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WP2: INLAND WATERWAYS FAIRWAY TECHNOLOGIES

Interim report of 2.1, 2.2, 2.3 parts of WP2

Project «Future potential of inland waterways» («INFUTURE»)

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INFUTURE

Admiral Makarov SUMIS

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INTRODUCTION

This scientific work executed within the framework of international project "Future potential of inland waterways" ("INFUTURE") in conformity with Cross-border cooperation program with financing from the European Union, the Russian Federation and the Republic of Finland.

This report contains Interim report of parts No. 2.1, 2.2, 2.3 of WP2:

2.1 Feasibility study about prolonging the navigation period in inland fairways and canal routes;

2.2 Evaluation on advanced navigation and hydrography services;

2.3 Comparisons of up-to-day digital technologies for inland waterway traffic monitoring and control.

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LIST OF ABBREVIATIONS

The following abbreviations are used in this report:

ASS	Automated Sounding System
IWW	Inland Waterways
IWT	Inland Waterway Transport
ME	Main Engine
HC	Hydrometeorological conditions
GOST R	State Standard of the Russian Federation
AMSUMIS	Admiral Makarov State University of Maritime and Inland Shipping
CL	Centerline
PSU	Propulsion/steering unit
UDWS	Unified Deep Water System
PPI	Plan-Position Indicator
HA	Heading Angle
STCW	International Convention on Standards of Training, Certification and Watch-keeping for Seafarers with amendments
NHC	Navigation and Hydrographic Conditions
RW	Research Work
PoD	Print on Demand
RIS	River Information Service
W&NA	Waterway and Navigation Areas
HF&NA	Hydraulic Facilities and Navigation Areas
RD	Regulation Document
Radar	Radiolocation Station
RRR	Russian River Register
RF	Russian Federation
ARPA	Automatic Radar Plotting Aids
NA	Navigation Aids
ECDIS	Electronic Chart Display and Information System
CoT	Centre of Turning
FBI	Federal Budgetary Institution
ENC	Electronic Navigational Chart

1. FORMATION OF A CLASSIFICATION LIST OF ORGANIZATIONAL AND TECHNICAL MEASURES AIMED AT IMPROVING THE SAFETY OF NAVIGATION DURING THE NAVIGATION EXTENSION PERIOD

1.1 Navigation during navigation extension period

The instability and variability of the factors ensuring the navigation safety during a given period from the phase of safe navigation to the phase of its prohibition within a short period of time is a distinctive feature of navigation conditions during the navigation extension period. To improve the navigation safety during the navigation extension period, it is necessary to pay close attention to the monitoring of factors that directly affect the navigation safety and actively change over a short period of time.

Let us consider in more detail what factors affect the safety of navigation during navigation extension period and then, on their basis, we will form the classification list of organizational and technical measures aimed at improving the safety of navigation during the navigation extension period.

1.2 Changes in water levels

To ensure the navigation safety, constant monitoring of water levels along the entire waterway shall be provided. On the Neva River such a monitoring is carried out using water measuring posts. The Federal Budgetary Institution Volgo-Balt Administration uses data both from its own water measuring posts and from Roshydromet measuring stations. Data from Roshydromet are provided on a contractual basis and registered in the form of values exceeding the water level at the level “0” of the water measuring post in centimeters.

The water measuring post of the FBI Volgo-Balt Administration is located in the city of Shlisselburg. Roshydromet water measuring posts are located in St. Petersburg (the Mining University) and the settlement Ivanovskoe (Figure 1.1).

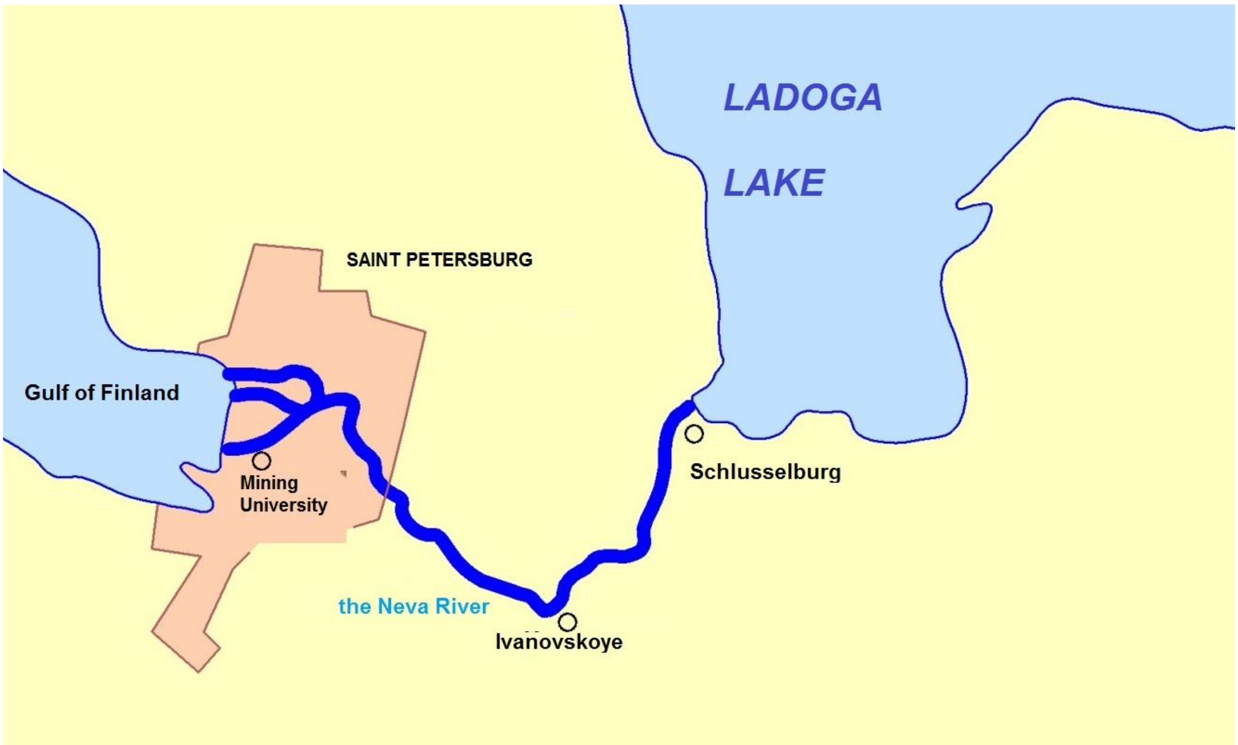


Figure 1.1 Location of measuring posts

Figure 4.2 shows a schematic longitudinal profile of a section of the Volga-Baltic Waterway from St. Petersburg to the Svir River mouth, including the Neva River.

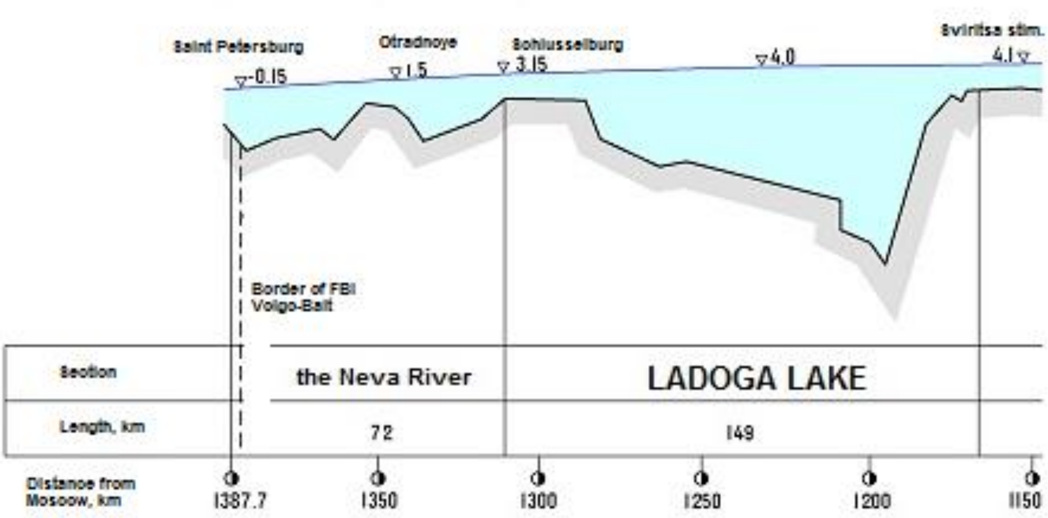


Figure 1.2 Schematic longitudinal profile of a section of the Volga-Baltic Waterway

Currently on the waterways of the FBI Volgo-Balt Administration an automated water-level measuring post is being tested (Figure 1.3).

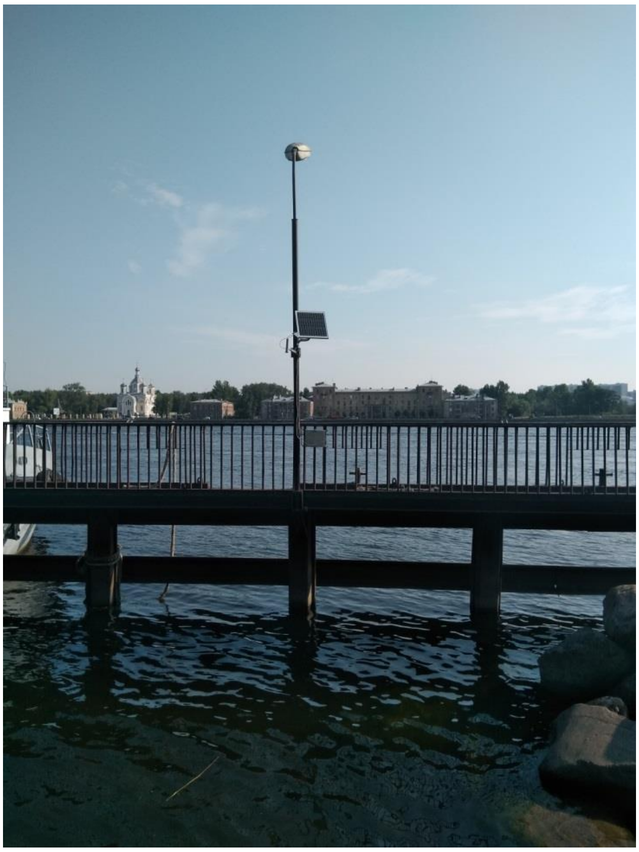


Figure 1.3 Automated water-level measuring post

The main functions of the МАУП-А automated water-level measuring post are automatic water level measurements and transmission of the received information to the server via a communication channel.

To transfer information the SMS (Short Message Service) technology is used, which is part of the cellular communication standards, and allows receiving and transmitting short text messages over the channel of GSM networks.

Data from the МАУП-А post is transmitted to the portal, where, in addition to data imaging in standard tabular form, it is possible to turn on the graphical one. The water level graph supports the scaling function (zoom) for any time period specified by the system user (Figure 1.4).

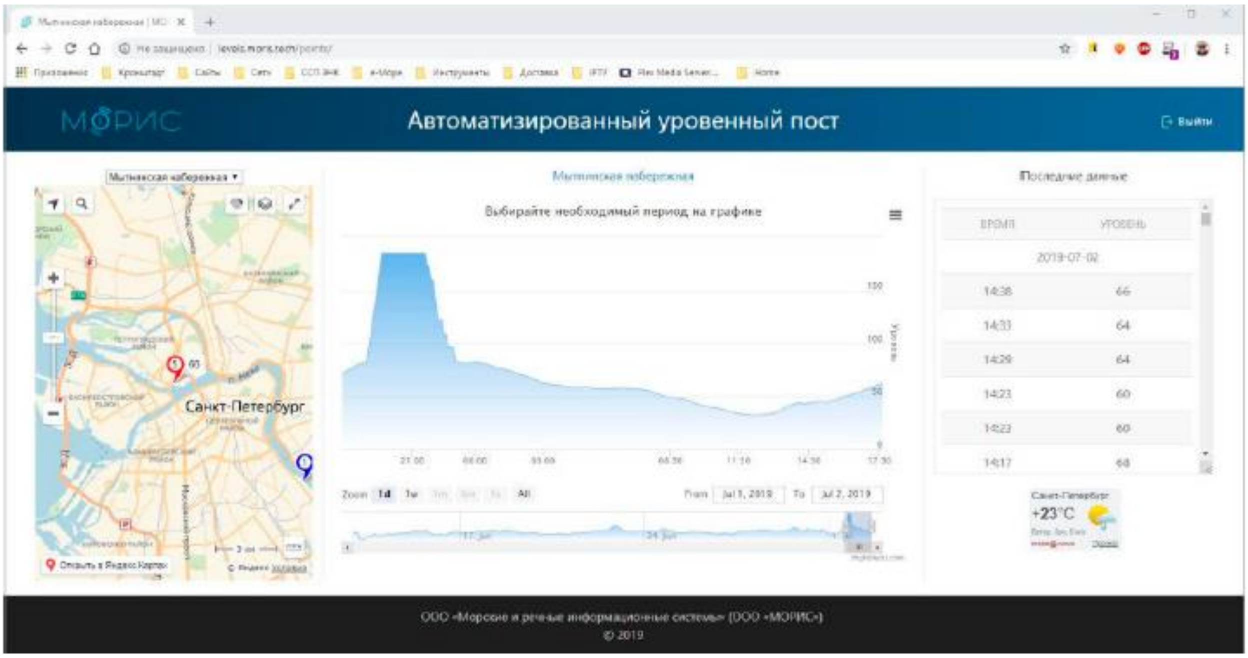


Figure 1.4 Example of МАУП-А data

1.3 Changes in hydrometeorological conditions

The FBI Volgo-Balt Administration receives this data from Roshydromet; there are no its own automated hydrometeorological posts. However for the navigation extention, it may be necessary to install several devices of this type. The quantity shall be determined by a separate project.

1.4 Changes in ice conditions

During the navigation extension period, ice conditions monitoring is one of the most important organizational and technical measures that directly affect the level of navigation safety. Since the weather conditions during this period are quite unstable and the formation of a thick ice cover is possible in a short period of time. An example of such a phenomenon is the events that took place in November 2016, when according to observations the beginning of November in St. Petersburg became the coldest one over the period of 46 years. Interfax reported that the weather situation was unusual and rare one. So frosty days are uncharacteristic for the beginning of November. This already happened in 1995, but then there were positive temperatures, but now the situation is a little different: the "minus" keeps all the time. The last time such an early November was recorded was in 1970.

The weather forecast was as follows: “... frosty weather in St. Petersburg will remain at least until the middle of the month. Heavy snowfalls are expected in the coming days. The chief forecaster added that in the second half of November, the snow will melt, and the temperature background will slightly increase. In St. Petersburg, since the beginning of November, the air temperature does not rise above zero, it snows. Cyclones passing south of the City on the Neva will bring snowfalls and blizzards. On November 8 snow is expected, heavy snow at night, blizzard with gusts of wind 12-15 m/s, moderate daytime, heavy snow in places, light snowstorm. Air temperature at night -5...-7°, in the daytime at -4...-6°. On November 9-10 there will be light, moderate snow in places. air temperature at night -5...- 7° (November 10 — to -9°), in the daytime -4...-6°.

