75	60	70	
27.1		95	145	65	80	120	45	75		
27.2		95	150	70	50	170		80		
27.3		120	170	80	80	120		80		
27.3*		80	140	80	80	120	-	75	60	-
29.1		100	155	75	75	150	35	65		
29.2	40	110	165	65	70	130		75		
29.3	35	110	155	75	70	140		60		
29.3*	55	90	145	30	105	200	-	70	75	-

Lentelė 8.12

Alternatyva 4A. Atstumų lentelė (metrais) – įplaukimas/ išplaukimas, nuo SGD iki krantinės, pučiant vakarų krypčių vėjui

Plauk. Nr.	SGD laivas	Kr. Nr. 147 17 m riba	Kr. Nr. 147 pirsas	Buja Nr. 31	Kr. 149-152 17 m riba	Terminalo krantinės Nr. 1 kampas	Apsisuk. rato 17 m riba	Buja Nr. 37	Laivas prie term. kr. Nr. 1	Apsisuk. skersmuo
2.1	90	35	90	95	65	60	90	95		420
2.2	95	45	100	55	145	135	35	40	110	440
2.2*	60	85	145	65	85	190	-	80	100	-
2.3	80	45	105	65	70	110	65	80		
2.3*	100	50	105	75	90	190	-	45	55	-
4.1	60	90	135	80	65	140		100		
4.2		110	160	60	105	90	80	65		
4.3	60	90	145	60	80	70	70	60		490
4.3*	125		75	130		75	-	55		-
6.1		70	120	70		45	60	110		
6.2		100	155	60	95			60		
6.3		90	140	70				95		
6.3*	-	-	-		-	275	-	60		-
11.1	60		55	80		110	40	45		
11.2		100	160		105	45	85	85		
11.3	80	55	105	45	75	125	40	56		
11.3*		95	140		150	185	-	60		-
14.1	65	85	135	60	100	110	35	75	65	470
14.2	85	45	105	60	60	90	65	55	105	440
14.3			90	90	70	85	40	95		
16.1		100	155	70	70	65	35	105		490
16.1*		125	180	95	90	130	-	60		-
16.2		95	145	95		70	75	90		480
16.3	60	85	135	55	95	105	35	85	60	450
16.4		35	75	85	90	135	40	75	75	440
16.5		100	150	70	80	95		65		
16.5*	70	55	105	80		165	-	40	105	-
18.1		105	160	65	60	60	35	100		
18.2		115	165	90		80		70		
18.3		90	140	80	80	105	40	60	60	
18.4		80	135	85	70	65	65	70		
26.1	70	65	115	130		85		65		460
26.2		90	140	45	80	55	40	70	60	
26.3		70	130	55	75	120	55	80		430
28.1		105	160	50	80	125	35	45		450
28.2		90	145	60	105	80	55	65		
28.3		70	120	75	75	100	85	50	80	460
28.3*	85	60	120	55		270	-		90	-
28.4	70	70	120	100	75	80	65	60		480
30.1		85	140	85		90	35	55		
30.2		105	150	45	105	105	40	55		
30.3		110	165	65	75	120	35	80		490
30.4	70	55	105	60		90	65	80		
30.4*	115		85	75		175	-	50	80	-
30.5		80	130	70		105	45	50	30	
30.5*		60	120	65	90	120	-	60		-
30.6		80	135	75		120	70	70		460

30.6’	70	15	70	75	50	110	-	95	45	-
30.7	90	60	115	90	55	85	0	70	30	650
30.7*	50	55	105	80	70	135	-	50	110	-

Table 8.13

The ship**'s course relative to the wind in the north** (N) **direction**

Wind direction, Wind speed	Wind speed, mls	Current speed, knots	Drift lane width, m		
			Option 2A	Option 3A	Option 4A
N	10	0.7	75–100	100–120	80–100
		1.5	100–110	120–140	95
		2.0	90–110 (145)	120 (160)	-
	14	0.7	75–105	90–115	95–110
		1.5	1 05-115 (140)	115-1 20 (15 0)	100-125
		2.0	115–120	80–130 (1 60)	100–135
	18	0.7	90–100	75–110 (15 0)	65–75
		1.5	100–105 (135)	80–125	90–115
		2.0	95–110 (160)	105–110	70–120

Table 8.14

Northwest (NW) wind: ship**'s** course **relative to the drift**

Wind direction, rumbai	Wind speed, mls	Current speed, nodes	Width of the movement zone, m		
			Alternative 2A	Option 3A	Option 4A
NW	10	0.7	90–110	110–135	120–130
		1.5	100–130	90–130 (160)	110–130
		2.0	160–165	130–145	115–125
	14	0.7	140–150	130–135	110–125
		1.5	110–130	90–120	130–165
		2.0	125–160	90–135	105–120
	18	0.7	110–140	170	130–135
		1.5	110–120 (170)	150–160	100
		2.0	1 15–120	130–155 (180)	80-135