In the Leningrad region and neighboring regions (Pskov and Novgorod regions), the next night (November 8), heavy, in places moderate snow, in places a blizzard with gusts of wind up to 11-15 m/s, in the daytime moderate, in places heavy snow, a weak blizzard, are expected. Air temperature at night -4...-9°, in the daytime at -3...-8°. In Karelia the weather is also snowy with a blizzard, the wind will be stronger, 15-20 m/s, near water bodies up to 24 m/s. The temperature at night on November 8 will drop to -17° in places, in the daytime mostly -1...-6°.

On November 9 and 10 in the north-western regions, snow and cold snap, temperature at night -6...-11°, in places -13...-18°, in the daytime -4...-9°, in the south of the Pskov region go to 0°.

In Karelia the temperature will continue to drop, at night -7...-12°, in some places -15...-20°, in the daytime -3...-8°".

This phenomenon seriously restricted the movement of ships (Figures 1.5, 1.6).

Figure 1.5 Ice phenomena on the Neva River in 2016

Figure 1.6 Ice phenomena on the Neva River in 2016

1.5 Changes in waterway depths

In order to ensure a high level of navigation safety during the navigation extension period, it is also necessary to monitor the waterway depths as in the main navigation period.

The depth control on the Neva River is carried out by the Nevsko-Ladozhsky Grand Division for Waterways and Shipping (the FBI Volgo-Balt branch) with the use of automated sounding systems.

An automated sounding system is a complex of technical (hardware) and software tools combined into a single system, necessary for the automated production and processing of the results of hydrographic and topogeodetic works during channel surveys on inland waterways in order to collect and process navigation, hydrographic information and geodetic data in order to create unified electronic cartographic support of the IWW, as well as for navigational and hydrographic support of dredging, river training and other engineering works, monitoring the state of ship fairways and the navigational buoyage system.

The schematic diagram of the automated sounding system (ASS) is shown in Figure 1.7.

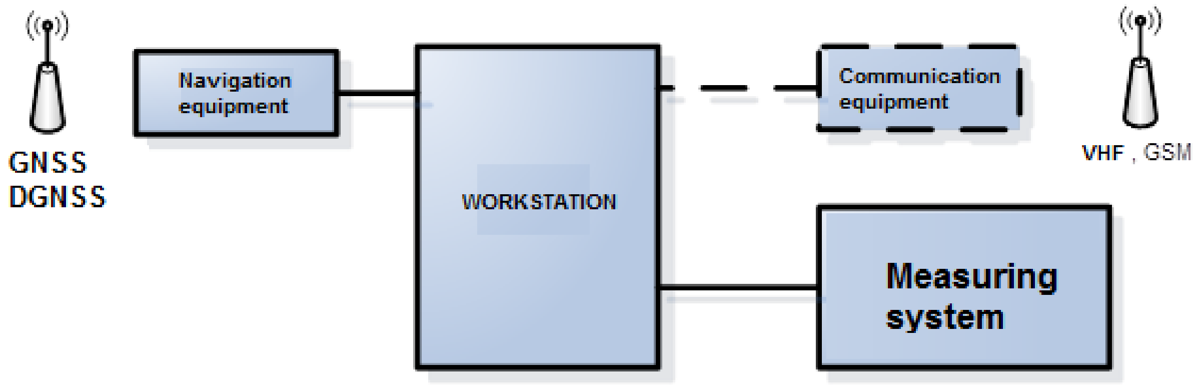


Figure 1.7 The schematic diagram of the automated sounding system (ASS)

The hardware and software tools of automated sounding system, when operating in conditions of all types of the RF waterways, shall ensure the successful solution of the following tasks:

– measurement of the operational characteristics of waterways during hydrographic and engineering works with an accuracy not worse than that specified in the regulatory documentation in relation to the area of work (sea water area or inland waterway);

- transformation of information received from the measuring sensors of the system, for their subsequent processing by the system software in order to form a database of navigation information for compiling a fair sheet for the production of hydrographic works in accordance with the regulatory documentation in relation to the area of work (sea water area or inland waterway);
- selection, provision and control of the process of carrying out hydrographic works in automatic or computer-aided survey mode;
- display and output in digital and analog forms of all parameters of the functioning of the ASS to the visualization device;
- creation of messages in the form of warning signals in visual and audible forms about unplanned deviations and reductions of the established limitations of parameters during the hydrographic works;
- accumulation and storage of navigational data obtained in the course of hydrographic work in electronic form;
- transmission of navigation data obtained during hydrographic work to the basin center for the processing and accumulation of navigation information.

The following components shall be included in the automated sounding system:

- measuring sensors;
- channels and devices for data transmission;
- hardware and software for information processing;
- power supply units;
- data output devices.

The data output after processing in the ASS shall be carried out in graphical form (on paper), or in electronic form for further creation on the basis of the received data of electronic navigation charts of sea areas, IWW or special digital models of fairway parameters.

Carrying out hydrographic work on the RF waterways to ensure the collection, processing, storage and transmission of navigational information using the ASS shall include the following main stages:

- making tacks based on the data of the IWW ENC (if any), or on the raster image of the given area or fragment of the satellite image in the “geotiff” format;
- continuous display of tacks made or special waypoints to keep the sounding vessel within the route line, taking into account the impact of hydrometeorological factors affecting the vessel during hydrographic work;
- survey of the IWW area and measurement (survey) of depths according to a pre-planned tack system and recording the received navigation information;
- determination and recording of the current coordinates generated by the navigation system GNSS GLONASS/GPS, which is a part of the ASS, with the specified discreteness and accuracy necessary for carrying out hydrographic work on the current section of the IWW;
- control of operating modes of the ASS equipment;
- monitoring of errors affecting the determination of the measured parameters to calculate and subsequently take into account corrections to them;
- keeping an electronic log of the ASS operation in real time;
- displaying the monitoring results in the working layer of the specialized ASS software synchronized with the ENC of the area of work (if any);

- prompt notification of the ASS operator about the detected navigation hazards;
- processing and transmission of navigation information data to the basin navigation cartographic information processing center.

The data exchange standards used in the ASS shall allow to work in a single information field with other models of the equipment used within the RF IWW. The ASS shall be an integral part of the navigation, hydrographic and cartographic system for the RF IWW, as it is the main means to obtain reliable navigation and hydrographic information for the compilation and updating of navigation maps.

When carrying out hydrographic work on the IWW, the ASS shall provide an automated solution to the following tasks:

- study of the IWW state and characteristics at the beginning of navigation or during navigation period, to identify areas requiring engineering and dredging works, as well as the sequence of these works;
- carrying out primary, repeated and control surveys of bottom relief;
- formation of a database of navigation information in electronic form for the subsequent design of engineering and dredging works;
- formation of a database of navigation information in electronic form to create ENC and its corrections on its basis;
- creation of plans of water areas obtained by channel survey parties during the navigation period;
- execution of onshore geodetic works (with office processing) for the preparation of initial geodetic data to create the RF IWW ENC on the basis of the received data;
- tracing of operational dredging cuts, and their setting out;
- drawing up outline plans of cuts.

The work of each ASS segment shall be controlled by the operator. The operator controls the surveying process, operation of the navigation equipment and other sensors included in the ASS, and selects the system operating mode based on the data received.

The ASS shall allow operational control of the survey quality by conducting primary processing, and develop recommendations for the ASS operator to correct the hydrographic work process based on the results of primary data processing.

The Nevsko-Ladozhsky region of waterways and shipping uses two types of ASS:

- ASS "Delta" manufactured by LLC Kronstadt;
- ASS with a SeaBat T20 multibeam echo sounder.

The appearance of ASS "Delta" is shown in Figure 1.8, and the interface of ASS "Delta" is shown in Figures 1.9, 1.10.

Figure 1.8 Automated Sounding System ASS "Delta"

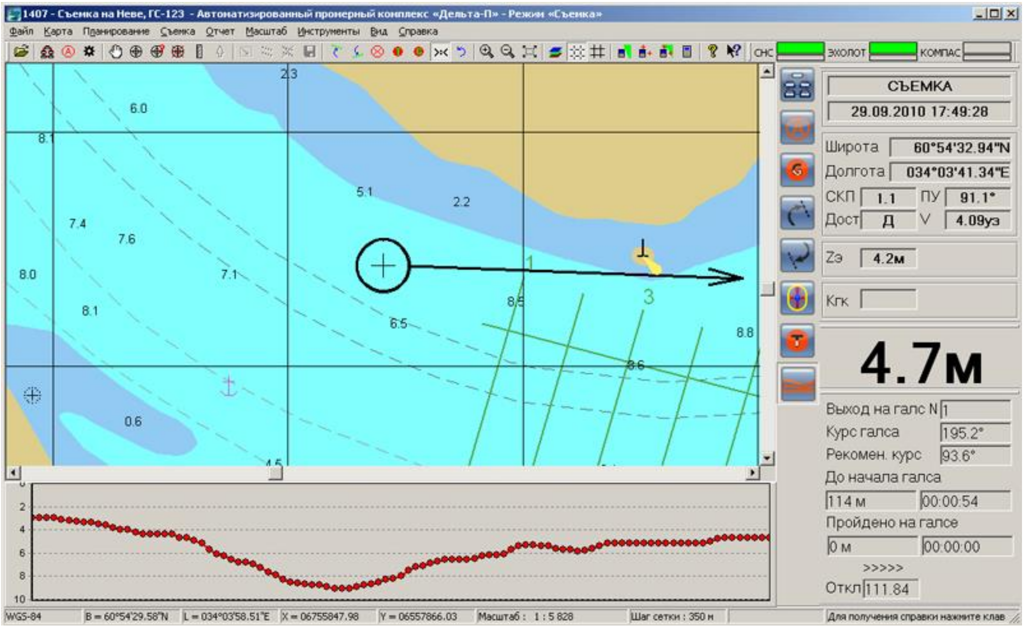


Figure 1.9 View of the working screen of the sounding system with the mark of the sounding vessel entering the area of work

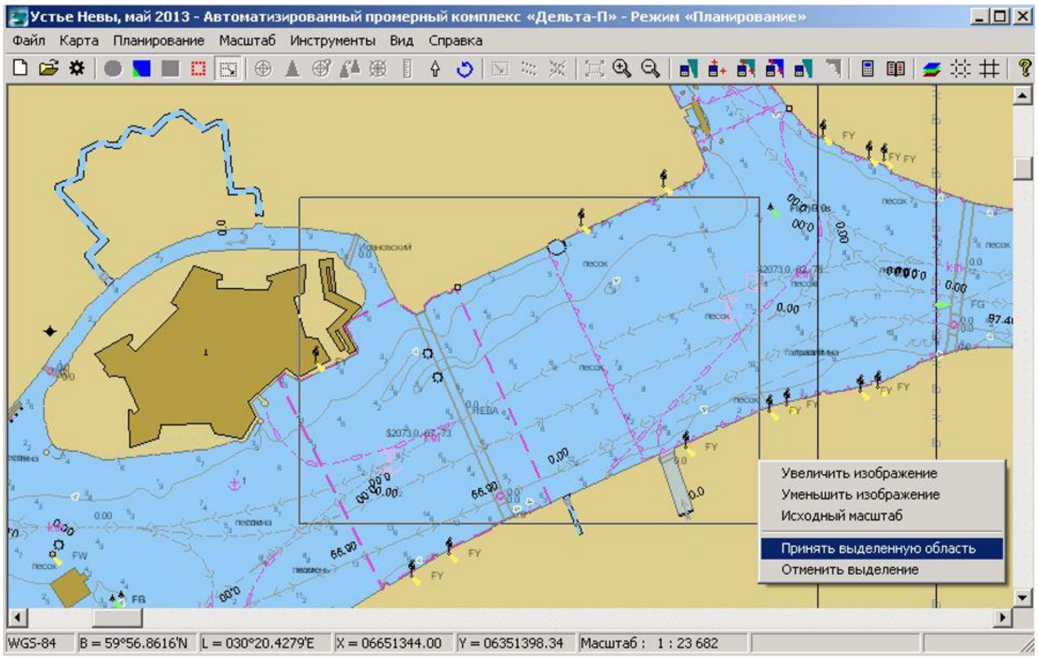


Figure 1.10 The workstation screen of the sounding system with loaded ENC for planning and drawing tacks on the work area

For the purpose of creating and updating ENC atlases for the inland waterways of the Volga-Baltic basin, the cartographic service uses data received from the ASS with a SeaBat T20 multibeam echo sounder with two emitters. The SeaBat T20 system specification shown in Figure 1.11.

SEABAT T20 SYSTEM SPECIFICATION

INPUT VOLTAGE	24 B= OR 100-230 B~ 50/60 Hz
POWER (standard/maximum)	200 W/ 300 W
PROTECTION CLASS	Waterproof (IP54)
CABLE LENGTH TO TRANSCEIVER	10 m (standard), 25 m and 50 m (option)
TEMPERATURE RANGE (OPERATION/STORAGE)	Echo sounder portable control unit: -2°C to +40°C/ -30°C to +55°C
	Submerged part: -2°C to +30°C/ -30°C to +55°C

	Height [mm]	Width [mm]	Depth [mm]	Weight [kg/in air]	Weight [kg/in water]
T20 RECEIVING ANTENNA (EM7219)	102.0	254.0	123.0	5.0	4.2
T20 EMITTER (TC2181)	86.6	93.1	280	5.4	3.4
ECHO SOUNDER PORTABLE CONTROL UNIT	131	424	379	14	-

ACOUSTIC PROPERTIES	400 kHz (max frequency)	200 kHz (min frequency)
CROSS COURSE BEAMWIDTH ON RECEIVE (rated values)	1.1° (at centre)	2.2° (at centre)
TRANSVERSE COURSE BEAMWIDTH ON RECEIVE	1.1°	2.2°
NUMBER OF BEAMS	Maximum 512. Minimum 10	
ANGULAR COVERAGE (MAX. ANGLE)	140° (165°)	140°
DEPTHS	0.5-150 m	0.5-400 m
MAXIMUM INCLINED RANGE	500 м	
PULSE TRANSMISSION SPEED (vs inclined range)	Up to 50 impulses per sec	
PULSE LENGTH (CW)	30-300 msec	
PULSE LENGTH (FM)	300 msec - 10 MLS	
DEPTH RESOLUTION	6 mm	
AVAILABLE ECHO SOUNDER ANTENNA DEPTH	50 m	

Figure 1.11 SeaBat T20 system specification

The beamwidth at depths of 3-4 m is from 18 to 20 meters, and at depths of more than 6 m it reaches 110 m, depending on the hydrological conditions of the environment and reference angle.

The main advantage of a multibeam echo sounder is the ability to survey a large area of the waterway areal. There is no need to tack, as is the case with a single beam echo sounder, the quality and density of the received data is much higher.

The equipment of the SeaBat T20 system is shown in Figure 1.12.

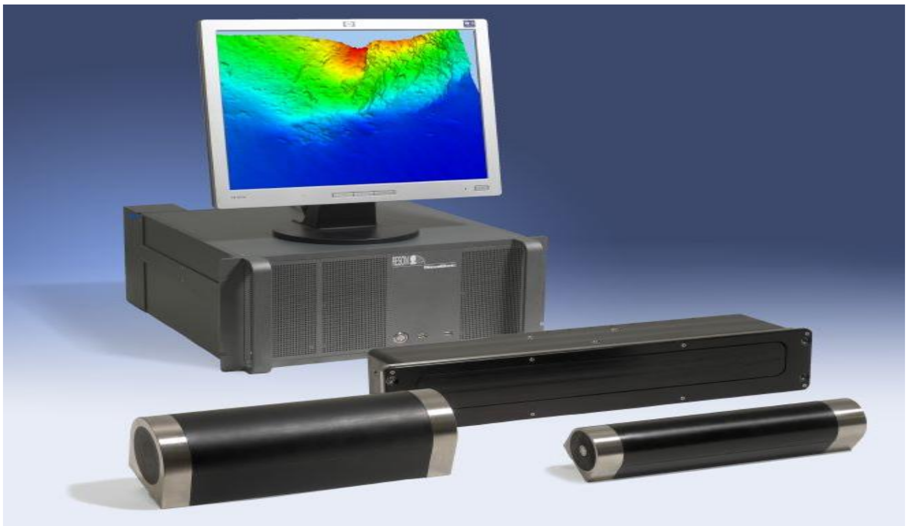


Figure 1.12 SeaBat T20 system equipment

1.6 Dispatch control on the Neva River and Lake Ladoga

The dispatch control is organized in accordance with the requirements of the Procedure for dispatch control of the vessel traffic on the inland waterways of the Russian Federation (see Appendix 1), which applies to all ships navigating along the Volga-Baltic Waterway route, regardless of their ownership.

The movement and anchorage of vessels performing voyages on the Volga-Baltic Waterway route and lakes are subject to mandatory control and monitoring at control points (CP). Information about the CP is given in Table 1.

Table 1.1 Control points with mandatory masters communication with traffic dispatchers by VHF radio

It. No.	Control point	Sheet no.	Message distance, km	Communication channel no.*	Line control center	Call sign
1	Blagoveschensky and Tuchkov bridges	2	1385	4 (5)	Saint Petersburg	Peterburg-3-moving/«Петербург-3-движение»
2	Ust-Slavyanka roadsteads	5	1361	2 (5)	Saint Petersburg	Peterburg-3-moving/«Петербург-3-движение»
3	Nevsky Lesopark roadstead	6	1356	2 (5)	Saint Petersburg	Peterburg-3-moving/«Петербург-3-движение»
4	Cape Shcherbinka	7	1350	2 (5)	Cape Svyatki	Ivanovskoye-3-moving/«Ивановское-3-движение»
5	Lobanovo	9	1334	2 (5)	Lobanovo	Lobanovo/«Лобаново»
6	Ladozhsky bridge	10	1321,5	3 (5)	Shlisselburg	Shlisselburg-/«Шлиссельбург-3»
7	Shlisselburg roadstead	11	1319	3 (5)	Shlisselburg	Shlisselburg-3/«Шлиссельбург-3»
8	Bugrovsky buoy	13, 14, 15	1302	3 (5)	Shlisselburg	Shlisselburg-/«Шлиссельбург-3»
9	Konevets island traverse	15	–	3 (5)	Shlisselburg	Shlisselburg-3/«Шлиссельбург-3»
10	Sukho lighthouse traverse	14, 15	1230	3 (5) 2 (5)	Shlisselburg, Sviritsa	Shlisselburg-3, Sviritsa-3/«Шлиссельбург-3», «Свирица-3»
11	Novaya Ladoga	14, 15	–	2 (5)	Sviritsa	Sviritsa-3/«Свирица-3»
12	Pitkyaranta	15	–	5 (6)	Pitkyaranta	Pitkyaranta radio/«Питкяранта-радио»
13	Valaam	15	–	3(5,7)	Priozersk	Priozersk radio/«Приозерск-

						радио»
14	Rovnoye	15	–	3(5,7)	Priozersk	Priozersk radio/«Приозерск-радио»
15	Burnev bouy № 1104	15	–	3(5,7)	Priozersk	Priozersk radio/«Приозерск-радио»
16	Svir receiving buoy	14, 15	1173	2 (5)	Sviritsa	Sviritsa-3/«Свирица-3»

*The back-up communication channel number for the radio operator is indicated in brackets.

Notes.

1. The master of a vessel moving both from the sea and from inland waterways to the boundaries of responsibility of the FBI Volgo-Balt Administration, no later than 24 hours before the approach, shall report the following data to the Central Dispatch Service the following:

– name and flag of the vessel, owner, agent;

– ports of departure and destination;

– length overall;

– extreme breadth;

– hull height;

– bow draft and aft draft;

– height overall;

– number of passengers;

– cargo name, special properties, quantity;

– need for pilotage and bridge rising;

– vessel class and restrictions by the wind-wave regime when navigating in the basin of category "M" and "O" (the Register’s permission).

The master submits to the shipping agent a request for port services, clearance of arrival and departure, checkpoint, customs, sanitary and epidemiological service, State Regional Fire Inspection, etc.

2. When navigating the main route, the master shall contact the traffic dispatcher and report the time of the checkpoint passing.

3. The master of the vessel passing for loading, unloading, repairing or for refuge shall inform the traffic dispatcher of the time of approach the berthing points.

4. In case of unforeseen stops along the way, the master shall inform the traffic dispatcher about the stop of movement, the reason for the stop and estimated time when the movement will be continued.

5. The master of a vessel intending to start movement from the points of loading, unloading, repair or refuge, from roads, shall inform the traffic dispatcher about the estimated time of departure, as well as the data specified in it.1, and obtain permission to start movement.

Dispatch control on the Volga-Baltic waterway is carried out on the basis of the document Procedure for dispatch control of the vessel traffic on the inland waterways of the Russian Federation (see below in the following section).

APPROVED

by order of the Ministry

of Transport of Russia

dated March 1, 2010

No. 47

Procedure
for dispatch control of the vessel traffic
on the inland waterways of the Russian Federation

I. General provisions

1. This Procedure establishes the rules for dispatch control of the vessel traffic on the inland waterways of the Russian Federation (hereinafter - IWW) in order to ensure the safety of navigation.

2. Dispatch control of vessel traffic on the IWW is organized by the Federal Agency for Maritime and River Transport through subordinate organizations authorized to carry out dispatch control of vessel traffic on the IWW (hereinafter - organizations subordinate to Rosmorrechflot), and is carried out in accordance with this Procedure.

3. All self-propelled vessels (except for small vessels) and towed (pushed) convoys are subject to dispatch control of vessel traffic on the IWW.

4. Dispatch control of the traffic of non-self-propelled and towing (pushing) vessels in convoys is carried out taking into account the features determined by the schemes of their formation prepared by the shipowners and agreed with the territorial bodies of the Federal Service for Supervision of Transport and organizations subordinate to Rosmorrechflot.

5. Dispatch control of vessel traffic on the IWW is carried out by dispatchers of organizations subordinate to Rosmorrechflot (hereinafter - the dispatcher) in cooperation with dispatchers of legal entities and individual entrepreneurs.

6. Dispatch control of vessel traffic on the IWW is carried out in the entire basin or in certain sections of the basin inland waterways (hereinafter referred to as the regulated section). On rivers on which artificial water retaining and navigation facilities have been erected that have changed the natural flow regime, on canals, as well as regulated sections of the IWW that have restrictions on navigation conditions, dispatch control of vessel traffic on the IWW is mandatory for the vessels specified in clause 3 of this Procedure.

7. The temporary introduction of compulsory traffic control on the IWW is announced in the notices to navigators and in the operational route information.

II. Activity management of dispatchers

8. The IWW dispatcher is the organizer of safe navigation on the IWW in terms of the implementation of dispatch control of vessel traffic on the IWW in accordance with the requirements of this Procedure.

9. Dispatcher:

1) take measures to ensure the safe navigation of vessels on the controlled area, timely transfer operational information on the safety of navigation to the vessels;

2) receives information from the masters (watch officers) of vessels on the compliance of the dimensions of vessels and convoys with the dimensions of the route, locks, bridges, compliance with the established underkeel clearances;

3) informs masters about restrictions for the movement of vessels on inland waterways and carries out dispatch control in accordance with these restrictions;

4) transmit to vessels, at the master's request (watch officer) and the vessel owner, information on the navigation conditions on the IWW, as well as on phenomena hazardous for the navigation;

5) upon receipt of a distress signal from a vessel, immediately notify the State Maritime Rescue Coordination Center, as well as all vessels in this area, its coordinates to assist in the rescue of the vessel, people and property;

6) upon receipt of information about a transport accident, immediately notify about them to the head of the organization subordinate to Rosmorrechflot, which carries out dispatch control on the controlled area of the IWW, to the territorial bodies of the Federal Service for Supervision of Transport, and to the State Maritime Rescue Coordination Center and to the vessel owner (vessel agent);

7) for the purpose of dispatch control of vessel traffic on the IWW, has the right to receive information from the head of work on the remediation of the consequences of transport accidents within the controlled area;

8) carries out planning and passage of vessels and convoys through locks in accordance with the Rules for the lockage of vessels and convoys within the internal waterways of the Russian Federation, approved by order of the Ministry of Transport of Russia dated July 24, 2002 No. 100 (registered by the Ministry of Justice of Russia on July 31, 2002, registration No. 3643);

9) take measures to ensure the timely passage of vessels and convoys through locks and through controlled areas;

10) in order to regulate the vessel traffic on the IWW, fixes the location of vessels in the controlled area. On the schedule or location of vessels, the vessel name, owner, lessee, agent, number of passengers, type and amount of cargo, points of departure and destination, shall be indicated;

11) informs, at the master's request (watch officer), about the location of environmental facilities and integrated service points for the fleet;

12) transmits, upon request of legal entities and individual entrepreneurs, information on the location of their vessels and convoys;

13) maintains the following documentation:

watch log-book;

dispatch records;

log of telephone messages (fax messages);

order log;

magazines (files, data files) of weather forecasts and route conditions;

traffic accident log;

14) requests and receives from legal entities and individual entrepreneurs information about the location of their vessels, their arrival, departure and transport accidents;

15) when a vessel approaches a controlled area of classes "O" or "M” of the inland waterways, transfers to the master (watch officer) the weather forecast for the planned transition period and other available information regarding ensuring the safety of navigation on the IWW;

16) depending on the restrictions on the wind-wave regime and(or) ice conditions of navigation of vessels and weather forecast established for the vessel, give permission to passage or prohibit it;

17) receives a master’s report on the further movement or stop of the vessel;

18) shall know the location of the rescue (tug) vessels of the class "M" assigned to the IWW controlled section and have radio communication with them.

10. Dispatchers of the adjacent basins inform each other about vessels approaching the basin boundaries.

11. The dispatcher has the right to receive information from the shipowners about the organization of a temporary dispatch center to manage the work of the fleet on temporarily used sections of inland waterways (expeditionary carriage) or in places where technical facilities for the production and loading of aggregates are located.

12. The dispatcher of the control point shall promptly transmit to the masters operational information on the safety of navigation and on features of navigation of vessels in the area, moving and anchored vessels, as well as navigation situation changes.

The dispatcher of the control point gives permission for the vessel movement in the area, departure from the points, from the roadsteads, based on the existing fleet deployment and considering the actual hydrometeorological situation.

III. Interaction of the vessel's master with the dispatcher

13. When the vessel approaches the controlled area, as well as the location of the control center (control point), the master (watch officer) transmits the following information at the dispatcher's request:

name and class of the vessel, owner, lessee, dimensions and technical condition of the vessel, maximum draft, as well as points of departure and destination, type and amount of cargo, number of passengers;

date and time of the vessel's departure from the point of departure;

estimated time of the vessel arrival at the destination point;

forced or planned stopping of the vessel on passage and its end;

damage, malfunction or absence of navigation signs, traffic accident, pollution of the water environment;

unfavorable sanitary and epidemiological situation onboard the vessel.

14. If it is impossible to transmit the information set forth in clause 13 of this Procedure, the master (watch officer) brings it to the vessel owner (lessee), who brings this information to the dispatcher.

15. The vessel master (watch officer) asks the dispatcher for permission to move through the area, the vessel's departure from the anchorage point, as well as from the roadstead.

16. The master (watch officer) when the vessel approaches the section of the inland waterway of the "O" or "M" categories, informs the dispatcher about the restrictions set for the vessel on the wind and wave regime, as well as on the ice conditions of the vessel's navigation and requests permission to continue moving.

The master (watch officer) reports to the dispatcher on the further movement of the vessel indicating the time of the vessel's departure, the estimated and actual time of passage of the "O" or "M" category areas, or the vessel stoppage and makes a corresponding entry in the logbook.

If it is impossible to transmit information to the dispatcher, the information is transmitted by the master (watch officer) to the dispatcher of the nearest dispatcher station.

Item 7 assumes that compulsory dispatch control can be temporarily introduced in certain sections of the IWW. This item can be used when organizing navigation during navigation extension period in areas where there is no such regulation.

Within this section, item 9 (especially 9.1 and 9.3) on informing for navigators is the most important.

1.7 Timely informing for navigators

During the navigation extension period, it is especially important to timely inform navigators about all changes along the waterway. This information is provided using radio communication aids.

The navigators sailing along the Volga-Baltic Waterway shall be guided by the Instructions on the organization and maintenance of radio communication with vessels when navigating on inland waterways of the European part of the Russian Federation. While the vessel is in motion, the VHF radio station shall be constantly switched on channel 5 (frequency 300.2 MHz), which is used by coastal radio stations to call ships, and by ship stations - to call each other, to answer a call, brief negotiations on overtaking, passing of ships and messages about the transition to another frequency.

In the event of an emergency, the master (watch officer) is obliged to call the nearest vessels and coastal radio stations on channel 5 (frequency 300.2 MHz) and report the incident.

In case of changing the communication channel number, in order to exclude the occurrence of an emergency situation due to errors when using the inter-ship communication channels, the watch officer shall ensure that channel 5 is monitored at the backup radio station.

Channel 22 is used for communication between the vessels on the waterways of St. Petersburg and the dispatcher of the Water Transport Administration, the call sign is "Petersburg-radio-78". For communication between the dispatcher of the Administration and public water transport in St. Petersburg, channel 25 is used, call sign "Petersburg-radio-98". On the rivers and canals of St. Petersburg, which are not included in the list of inland waterways of the Russian Federation, the communication of ships between themselves and the dispatcher of the Water Transport Department is also carried out on channel 22.

To ensure the navigation safety along the entire length of the Volga-Baltic Waterway, monitoring of channel 5 of inter-ship communication by coastal radio stations is provided.

The communication channel changes when the vessel moves during the opening of bridges and in areas near locks. The communication channel numbers in these sections are given in Table 2.