Table 8.15

Southwest (SW) wind: **ship's movement** range in terms of **drift**

Wind direction, rumbai	Wind speed, mls	Current speed, miles	Width of the track, rn		
			Option 2A	Option 3A	Option 4A
SW	10	0.7	80–100	90–100	85–110
		1.5	80–100	85–100	100–110
		2.0	85–100	80–120	105–120
	14	0.7	80–90	95–120	100–120
		1.5	80–115	100–130 (165)	105–125 (I 65)
		2.0	85–100	100–125	100–110
	18	0.7	90–110	100–120	125 (155)
		1.5	80–85	-	100–125
		2.0	75–90	120–125	105–115

Table 8.16

Wind direction (W) and ship's course in terms of drift

Wind direction, rumb	Wind speed, mls	Current speed, knots	Track width, m		
			Option 2A	Option 3A	Option 4A
W	10	0.7	85–125	105–110	110(145)
		1.5	85–100	90–105	110–120
		2.0	85–100	90–105	100–130 (15 0)
	14	0.7	90–120	115–130	110–135
		1.5	80–90	115–120 (1 55)	80–125 (15 0)
		2.0	80–100	115–130	115–130
	18	0.7	105–130	135–145	120–145
		1.5	85–90	100	115–140
		2.0	75–95	105-145(1 95)	70–150

Table 8.17

Rotation diameter with a **northward** wind

Wind direction, rumbai	Wind speed, m	Current speed, miles	Turn radius		
			Option 2A	Option 3A	Option 4A
N	10	0.7	410 (84 0)	445–560	500–750
		1.5	440–510	655–760	-
		2.0	590–760 (84 0)	625–735	-
	14	0.7	460–840	535–750	660–750
		1.5	605–770	645–740	700–780
		2.0	635–670	615–770	730–780
	18	0.7	530–720	650–720	800–820
		1.5	580–705	630–780	700–810
		2.0	655–745	740–800	700–790

Table 8.18

Turn radius with a northwesterly wind

Wind direction, rumbai	Wind speed, mls	Current speed, nodes	Tuı Diameter		
			2A alternative	3A alternative	Option 4A
NW	10	0.7	430–460	555–710	410–600
		1.5	420–550	650–760	650–740
		2.0	600–690	670–870	610–760
	14	0.7	620–680	720–810	620–655
		1.5	620–700	705–740	700–750
		2.0	690–730	655–695	700–870
	18	0.7	560–700	790	600–750
		1.5	660–880	650–780	850
		2.0	575–800	720–815	760–990

Table 8.19

Turn radius with a **southwesterly wind**

Wind direction, Wind speed	Wind speed, mls	Current speed, knots	Rotation diameter		
			Option 2A	Option 3A	Option 4A
SW	10	0.7	410–490	400–490	450–455
		1.5	490–530	430–505	460–500
		2.0	575–600	450–525	510–540
	14	0.7	500–550	565–690	480–515
		1.5	480–685	415–570	500–540
		2.0	460–615	490–620	580–630
	18	0.7	420–520	520–690	550–560
		1.5	535–550	-	520–550
		2.0	615–650	480–630	570–615

Table 8.20

Turning radius with a headwind

Wind direction, rumbai	Wind speed, mls	Current speed, knots	Turn radius		
			Option 2A	Option 3A	Option 4A
W	10	0.7	430–550	460–550	420–540
		1.5	435–550	410–525	490–540
		2.0	480–550	520–580	500–770
	14	0.7	430–520	450–510	440–505
		1.5	410–520	490–530	440–500
		2.0	555–615	470–605	545–580
	18	0.7	450–480 (78)	680–720	430–500
		1.5	545–550	635	460–570
		2.0	515–550	520–600	460–570 (650)

9. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1. The test results showed that all three alternatives (2A, 3A, and 4A) are suitable for accommodating the largest 400-meter-long container ships with a maximum draft of 15.3 m. However, given the navigational situation for each alternative, different hydrometeorological restrictions apply to each of them.

2. All three alternatives (2A, 3A, and 4A) present an equally complex navigational situation near the LNG terminal (berth No. 157), particularly when two gas carriers are berthed. At this location, to avoid the significant impact of passing vessels on moored vessels, due to the relatively short passing distance of 30–80 meters, vessels must navigate at a speed of no more than 4 knots. When sailing at this speed, vessels 400 meters in length require at least 3 tugs to ensure safety, and when two gas carriers are moored, additional hydrometeorological restrictions are required for the passage of vessels of this size.

In addition to the aforementioned problem area, there is also a channel edge that has not been fully dredged between the bow of Berth No. 146/147 and the corner of Berth No. 148/149, where remaining shoals limit the ability to maintain a safe distance from LNG vessels.