Table 1.2 Working channels of VHF radio communication between ships on the section of the Volga-Baltic waterway from St. Petersburg to Lake Ladoga

Waterway section, km	Communication channel no.*	Atlas sheets	Notes
The Neva River			
1384.6-1376.6	4, 5	2-3	Channel 4 is only used when moving during bridge rising time
1376.6-1355.5	2, 5	3-6	Channel 2 is only used when moving during bridge rising time
1355.5-1321.8	5	6-10	-
1321.8-1301.2	3	10-13	Channel 3 is used for communication with the traffic dispatcher in Shlisselburg
Lake Ladoga			
1301.2-1172.7	5	13-14	-

Radio communication on the Volga-Baltic waterway is carried out on the basis of the document Organization of radio communications for the safety of navigation, ship traffic control and ship flow monitoring on the Volga-Baltic waterway, which is given below in the section.

APPROVED BY:

CEO
FBI Volgo-Balt Administration

<*signature*> Shishlakov F.V.

Stamp
________________ 2020

Organization of radio communications for the safety of navigation,
ship traffic control and ship flow monitoring on the Volga-Baltic waterway
(as of 01 May 2020)

Head of the Basin Communication Centre
FBI Volgo-Balt Administration <*signature*> Brodsky E.L.

CONTENTS

General Provisions

This document was developed on the basis of the "List of coastal radio stations and their schedule of operation on the waterways of the Unified deep-water system of the European part of the Russian Federation" as of 01.09.2012 and **amended as of 01 May 2020**, in accordance with the "Rules for radio communication of mobile service and mobile-satellite service on inland waterways" and other guidance documents.

Inland waterway ships shall be equipped with radio communication equipment in accordance with the current Rules for the Classification and Construction of Ships (RCCS) of the Russian River Register, Part VII, p. 2.1.

When determining the composition of the equipment, it should be borne in mind that there are "dead zones" in the water area of Lake Ladoga, where VHF communication is not guaranteed. "Dead zones" are indicated on the map of Lake Ladoga (Appendix 1).

Inland waterway ships navigating along the Volga-Baltic waterway are provided with the following types of technological radio communication:

- radiotelephone communications with coastal stations monitoring distress, urgency and safety calls (**Table 1**);
- weather forecasts, navigational warnings and route information (**Table 2**);
- radio communication to provide traffic control and public correspondence processing (**Table 3**).

1. Distress, urgency and safety signals

1.1. Ship UHV radio stations shall ensure constant surveillance on the frequency (channel) of calling for distress, urgency and safety (300.2 MHz, channel 5).

1.2. If only one UHF radio station is installed on a ship, then for radio communication, it can briefly switch to other frequencies (channels), while after the end of radio communication, this ship's radio station shall immediately be switched to the distress, urgency and safety frequency (channel). It is prohibited to switch such a ship's radio station from the distress, urgency and safety frequency (channel):

- within the fairway areas with visually limited view of the coastal objects at night;
- when the vessel is moving in conditions of limited visibility;
- in case of passing with other ships;
- when the ship is anchored within the fairway.

1.3. Calling a ship in distress has priority over all other radio broadcasts. All radios receiving a distress signal are required to stop any transmission that could interfere with radio communications in the event of a distress. Acknowledgment of reception of the distress call is made after receiving the distress call and the distress message.

1.4. Calls and messages about distress, urgency and safety are transmitted only at the direction of the ship master, the person acting on behalf, or the master of a small boat, if the crew of such a ship consists of one person who is navigating.

1.5. Upon reception of distress, urgency and safety signals, a member of the ship's crew who maintains a radio watch (navigator, head of the radio station, radio operator) shallreport immediately:

- if onboard a ship - to the ship's master or dredger commander;
- if from a coastal radio station - to a person appointed by the head of the coastal radio

station.

By order of the ship master that has received the distress signal, the crew member in charge of the radio watch shall ensure relay of the distress signal and the distress message to the coastal radio station.

1.6. The radio station of a ship in distress, or a ship through which radio communication in distress is carried out, is obliged to maintain continuous radio communication with the coastal radio station of the organization that manages the search and rescue of the ship in distress.

1.7. A distress signal is used by a ship to notify that she is under threat of serious and imminent danger and asks for immediate assistance.

A telephone distress call consists of:

– the word "MAYDAY" transmitted three times;

– the words "This is" transmitted once;

– the ship name transmitted three times.

After the distress call, a distress message is sent, which contains:

– the word "MAYDAY";

– name of the ship in distress and its call sign (if any);

– information about the location of the ship in distress;

– information about the distress nature and the necessary assistance.

The distress call and distress message are repeated until an acknowledgment of its receipt is received.

If the radio station of a ship in distress does not receive a response to the distress signal and a distress message on one of the frequencies where the distress, urgency and safety signals are being monitored, this message may be repeated on any other available frequency (channel) at which attention can be drawn.

1.8. The radio operator of the coastal radio station or a member of the ship's crew, keeping the radio watch, who has received the distress message, confirms the receipt of the distress signal and the distress message to the ship by transmitting a message that contains:

– the word "MAYDAY" transmitted once;

– the name of the ship that sent the distress message and its call sign (if any) transmitted three times;

– the words "This is" transmitted once;

– the call sign of the coastal radio station confirming the reception, or the name and call sign (if any) of the ship confirming the reception, transmitted three times;

– the words "Received MAYDAY" transmitted three times;

– the word "MAYDAY" transmitted once.

In what follows, the word "MAYDAY" in the distress exchange by telephone radio communication is transmitted before each call to communication.

1.9. The control of radio communications in distress is carried out by crew members authorized to operate the radio station of a ship in distress, or by members of the ship's crew authorized to operate a ship's radio station that transmitted a distress signal and a distress message, or employees of a coastal radio station that transmitted a distress signal and a distress message.

Radio communications control may be shared with others who operate radios that provide communications with a ship in distress or those who operate radios that provide search and rescue control.

A ship in distress has the right to choose the radio station with which communication is provided. Other radio stations are prohibited from calling a ship in distress.

1.10. Crew members authorized to operate a ship's radio station in distress, or members of the ship's crew authorized to operate a ship's radio station, directing radio communications in the event of a distress, or employees of a coastal radio station managing radio communications in case of a distress, are entitled to transmit commands to all stations to stop transmissions to frequency (channel) of distress, urgency and safety (emergency radio) or only a radio station interfering with radio communications.

In this case, the following are transmitted by telephone radio communication:

– the call sign of the relevant coastal radio station, or the name and call sign (if any) of the ship concerned;

– the words "Stop transmitting";

– the word "MAYDAY".

1.11. At the end of the radio communication in distress, the person operating the radio station in charge of the radio communication transmits a message addressed to all radio stations about the end of the radio communication in distress, which contains:

– the word "MAYDAY", transmitted once;

– the words "This is" transmitted once;

– the call sign of the relevant coastal radio station, or the name and call sign (if any) of the vessel concerned, transmitted three times;

– Moscow time of the message transmitted once;

– name of the ship in distress transmitted once;

– the words "MAYDAY SEELONCE FEENEE" transmitted once.

1.12. Urgency signal means that the calling radio station has an urgent message to transmit concerning the safety of the ship, the person on board or visible from the ship.

– The urgency signal is transmitted on the same frequencies (channel) on which the call and the distress message are transmitted and has priority over all other radio messages, except for the distress message.

– All stations that receive it must not interfere with the transmission of the message following the urgency signal.

– The urgency signal for telephone radio communication consists of three times repetition of a group of word "Urgent", transmitted before the call, which can be addressed both to one specific station and to groups of ship radio stations with the words "ALL STATIONS" being transmitted.

1.13. Radio operators of the coastal radio station or the ship crew members keeping a radio watch, who have received the urgency signal, shall continue to monitor its transmission for three minutes.

1.14. Members of the ship's crew who are authorized to operate the ship's radio station, or employees of the coastal radio station that transmitted the urgency signal and the message following it, shall immediately report the cancellation of the urgency signal as soon as it becomes known that the need for this message has disappeared.

1.15. A safety signal means that the radio station intends to transmit a message regarding the safety of navigation:

– storm and other urgent hydrometeorological warnings;

– notifications about changes in navigation and route conditions.

The signal and the safety message are transmitted on the same frequencies on which the distress and urgency messages are transmitted.

The safety signal consists of repeating the word "Safety" and the words "All Stations" three times.

Radio stations that receive the safety signal shall receive the safety message up to the end of transmission.

1.16. The list of coastal radio stations monitoring distress, urgency and safety calls is given in Table 1.

2. Transmission of route information and weather forecasts

2.1. Coastal radio stations broadcast special radio broadcasts containing the following information:

– route information containing updated information on the state of the navigable route (fairway), on the water levels at the main hydrometeorological posts, on the lowest depths and width of the fairway, indicating the limiting sections of the route, information on the state and changes in the location of navigation signs, on opening or closing of ship passages, restrictions and special conditions for the movement of ships, navigation conditions in places where there are underwater technical, dredging, blasting and other works that complicate the passage of ships, warnings about floating objects and shoals, other information related to navigation within the Volga-Baltic basin inland waterways;

– weather forecasts and weather reports;

– storm and ice warnings.

IWW Basin Administration can duplicate the listed information on its official website via the information and telecommunication network Internet.

2.2. Coastal radio stations shall transmit storm warnings immediately and duplicate every next hour, as well as in the next session of the transmission of meteorological messages according to the schedule.

2.3. During the transmission of route information and weather forecasts, ship radio stations shall remain silent except for radio communications related to distress, urgency and safety.

2.4. In the event that, when receiving navigation information by the ship's radio station, words or phrases were missed, the ship's radio station may request a repeat of the route information from the coastal radio station.

2.5. The transmission of route information and weather forecasts is carried out according to the schedule in accordance with **Table 2**.

If it is impossible to obtain information at the time indicated on the schedule, the masters have the right to request information at another time. This service is paid and provided at the rates of radiotelephone conversations.

3. Radio communication to provide traffic control

3.1. Negotiations with traffic dispatchers, watchkeepers of locks and waterworks, ports, quays and other onshore facilities shall be carried out on the channels (frequencies) in accordance with **Table 3**.

3.2. Before making a call, the radio station shall check whether the called radio station is busy with radio traffic, make sure that its operation does not interfere with radio communication between the called radio station and other stations. The call shall be made after the called radio station communication is stopped.

3.3. In the event that the calling radio station has a distress and safety message to transmit, it has the right to make a call without waiting for an interruption in the operation of the called radio station.

3.3. Channel 5 (300.2 MHz) may only be used to call a coastal radio station. Non-distress and safety communications are **NOT ALLOWED** on channel 5.

3.4. If the call and answer to it were made on the safety and distress channel, then after the establishment of communication, the radio stations by mutual agreement switch to working frequencies (channels).

3.5. When calling the ship's radio, the ship's name is used. To call the coastal radio station from the ship, the call signs of the coastal radio stations are used.

3.6. Correspondence addressed to the ship is sent through the coastal radio station in the coverage area of which the ship is currently located. Ship radio stations work with the coast radio station in the coverage area of which the ship is located during the communication session.

4. Radio wire for handling public correspondence

4.1. Radio wire communication with ships is carried out through linear radio stations located at coastal points and marked with a "+" sign on the radio channel assigned to the coast radio station, in accordance with Table 3.

4.2. The provision of radio communication with access to the technological communication network of inland water transport, connected to the public communication network, is carried out for ships of all forms of ownership, provided that the shipowner has entered into an agreement for the provision of communication services with the Basin communication center of the FBI "Volgo-Balt Administration".

4.3. **Priorit**y radio wire is provided for distress reporting and assistance negotiations for the ship in distress.

5. Onshore traffic monitoring systems

5.1. Coastal Radar Stations - data are shown in Table 4.

5.2. Coastal AIS stations are shown in Table 5.

6. Layouts of radio facilities and coverage areas - in Appendices 2÷7.

7. Zones of receiving signals of differential corrections - in Appendix 8.

Table 1
List of coastal radio stations, monitoring distress, urgency and safety calls

Km	Location	Call sign	channel	Working hours
Rybinsk Reservoir (within the boundaries of FBI Volgo-Balt Administration)				
465÷567	Cherepovets	Cherepovets radio	5	24/7
Sheksna River, Lake Beloye				
465÷567	Cherepovets	Cherepovets radio	5	24/7
560÷631	Sheksna	Cherepovets radio	5	-
630÷700	Ivanov Bor	Cherepovets radio	5	-
694÷759	Belozersk	Cherepovets radio	5	-
720÷815	Novokemsky	Cherepovets radio	5	-
Volga-Baltic Canal, Lake Onega, the Svir River				
795÷849	Annensky bridge	Vytegra radio	5	24/7
825÷879	Devyatiny	Vytegra radio	5	-
861÷893	Vytegra	Vytegra radio	5	-
890÷940	Paltoga	Vytegra radio	5	-
900÷972	Vozneseniye	Vozneseniye radio	5	-
972÷1032	Plotichnoe	Podporozhye radio	5	-
1047÷1009	Hevronino	Podporozhye radio	5	-
1019÷1073	Podporozhye	Podporozhye radio	5	-
1078÷1125	Lodeynoye Pole	Podporozhye radio	5	-
1125-1167	Sviritsa	Sviritsa radio	5	-
Lake Ladoga				
Ladoga	Sviritsa	Sviritsa radio	2182	24/7
1159÷ R30	Sviritsa	Sviritsa radio	5	-
R30	Pogran-Kondushi	Sviritsa radio	5	-
R20	Uuksu	Sviritsa radio	5	-
R20	Pitkyaranta	Sviritsa radio	5	-
R50	Island Valaam	Priozersk radio	5	-
R50	Priozersk	Priozersk radio	5	-
R50	Island Konevets	Shlisselburg radio	5	-
R50	Cape Osinovets	Shlisselburg radio	5	-
R50	Shlisselburg	Shlisselburg radio	5	-
Ladoga	Shlisselburg	Shlisselburg radio	2182	-
The Neva River				
1332÷1358	Otradnoe (Cape Svyatki)	Ivanovskoe-3	5	24/7
1390÷1340	St. Petersburg	Petersburg radio	5	-
The Volkhov River, Lake Ilmen, Lake Chudskoye, Lake Pskovskoye				
R50	Novaya Ladoga	Shlisselburg radio	5	24/7
R30	Novgorod-dispatcher of the Novgorod region area of waterways and shipping office	Novgorod-1	5	8-20
R25	Pskov-traffic dispatcher	Pskov	5	8 – 17 working days

Table 2
List of coastal radio stations broadcasting route information and weather forecasts

Km	Location	channel	Time of transmission of weather forecasts and warnings	Time of transmission of travel information
The Sheksna River, Lake Beloye, Volga-Baltic Canal, Lake Onega, the Svir River				
485÷560	Cherepovets	7,8	0035-0045, 0435-0445 0835-0845, 1235-1245 1635-1645, 2035-2045	0045-0100 0645-0700 1245-1300 1845-1900
700÷759	Belozersk	8	0035-0045, 0435-0445 0835-0845, 1235-1245 1635-1645, 2035-2045	0045-0100 0645-0700 1245-1300 1845-1900
824÷879	Vytegra	10	At the request of ships, 24/4	0450-0500 1250-1300 2050-2100
972÷900 (R23)	Voznesenye	11	0050- 0100 0850-0900 1650-1700	0050- 0100 0850-0900 1650-1700
1032 – 972	Plotychno	9	0050-0100, 0850-0900 1650-1700	0050-0100, 0850-0900 1650-1700
1073 – 1019	Podporozhye	8	0050-0100, 0850-0900 1650-1700	0050-0100, 0850-0900 1650-1700
1125 – 1078	Lodeynoye Pole	6	0050-0100, 0850-0900 1650-1700	0050-0100, 0850-0900 1650-1700
1125-1167	Sviritsa	9	0100-0110, 0400-0410 0900-0910,1300-1310 1800-1810, 2100-2110	0650-0700 1600-1610 2250-2300
Lake Ladoga				
R30÷1159	Sviritsa	9	0100-0110, 0400-0410 0900-0910,1300-1310 1800-1810, 2100-2110	0650-0700 1600-1610 2250-2300
R20	Pitkyaranta	6	0700-0710 1230-1240 2000-2010 after transmission of route information	0700-0710 1230-1240 2000-2010
R50	Priozersk	7	0830-0840 1430-1440 1900-1910 after transmission of route information	0830-0840 1430-1440 1900-1910
R50	Shlisselburg	6	0450-0500 1250-1300 2050-2100, after transmission of route information	0450-0500 1250-1300 2050-2100
The Neva River				
1390÷1340	Saint Petersburg	7	At the request of ships, 24/4	0750-0800 1450-1500 2250-2300
The Volkhov River, Lake Ilmen, Lake Chudskoye, Lake Pskovskoye				
	Novgorod - maintenance area dispatcher	4	At the request of the ships, 8 - 17, on weekdays	At the request of the ships, 8 - 17, on weekdays
	Pskov-traffic dispatcher	3	At the request of the ships, 8 - 17, on weekdays	At the request of the ships, 8 - 17, on weekdays

Table 3
List of coastal radio stations for traffic control and public correspondence processing

Km	Name of the point and coastal service	Call sign	Channel	Maintenance area
The Sheksna River, Lake Beloye, Volga-Baltic Canal, southern part of Lake Onega				
485÷560	Cherepovets +	Cherepovets radio	5,7,8	Dor -Cherepovets-Romanda
535÷550	Cherepovets-ERNK	Cherepovets-2	3	Roadstead
527÷550	Cherepovets - traffic dispatcher	Cherepovets-4	4,5	Roadstead
527÷540	Cherepovets - dispatcher of the industrial port of ChMK	Cherepovets-5	25	-"-
535÷550	Cherepovets - passenger dispatcher	Cherepovets-6	23	-"-
535÷550	Cherepovets - port dispatcher	Cherepovets-9	5,10	Gorodische - Cherepovets-Lapach
535÷550	Cherepovets - complete service dispatcher	Cherepovets-8	3	-"-
538÷550	Cherepovets - captain of the roadstead	Cherepovets-13	4	Roadstead
527÷530	Cherepovets - chemical port dispatcher	Cherepovets-15	2	r.Koshta-Khimkanal
538÷550	Cherepovets-inspector of the State of Maritime and River Supervision	Cherepovets-16	5	Roadstead
580÷625	Sheksna-gateway 7-8 traffic dispatcher	Sheksna-3	3	Upper and lower pool
560÷631	Sheksna-traffic dispatcher	Cherepovets-4	5	Romanda-Irma
570÷625	Sheksna +	Cherepovets radio	5,6	Romanda-Irma - Sizminsky razliv
635÷690	Ivanov Bor +	Cherepovets radio	5,11	Sizma-Novodevichye
630÷700	Ivanov Bor-traffic dispatcher	Belozersk	5	Sizma-Novodevichye
694÷759	Belozersk-traffic dispatcher	Belozersk	3,5	Lake Beloye
700÷759	Belozersk +	Cherepovets radio	5,8	Lake Beloye
700÷759	Belozersk Port Dispatcher	Belozersk	2	Lake Beloye
730÷800	Novokemsky +	Cherepovets radio	5,7	Central part of Lake Beloye - the Tumba river
720÷815	Novokemsky - traffic dispatcher	Belozersk	5	Central part of Lake Beloye - the Tumba river
810÷844	Annensky Bridge - traffic operator	Annensky Bridge	5	On the approaches
795÷849	Annensky Bridge +	Vytegra radio	5,6	Kurdyug-Devyatiny
824÷849	Volokov bridge operator	Volokov	3	On the approaches
824÷879	Devyatiny +	Vytegra radio	3,10	Annensky Bridge - Vytegra
844÷861	Pakhomovo-gateway 6	Gateway 6	3	-"-
855÷862	Nowinky -gateway 5	Gateway 5	3	-"-
861÷863	Nowinky -gateway 4	Gateway-4	3	On the approaches
862÷869	Nowinky -gateway 3	Gateway 3	3	-"-
863÷879	Belousovo-gateway 2	Gateway 2	3	-"-

869÷893	Vytegra - gateway 1	Gateway 1	3	-"-
861÷893	Vytegra +	Vytegra radio	5,7	-"-
823÷940	Vytegra Channel Manager	Vytegra-5	3,5	On the approaches
861÷940	Vytegra - traffic dispatcher	Vytegra-2	2	-"-
869÷880	Vytegra-dispatcher of the Belozersk port	Vytegra-4	4	-"-
880÷893	Vytegra-Onega-Transles	Onega-1	24	-"-
890÷940	Paltoga +	Vytegra radio	5,6	Southern part of Lake Onega
890÷940	Paltoga-traffic dispatcher	Vytegra-2	2	-"-
Southern part of Lake Onega, the Svir river				
972÷900	Vozneseniye +	Vozneseniye radio	5,11	-"-
972÷900	Vozneseniye - traffic controller	Vozneseniye-3	5	-"-
1032÷972	Plotichnoye +	Podporozhye radio	5,9	Ivinsky Razliv - Myatusovo
1047÷1009	Hevronino	Podporozhye-3	5	Myatusovo-Podporozhye
1047÷1035	Verkhne-Svirsky gateway	Verkhne-Svirsky	3	On the approaches
1073÷1019	Podporozhye +	Podporozhye radio	5, 8	-"-
1051÷1042	Bridge 1048.3 km	Bridge	5	-"-
1073÷1019	Podporozhye-traffic dispatcher	Podporozhye-3	5	Chyorny Bereg - Tolstoye
1098÷1073	Nizhne-Svirsky gateway	Nizhne-Svirsky	3	On the approaches
1104÷1087	Lodeynopolsky bridge	Bridge	5	-"-
1125÷1078	Lodeynoye Pole +	Podporozhye radio	5,6	-"-
1113÷1068	Lodeynoye Pole-dispatcher	Lodeynoye Pole 3	5, 2	-"-
R30÷1159	Sviritsa +	Sviritsa radio	5,9	On the approaches
R30÷1159	Sviritsa traffic dispatcher	Sviritsa-3	2	30 km area
P30	Novaya Ladoga - Sviritsa traffic dispatcher	Sviritsa-3	2	30 km area
Ladoga Lake, the Neva river				
R30	Pogran-Kondushi	Sviritsa radio	5	-"-
R20	Uuksu	Sviritsa radio	5	-"-
R15	Pitkyaranta +	Sviritsa radio	5,6	-"-
R50	Island Valaam	Priozersk radio	5, 3	
R50	Priozersk +	Priozersk radio	5,7	-"-
R50	Island Konevets	Shlisselburg radio	5,3	-"-
R50	Cape Osinovets +	Shlisselburg radio	5,8	-"-
R50	Shlisselburg +	Shlisselburg radio	5,6	-"-
R50	Shlisselburg- + (maritime mobile service)	Shlisselburg-72	4*	-"-
1280÷1329	Shlisselburg traffic dispatcher	Shlisselburg-3	3,5	Neva River - southern and southwestern part of Lake Ladoga
1306÷1322	Shlisselburg - traffic dispatcher	Shlisselburg-6	4	the Neva river from Maryino to Shlisselburg; Koshkinsky fairway

		The Neva River		
1314÷1321	Shlisselburg-NSSZ	Shlisselburg-8	2	On the approaches
1325÷1340	Lobanovo - traffic service operator	Lobanovo	2	On the approaches
1340÷1347	Otradnoye- sand mining dispatcher	Ivanovskoe-1	24	On the approaches
1332÷1358	Cape Svyatki - traffic dispatcher	Ivanovskoe-3	2,5	On the approaches
1390÷1340	St. Petersburg +	Petersburg radio	5,7,9	Otradnoye- Kronstadt
1390÷1340	St. Petersburg- + (maritime mobile service)	Petersburg-72	23*	Otradnoye- Kronstadt
1390÷1370	St. Petersburg - passenger port dispatcher	Petersburg-1	3	Okhta-Sea Port
1390÷1340	St. Petersburg - traffic dispatcher	Petersburg-3 traffic dispatcher	2,5	Roadstead of the Slavyanka river - Bolsheokhtinsky bridge
1390÷1340	St. Petersburg - traffic dispatcher	Petersburg-3 traffic dispatcher	4,5	Bolsheokhtinsky Bridge-Sea Port
1373÷1359	Volodarsky bridge - operator (for the opening period)	Volodarsky bridge	2	On the approaches
1374÷1368	Finlyandsky Bridge - operator (for the opening period)	Finlyandsky bridge	2	-"-
1387÷1383	Blagoveshchenskiy bridge - operator (for the opening period)	Blagoveshchenskiy bridge	4	-"-
1387÷1380	Tuchkov bridge - operator (for the opening period)	Tuchkov bridge	4	-"-
1390÷1370	St. Petersburg - sand mining dispatcher	Petersburg-9	2,4	Bolsheokhtinsky bridge-Kronstadt
1390÷1383	St. Petersburg - captain of the roadstead - Schmidt embankment	Roadstead Captain Schmidt embankment	4	Palace Bridge - Sea Port
1390÷1340	Petersburg-captain of the roadstead-Perevoznaya emb.	Petersburg-roadstead	2, 4, 5	Roadstead of the Slavyanka river - Bolsheokhtinsky bridge
1363–1365	St. Petersburg - dispatcher of JSC "Passenger Port"	Petersburg-1	3	On the approaches to the berths 1364 km.
		The Volkhov River, Lake Ilmen, Lake Chudskoye, Lake Pskovskoye		
	New Ladoga +	Shlisselburg radio	5,6	The middle part of the southern route of Lake Ladoga
	Novaya Ladoga (operated by traffic dispatcher Sviritsa)	Sviritsa-3 (traffic dispatcher)	2	Mouth of the Volkhov river - Volkhov gateway
	Volkhov gateway	Volkhov-gateway	4, 5	On the approaches
	Novgorod - maintenance area dispatcher	Novgorod-1	4, 5	-----
	Pskov-traffic dispatcher	Pskov	5	-----

Notes:

1. Column 1 indicates the approximate coverage area of this radio station "from" and "to" in kilometer marks according to the UGSS Atlas, Volume 3. For lakes, the range is indicated in km ***from*** this radio station.

For example, for Sviritsa **1134 ÷ R30** means a range of 30 km from the location of the radio station at 1134 km.

For example, for Uuksu, **R15** means a range of 15 km from the radio station itself.

2. "+" - a connection to the public telephone network is provided
3. "*" - radio station on the frequency of the maritime mobile service

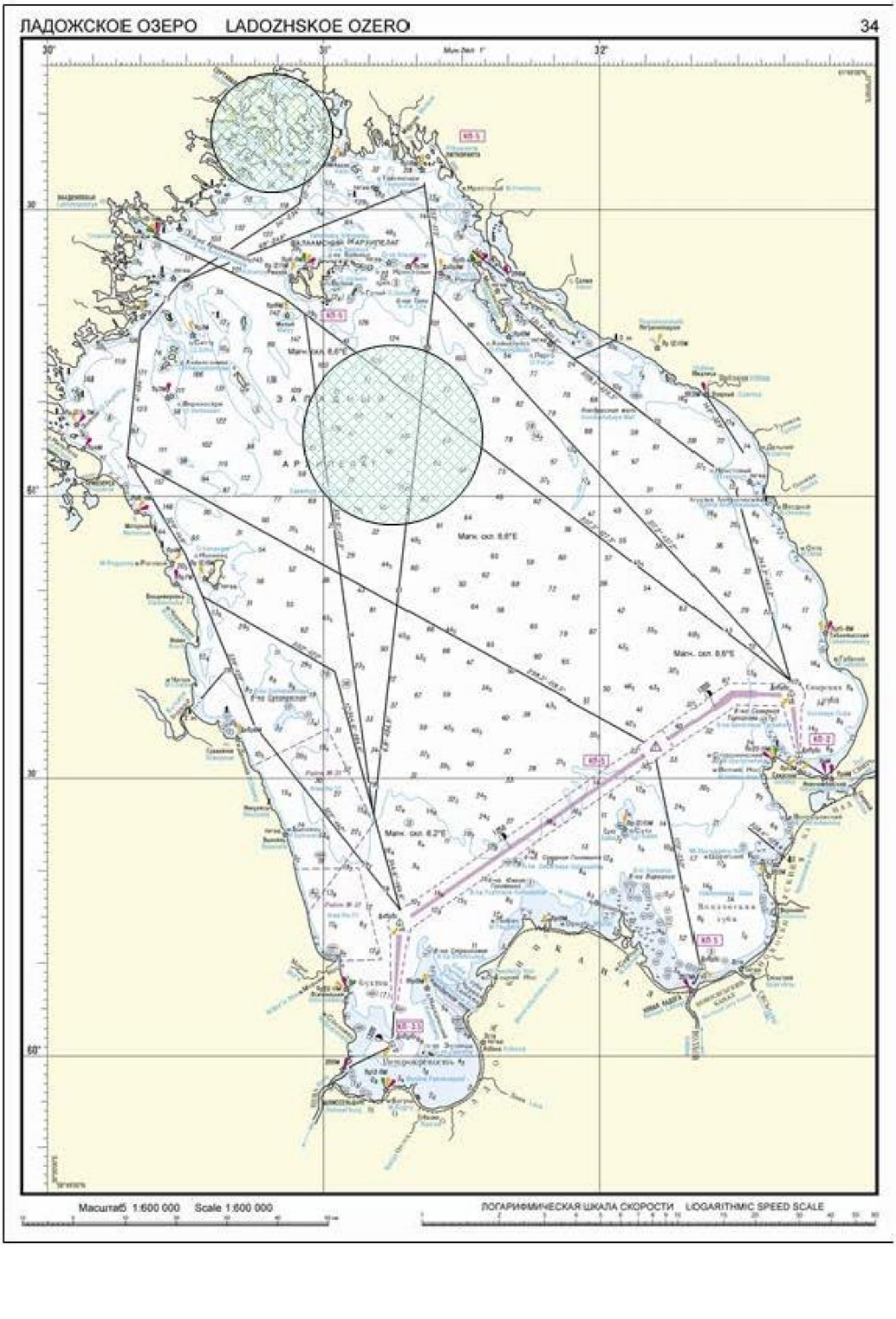
Table 4
Placement of coastal radar stations

It. No.	Installation site of coastal radar station	Coordinates	Radar type
1	Shlisselburg	59°56,23`N; 31°04,10`E	"Nayada-5" (3 cm.)
2	Sviritsa	60°27,16`N; 32°56,01`E	"Rapan" (3 cm.)
3	Voznesenie	61°01,04`N; 35°29,03`E	"Nayada-5MP" (3 cm.)
4	Paltoga	61°00,40`N; 36°11,54`E	"Nayada-5MP" (3 cm.)
5	Vytegra (1st gateway)	61°00,54`N; 36°25,24`E	"Nayada-5MP" (3 cm.)
6	Volokov Bridge	60°51,80`N; 36°54,38`E	"Nayada-5MP" (3 cm.)
7	Annensky Bridge	60°44,08`N; 37°07,22`E	"Nayada-5MP" (3 cm.)
8	Novokemsky	60°24,04`N; 37°39,03`E	"Nayada-5MP" (3 cm.)
9	Belozersk	60°02,07`N; 37°46,20`E	"Nayada-5MP" (3 cm.)
10	Sheksna	59°14,09`N; 38°30,30`E	"Nayada-5MP" (3 cm.)
11	Cherepovets (CHRVPiS)	59°06,87`N; 37°56,89`E	"Nayada-5MP" (3 cm.)