3. In Alternative 2A, in addition to the aforementioned problem area near the LNG terminal where two gas carriers are moored, navigation is also complicated by passage through the southern part of the new container terminal, past other vessels moored at the same terminal's berths. In the presence of a strong current and a strong crosswind, it is difficult to keep the vessel in the middle of the waterway between the two new quays, because the short distance to the moored vessels severely limits the tugboat's maneuverability, and therefore, in most cases, the vessel being towed passes at an unsafe distance from the moored vessels. Given this, when towing vessels of this size, it would be necessary to halt the loading of vessels moored at the quay.

In this alternative, vessels were safely towed in currents of up to 1.5 knots and winds of up to 14 m/s,

without operating the tugs at maximum capacity. In the event of stronger currents and winds, both the tugs and the ship's engines would operate at maximum capacity during navigation, and any technical or human error would be irreparable, potentially leading to a shipwreck.

Additionally, this alternative does not allow for extending the turning basin, which would be crucial for reducing restrictions on the largest ships in the future due to the strong currents that form.

4. **In Alternative 3A**, in addition to the previously mentioned problematic area near the LNG terminal where two gas carriers are moored, the S-shaped navigation channel to the new container terminal is also unfavorable from a navigational perspective. In the presence of a strong current and a crosswind, and when maneuvering the vessel at low speed, due to the additional turns required and the associated change in the current angle relative to the vessel, controlling the vessel is very difficult and, in most cases, impossible without the assistance of a tugboat.

The parameters of the turning circle and the water area in front of the quays are the most favorable for turning the ship among all alternatives. However, the direction of the quay line is the least favorable for mooring the ship among all alternatives. The quay is positioned at such an angle that it is constantly affected by the outflow from the port, and in the event of a stronger current and a crosswind, four tugs cannot ensure the safe mooring and unmooring of the vessel.

In this alternative, ships were safely guided and moored in currents up to 1.0 knots and winds up to 14 m/s, using tugboats not at maximum power. At a current of 1.5 knots and a wind speed of 14 m/s, both the tugboats and the ship's engines operated at maximum power, yet even at maximum power, the ship's safety could not be ensured during mooring and unmooring. In such a case, the ship's safety could be increased by adding more tugs, but not all ships have the capacity to accommodate additional tugs, and the number of tugs available in the port may be limited.

This is the least favorable alternative, and it is the one to which the strictest hydrometeorological restrictions on vessels should apply.

5. **Alternative 4A**, apart from the aforementioned problem area near the LNG terminal where two gas carriers are moored, has only one other area that is more challenging from a navigational standpoint, marked on the chart as Buoy 37, where, a turned-around vessel, in a 2-knot current and a crosswind of 14 m/s, may pass at an unsafe distance from the vessel moored at the quay.

In this alternative, the ships were safely navigated and moored in currents up to 2.0 knots and winds up to 14 m/s, using the tugboats at submaximum engine power. At a current of 2.0 knots and a wind speed of 18 m/s, during vessel maneuvering, both the tugs and the vessel's engines were operating at maximum power, and any technical or human error would be difficult to correct and could result in a vessel accident. In such a case, vessel safety can be increased by adding more tugs, but not all vessels have the capacity to accommodate additional tugs, and the number of tugs available in the port may be limited.

This is the most favorable alternative from a navigational perspective.

RECOMMENDATIONS

1. In the case of any alternative (2A, 3A, and 4A), at least one current meter and a meteorological station must be installed in the newly developed southern section.

2. For any of the alternatives (2A, 3A, and 4A), the eastern edge of the navigation channel must be dredged to the northern end of pier No. 146/147 and to the corner of pier No. 148/149.

3. For any of the alternatives (2A, 3A, and 4A), the possibility of turning the pier of Quay No. 146/147 at an angle should be evaluated, thereby forming a wider channel and increasing the safety of ships moored at the LNG terminal.

4. For any of the alternatives (2A, 3A, and 4A), when two LNG carriers are berthed at the LNG terminal, restrictions must be established for the pilotage of large container ships: wind not exceeding 14 knots, current not exceeding 1 knot, 4 tugs for vessel handling, and a speed not exceeding 4 knots. After conducting several trials, the handling restrictions would need to be reassessed.

5. In Alternative 2A, when maneuvering vessels past ships berthed at the new container terminal, halt the loading and unloading of the berthed ships, as well as any loading equipment that may obstruct the passing vessel.

6. 3A In Alternative , evaluate the possibility of install protective engineering structures on the western edge of the water area to shield the container terminal quays from the outgoing current.

7. In Alternative 3A, evaluate the possibility of deepening the lower southern part of the container terminal to 16.5 meters to expand the space for mooring at the farber quay and for unmooring.

8. In Alternative 4A, expand the water area in the southern section near the container terminal by deepening it directly from buoy No. 35 to No. 39 as marked on the plan to ensure safe operation of the entire terminal without interrupting cargo handling.

9. In Alternatives 3A and 4A, evaluate the possibility of extending the turning basin, which would be highly relevant for reducing restrictions on the largest ships in the future due to the strong currents that form there.