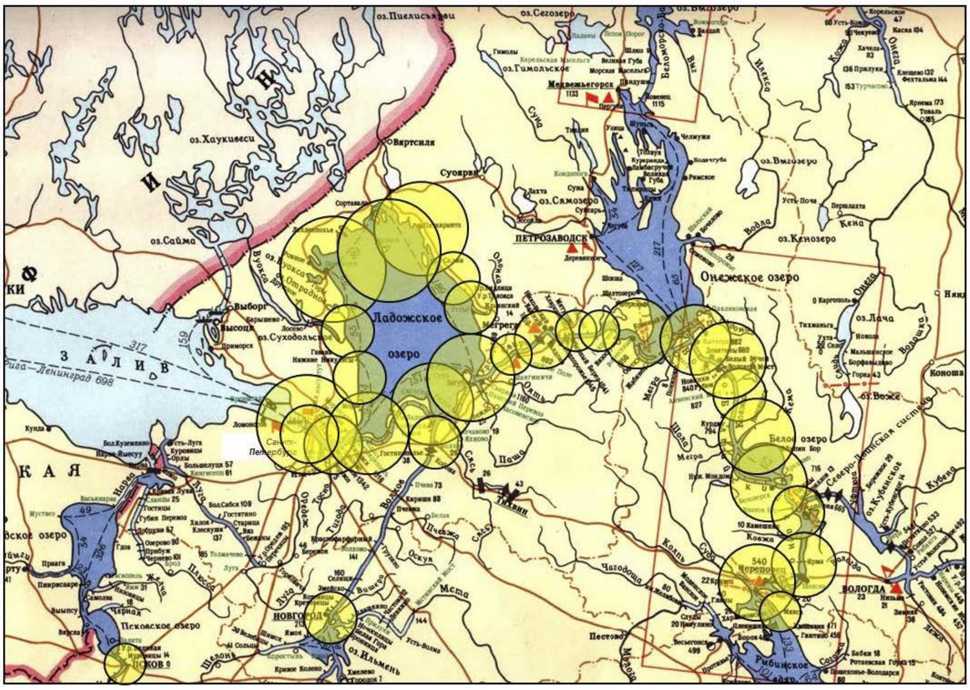
Table 5
Placement of AIS coastal stations

It. No.	Location	Coordinates	MMSI
1	St. Petersburg, Vilensky per., 15B	59°56,01`N; 30°18,57`E	x
2	St. Petersburg, Palace embankment, 8	59°56,70`N; 30°19,50`E	x
3	St. Petersburg, Obukhovskoy Oborony Ave., 116	59°52,16`N; 30°27,48`E	002734463
4	St. Petersburg, Bolshoy Obukhovsky bridge	59°51,23`N; 30°29,77`E	x
5	Otradnoe (Cape Svyatka)	59°46,21`N; 30°46,54`E	002734465
6	Shlisselburg	59°55,42`N; 31°04,21`E	002734464
7	Osinovets	60°06,78`N; 31°01,87`E	x
8	Island Konevets	60°51,20`N; 30°35,43`E	x
9	Priozersk	61°02,53`N; 30°10,47`E	002731241
10	Island Valaam	61°23,39`N; 30°57,92`E	x
11	Pitkyaranta	61°36,20`N; 31°25,43`E	x
12	Pogrankondushi	61°15,37`N; 32°12,22`E	x
13	Island	60°02,01`N; 31°48,97`E	x
14	Novaya Ladoga	60°06,48`N; 32°18,68`E	x
15	Sviritsa	60°27,16`N; 32°56,01`E	002734491
16	Lodeynoye Pole	60°44,49`N; 33°32,94`E	002734494
17	Nizhnesvirsky gateway	60°48,25`N; 33°42,53`E	x
18	Podporozhye	60°56,03`N; 34°09,50`E	x
19	Plotychno	60°58,63`N; 34°46,42`E	x
20	Voznesenie	61°01,04`N; 35°29,03`E	002731152
21	Paltoga	61°00,40`N; 36°11,54`E	x
22	Vytegra (2nd gateway)	60°56,85`N; 36°32,90`E	002734495
23	Devyatiny (6th gateway)	60°54,37`N; 36°46,16`E	002731146
24	Volokov Bridge	60°51,80`N; 36°54,38`E	x
25	Annensky Bridge	60°44,08`N; 37°07,22`E	x
26	Novokemsky	60°24,04`N; 37°39,03`E	x
27	Belozersk	60°02,07`N; 37°46,20`E	002734496
28	Ivanov Bor	59°46,29`N; 38°15,01`E	x
29	Ramenye	59°29,26`N; 38°29,64`E	x
30	Sheksna	59°14,09`N; 38°30,30`E	002731110
31	Cherepovets	59°07,60`N; 37°56,30`E	002731120
32	Velikiy Novgorod	58°32,61`N; 31°17,54`E	x

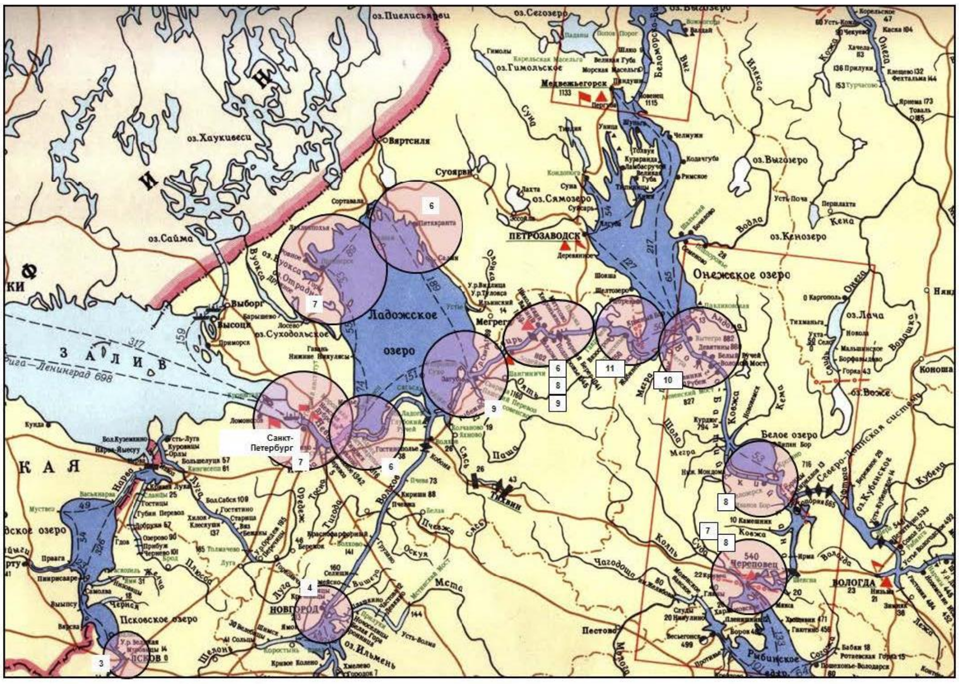
Appendix 1. Dead zones "VHF radio communications on Lake Ladoga (2020)



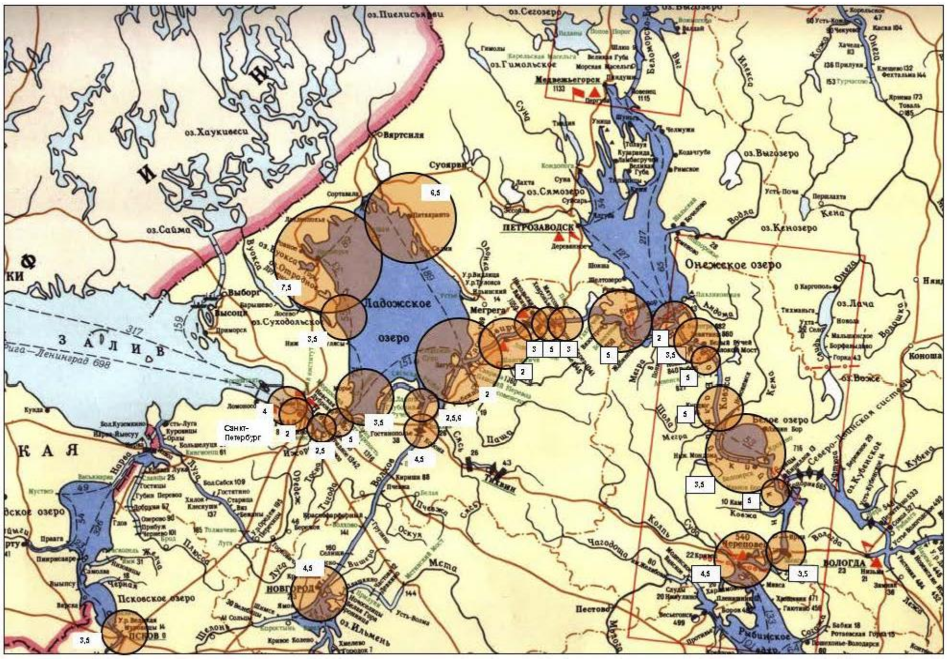
Appendix 2. Radio network of security channels (5 channel) for 2020



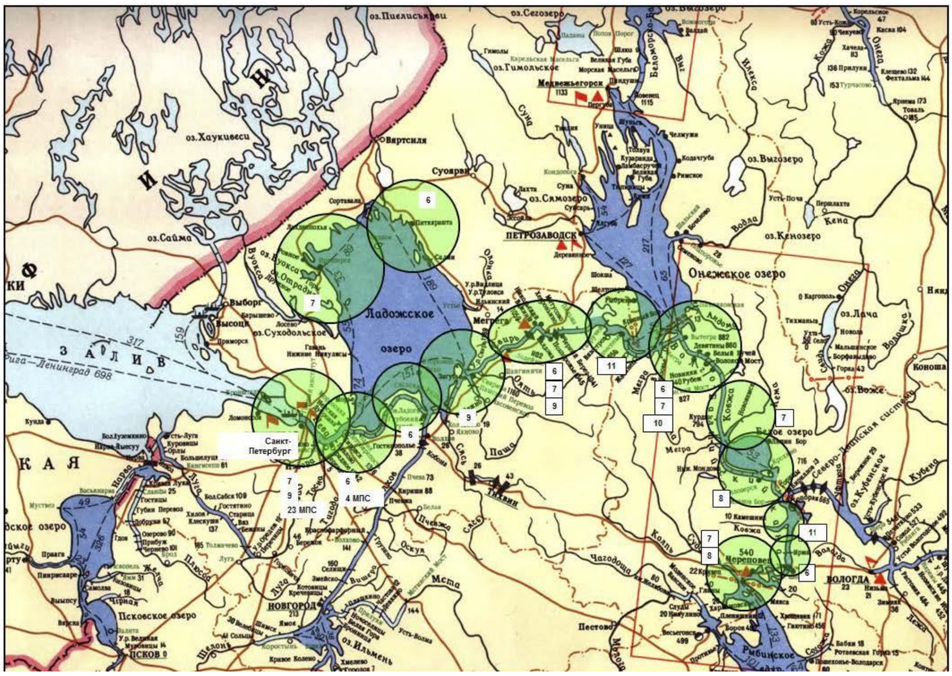
Appendix 3. Radio network for transmission of route and hydrometeorological information for 2020



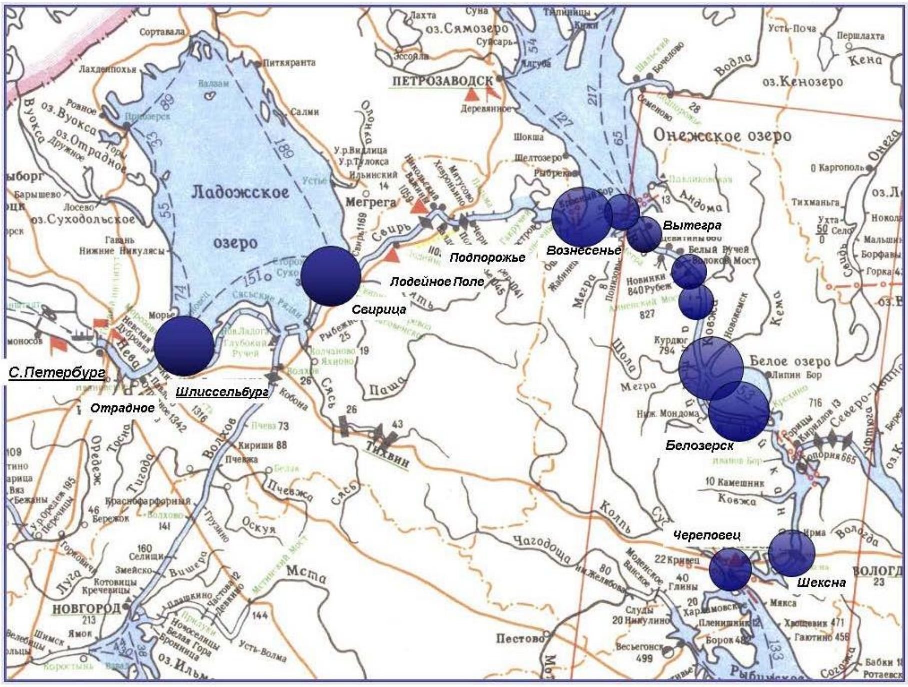
Appendix 4. Traffic control radio network for 2020



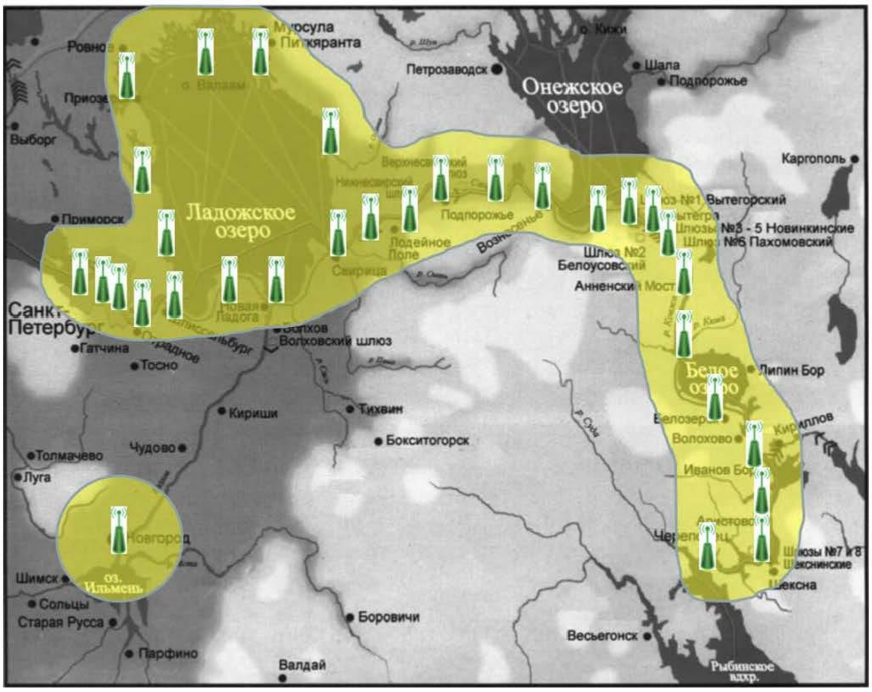
Appendix 5. Public Correspondence Processing Radio Network for 2020



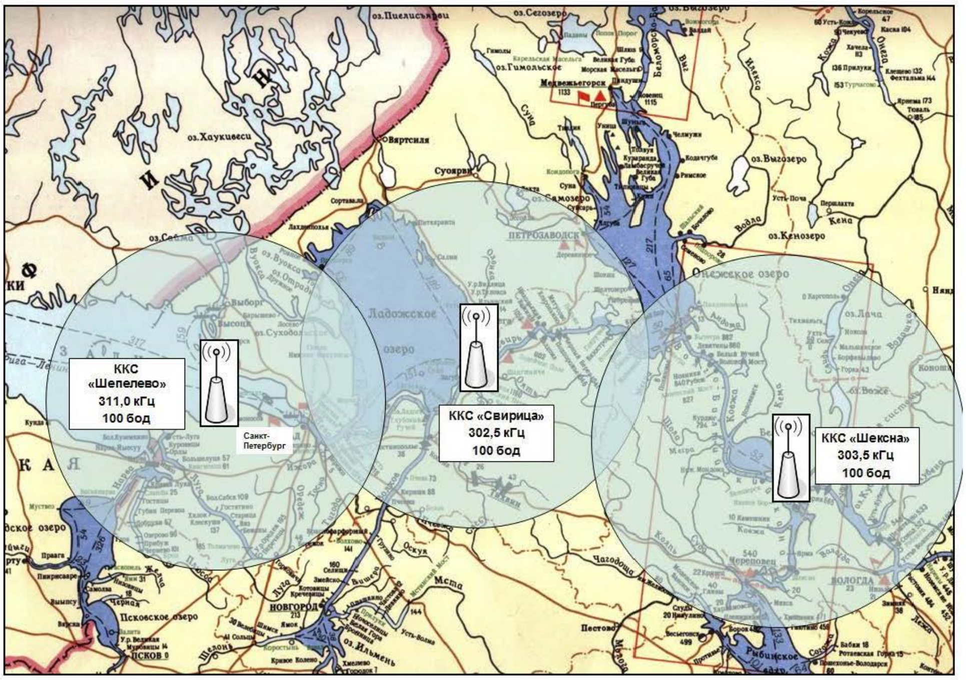
Appendix 6. Coastal radar coverage areas for 2020



Appendix 7. Coverage areas of coastal AIS stations for 2020



Appendix 8. Coverage areas of differential GLONASS/GPS corrections for 2020



1.8 Icebreaker support

During the navigation extension period on the Neva River, it may be necessary to use icebreakers and/or ice-class tugs (Figures 1.13, 1.14).

Figure 1.13 Icebreaker on the Neva River

Figure 1.14 Ice-class tug on the Neva River

Ice pilotage is ordered by the ship owner, therefore it is necessary to strike a balance between additional costs and the navigation safety. The number of icebreakers, as well as the schedule of their operation, shall be determined based on the intensity of vessel traffic during the navigation extension period. With a large number of ships and unfavorable ice conditions, icebreaker duty can be organized.

1.9 Classification list of organizational and technical measures

Based on the foregoing it is recommended to carry out the activities listed in the following list of organizational and technical measures using automated tools (Figure 1.15):

- water level monitoring;
- monitoring of hydrometeorological conditions;
- monitoring of ice conditions;
- monitoring of waterway depths;
- dispatching control of navigation;

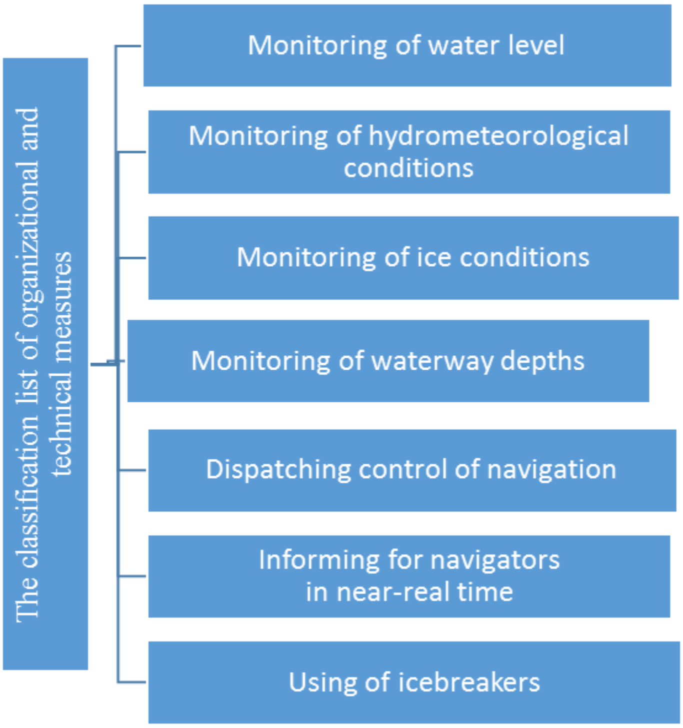


Figure 1.15 Recommended list of organizational and technical measures

- informing for navigators in near-real time;
- using of icebreakers.

2. ANALYSIS OF THE POSSIBILITY OF ICE NAVIGATION IN THE WATER AREA OF THE NEVA RIVER

2.1 Ice conditions of the Neva River

Depending on meteorological conditions the Neva River freezes for a period of 2 to 6 months. It is characteristic that the river freezes upstream (from the mouth to the source), and conversely the ice breaks downstream (from the source to the mouth).

Autumn ice drift across the river is observed in the second half of November; its average duration is about two weeks. The river freezes in an abrupt manner: the ice cover quickly spreads upstream, then stops and moves down; and sometimes, especially in the middle part of the Neva, ice jams form. Information on ice phenomena on the Neva River are shown in Table 1.

The spring ice drift on the Neva, as a rule, is divided into two periods. In the first, so-called period of the Neva ice drift, the river thaw out from ice for 3–5 days. Then, after a few days, the second period of the Ladoga ice drift begins, when within 8–12 days ice goes down from Lake Ladoga. Sometimes the Ladoga ice drift is delayed for a month with interruptions. In rare cases, in the absence of northeast winds, ice melts in the lake, and there is no repeated ice drift on the Neva. In general the spring ice drift from breakup to clearance of ice usually lasts about three weeks.

Table 2.1 Information on ice phenomena on the Neva River

Observation point	Freeze-up date			Date of clearance of ice		
	the earliest	the mean	the latest	the earliest	the mean	the latest
Saint Petersburg	6.XI	26. XI	14. I	8. IV	29. IV	18. V
Ivanovskiye Porogy rapids	12.XI	24.XII	12.III	7.IV	3.V	24.V
Koshkinsky fairway	11.XI	22.XII	26.II	8.IV	1.I	30.V

The ice conditions of the Neva River are greatly influenced by Lake Ladoga, since it is the source of the Neva River. In the event of an ice drift, a large amount of ice appears in the river bed.

2.2 Ice conditions of Lake Ladoga

The ice regime of Lake Ladoga is very complicated. Ice cover in different parts of the lake is established at different times; in this case, ice formation occurs in circles from the shores to the center of the lake. In the coastal part of the lake, ice appears in the form of shore ice, land fast ice or bottom ice that floats to the surface of the lake. In addition, ice is carried in large quantities by rivers flowing into Lake Ladoga.

Usually ice appears at the end of the first - beginning of the second decade of November, primarily in the shallow southern part and then in the deeper northern part of the lake. As a rule, in the open part of the lake ice forms from 12 to 26 November.

Freeze up occurs primarily in the southern part of the lake (at the beginning of December); in this case, as a rule, the eastern part of the Svir Bay and the southern parts of the Petrokrepost Bay and the Volkhov Bay freeze first. Then freezing spreads to the center of the lake, and by February 15–20 (and in severe winters by the end of January - early February) the lake is completely covered with fixed ice.

In mild winters, continuous ice cover does not form on Lake Ladoga; in such winters, the edge of motionless ice usually does not extend beyond the areas bounded by the 20 m isobath. Behind the edge of stationary ice, there is a strip of drifting ice; in the central part of the lake, ice-free water is retained throughout the winter.

The thickest ice cover is formed in the coastal zone, in creeks and bays. In the central part of the lake, ice is usually thinner and less snowy; it is characterized by dry cracks. The ice reaches its maximum thickness in March.

During the winter, ice is subjected to rather strong hummocking, as a result of which hummocked ridges are formed, separated from each other by strips of level ice.

Usually the breaking up of ice on Lake Ladoga occurs at the end of March in the reverse sequence of freezing.

The breaking of fixed ice begins around mid-April. In the second half of April, the ice cover is destroyed in all parts of the lake; most of the ice melts in place, and a smaller part (about 20%) is carried into the Neva River. Part of the ice is thrown ashore and sometimes remains here until the first half of July.

The ice is cleared from the lake first (at the end of April) in a narrow coastal zone. The lake is finally cleared from ice in mid-May.

Information on ice phenomena on Lake Ladoga is given in Table 2.2, (ellipsis means no data).

Table 2.2 Information about ice conditions on Lake Ladoga and in canals

Control point the earliest	First-ice date and floating-ice formation			Freeze-up date			Breakup date			Date of clearance of ice		
	the earliest	the mean	the latest	the earliest	the mean	the latest	the earliest	the mean	the latest	the earliest	the mean	the latest
Bugrovsky, lighted mark	22.X	10.XI	11.XII	1.XI	1.XII	30.I	27.III	12.IV	2.V	…	…	…
Voronovo, village (Novosvirsky canal)	19.X	6.XI	30.XII	23.X	12.XI	17.XII	3.IV	20.IV	6.V	12.IV	23.IV	14.V
Zagubye, village (Starosvirsky canal)	11.X	8.XI	2.XII	23.X	15.XI	29.XII	1.IV	22.IV	9.V	5.IV	25.IV	9.V
Caredzhi, lighthouse	4.XI	25.XI	29.XII	13.XI	7.I	12.III	26.III	22.IV	11.V	10.IV	2.V	22.V
Naziya, village (Novoladozhsky canal)	18X	15.XI	14.XII	9.XI	26.XI	25.XII	28.III	14.IV	28.IV	1.IV	17.IV	30.IV
Novaya Ladoga, city (Novoladozhsky canal)	22.X	15.XI	18.XII	27.X	26.XI	12.I	30.III	18.IV	5.V	1.IV	21.IV	7.V
Sviritsa, village (Novosvirsky canal)	18.X	12.XI	14.XII	24.X	21.XI	18.XII	4.IV	22.IV	9.V	12.IV	24.IV	10.V
Sortavala, city	1.X	12.XI	26.XII	3.XI	5.XII	27.I	7.IV	2.V	21.V	14.IV	9.V	30.V
Syaskye Ryadki, village (Starosvirsky canal)	19.X	11.XI	14.XII	25.X	16.XI	26.XII	31.III	22.IV	11.V	5.IV	24.IV	13.V
Chyernoye, village (Novoladozhsky canal)	15.X	8.XI	26.XII	29.X	23.XI	25.XII	31.III	22.IV	7.V	1.IV	23.IV	11.V

2.3 Ice navigation on the Neva River

As shown in paragraph 1.8 ice navigation on the Neva River is possible only if the vessel has an ice class, or when icebreaker assistance is provided. At the same time, it should be noted that in the last decade there has been a tendency towards a decrease in the thickness of the ice cover and even its absence in winter. The results of the analysis indicate a favorable forecast for the navigation during the navigation extension period. Table 2.3 shows the average annual temperature values for the last 10 years in St. Petersburg.

Table 2.3 Average annual temperatures

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	PER AN.
2010	-12.1	-8.4	-2.4	6.7	13.4	15.5	24.4	19.6	12.3	5.5	0.4	-8.3	5.6
2011	-5.8	-11.0	-1.9	5.7	11.0	17.7	22.5	17.5	13.1	7.6	3.6	1.9	6.8
2012	-4.8	-10.4	-1.0	4.9	12.7	15.2	19.5	16.3	12.9	6.6	2.9	-7.9	5.6
2013	-6.1	-2.6	-6.6	4.2	14.4	19.8	19.0	18.6	12.1	7.3	4.4	0.9	7.1
2014	-7.0	0.0	2.2	6.5	13.0	15.0	21.2	18.8	13.5	5.2	0.8	-1.0	7.4
2015	-2.7	-0.6	2.6	5.1	11.8	15.9	16.9	18.3	14.0	5.6	3.1	2.1	7.7
2016	-11.2	0.0	1.0	6.3	14.7	16.5	19.0	17.2	12.9	5.0	-1.8	-1.2	6.5
2017	-3.9	-3.5	1.3	2.8	9.4	13.6	16.5	17.4	12.5	5.6	2.3	0.4	6.2
2018	-2.9	-7.7	-4.4	6.0	15.1	16.2	20.9	19.2	14.5	7.3	2.8	-3.2	7.0
2019	-6.5	-0.5	0.0	7.3	12.1	18.7	16.6	17.0	12.2	6.1	1.9	1.8	7.2
2020	1.5	0.6	2.2	4.2									

In addition to the sharply distinguished 2016, there is a trend towards an increase in winter temperatures, so over time, an increasingly longer period of extended navigation can be without ice conditions.

3. DEVELOPMENT OF RECOMMENDATIONS FOR ENSURING ICE CHANNELING OF SHIPS IN THE WATER AREA OF THE NEVA RIVER

3.1 Coastal navigation signs

3.1.1 General information

In winter, even in the absence of ice cover, most floating navigation signs are removed from their original positions, but positions of all coastal navigation signs are remained unchanged.

Let us consider in more detail the situation with coastal navigation marks, since in the considered conditions coastal navigation signs are the most reliable aids, they can be affected neither by malfunctions in the operation of navigation information systems, nor by the negative impact of the environment (with a low probability).

In total 327 signs have been installed on the banks of the Neva River from the Blagoveshchensky Bridge to Orekhovy Island (Shlisselburg Fortress). Conventionally they can be divided into two groups: navigation fairway signs and information signs (Figure 3.1).

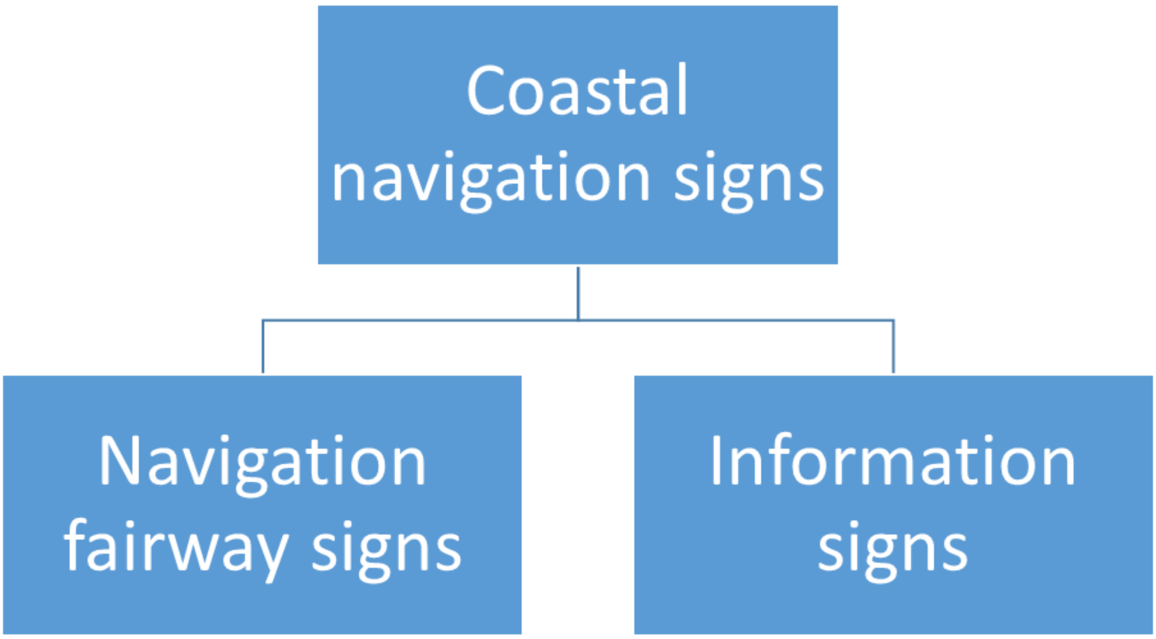


Figure 3.1 Coastal navigation signs

In total, on the Neva River there are 264 information signs and 63 navigation fairway signs. Let's consider each of the groups of signs in more detail.

3.1.2 Navigation fairway signs

The range signs are the basis of the group. They are used to determine the vessel position relative to the axis of the navigable fairway, most often they are installed on areas difficult for navigation (Ivanovskiye Porogy rapids, Koshkinsky fairway). The range signs are painted white or red, depending on the background on which they are visible from the river. The signs of the left bank are equipped with green light, and the signs of the right bank with red one (Figures 3.2, 3.3).

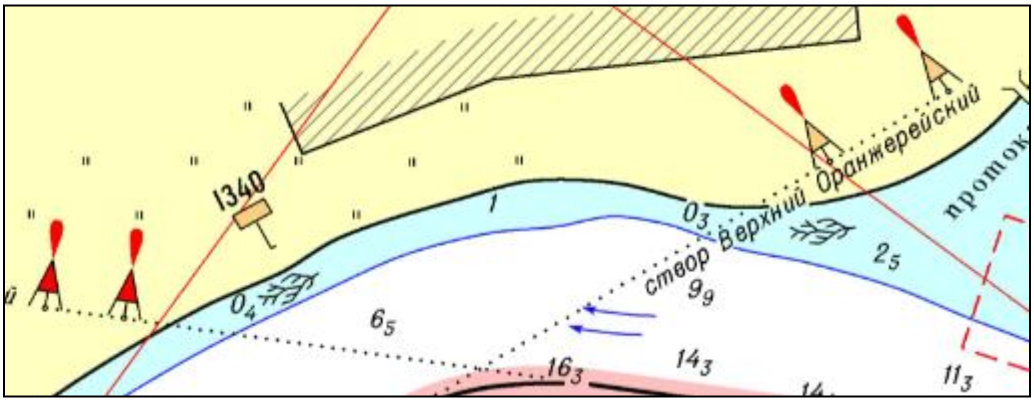


Figure 3.2 Range signs of the right bank

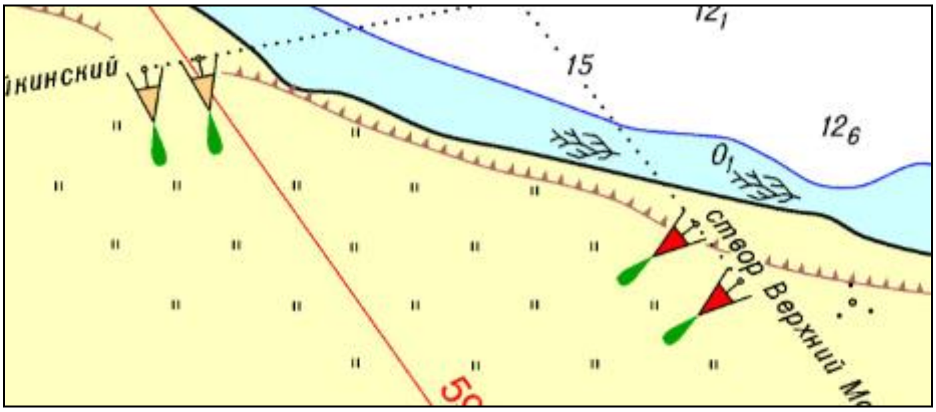


Figure 3.3 Range signs of the left bank

Since during the navigation extension period most of the floating navigation signs will be absent, these signs are the only physical means for the fairway marking, the list of signs is given in Table 3.1.

Table 3.1 - List of range signs

Range signs									
No.	**km**	**Bank**	**Light**	**Light type**	**No.**	**km**	**Bank**	**Light**	**Light type**
1	1360.1	left	lighted	Fixed green	28	1340.3	right	lighted	Fixed red
2	1360.1	left	lighted	Fixed green	29	1340.2	right	lighted	Fixed red
3	1358.85	right	lighted	Fixed red	30	1340.15	right	lighted	Fixed red
4	1358.8	right	lighted	Fixed red	31	1339.6	right	lighted	Fixed red
5	1357.9	left	lighted	Fixed green	32	1339.5	right	lighted	Fixed red
6	1357.85	left	lighted	Fixed green	33	1339.5	left	lighted	Fixed green
7	1351.8	left	lighted	Fixed green	34	1339.45	left	lighted	Fixed green
8	1351.7	left	lighted	Fixed green	35	1336.7	right	lighted	Fixed red
9	1350.0	right	lighted	Fixed red	36	1336.6	right	lighted	Fixed red
10	1349.9	right	lighted	Fixed red	37	1332.6	right	lighted	Fixed red
11	1349.1	left	lighted	Fixed green	38	1332.5	right	lighted	Fixed red
12	1349.0	left	lighted	Fixed green	39	1332.15	left	lighted	Fixed green
13	1347.5	left	lighted	Fixed green	40	1332.1	left	lighted	Fixed green
14	1347.4	left	lighted	Fixed green	41	1331.75	left	lighted	Fixed green
15	1345.8	right	lighted	Fixed red	42	1331.7	left	lighted	Fixed green
16	1345.7	right	lighted	Fixed red	43	1328.55	right	lighted	Fixed red
17	1344.7	left	lighted	Fixed green	44	1328.45	right	lighted	Fixed red
18	1344.6	left	lighted	Fixed green	45	1327.4	left	lighted	Fixed green
19	1344.3	left	lighted	Fixed green	46	1327.25	left	lighted	Fixed green
20	1344.3	left	lighted	Fixed green	47	1318.6	right	lighted	Fixed red
21	1343.2	right	lighted	Fixed red	48	1318.5	right	lighted	Fixed red
22	1343.1	right	lighted	Fixed red	49	1317.0	left	lighted	Fixed green
23	1342.95	left	lighted	Fixed green	50	1316.95	left	lighted	Fixed green
24	1342.9	left	lighted	Fixed green	51	1315.5	right	lighted	Fixed red
25	1342.75	left	lighted	Fixed green	52	1315.4	right	lighted	Fixed red
26	1342.7	left	lighted	Fixed green	53	1314.85	right	lighted	Fixed red
27	1340.45	right	lighted	Fixed red	54	1314.75	right	lighted	Fixed red

Based on the analysis of the data in Table 3.1, it can be noted that the distribution of range signs along the Neva River bed is fairly uniform over the entire distance (Figure 3.4).

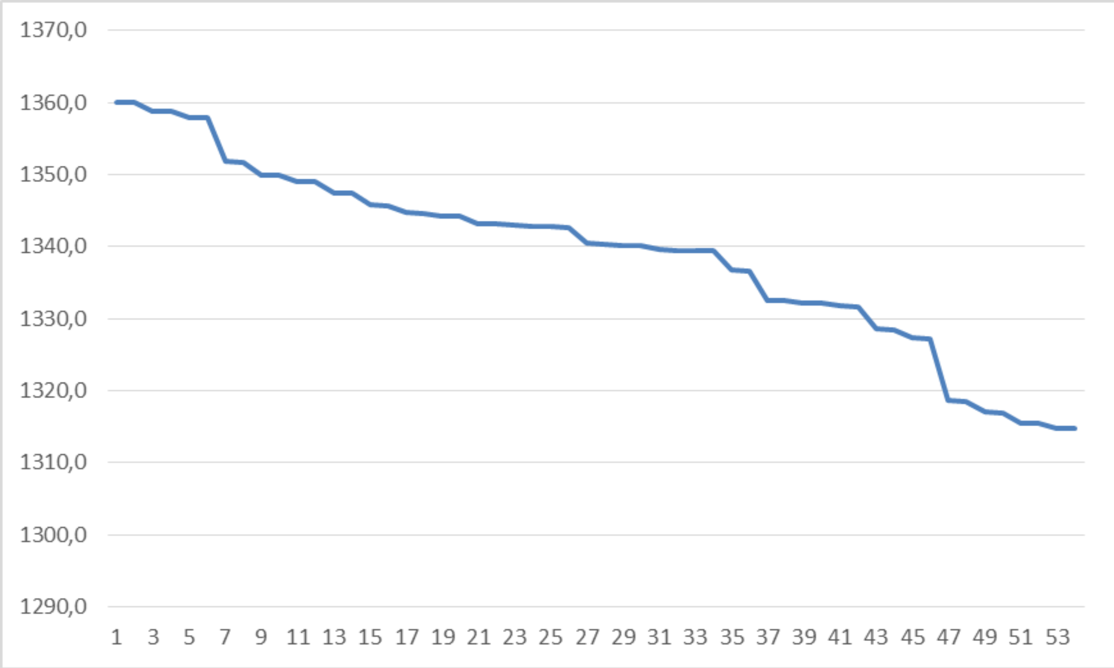


Figure 3.4 Distribution of range signs by distance

At the same time, the ratio along the banks indicates an even distribution of signs along the waterway section (Figure 3.5).

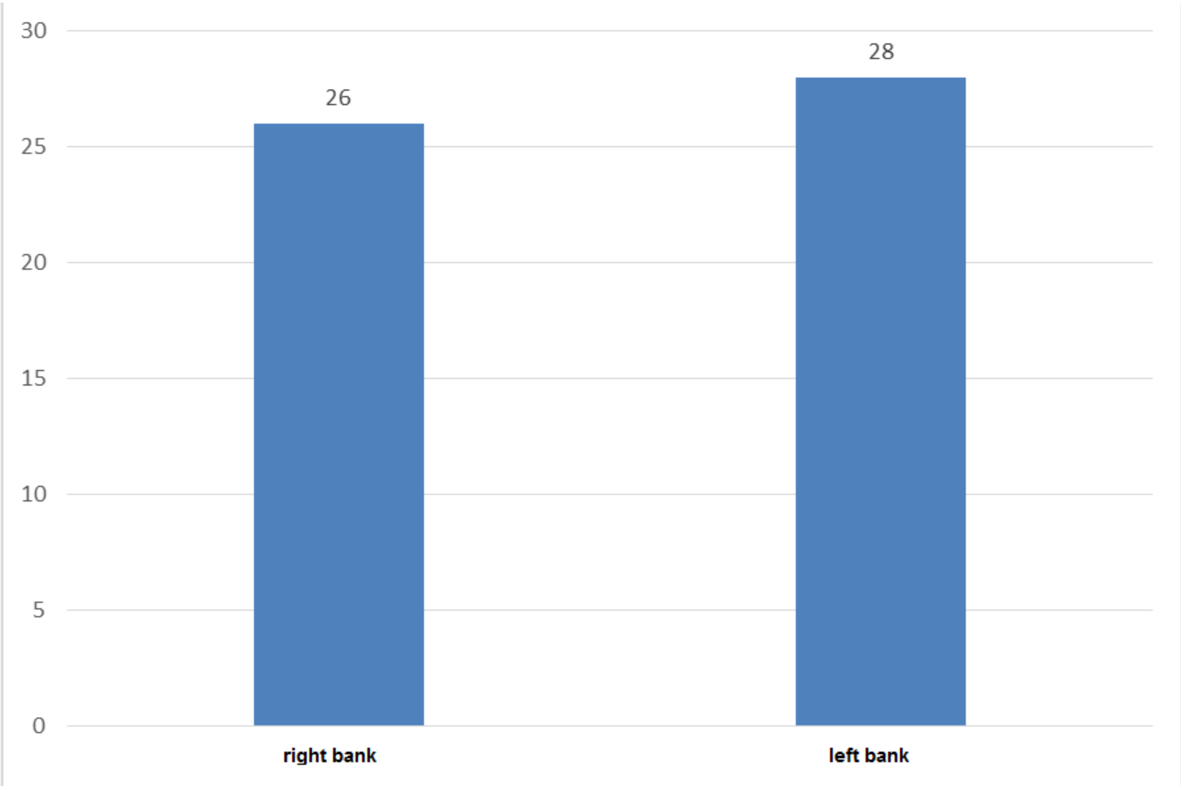


Figure 3.5 Distribution of signs by bank

All signs are lighted, which is favorable for the navigator, since coastal navigation signs are the main ones for marking the fairway, which is especially critical during the extended navigation period, given that floating signs will be removed from their regular places (except for ice ones, which will be discussed below in this section).

To designate characteristic noticeable places (cape, island, etc.) the Visual sign is used, which can also be attributed to this group. The ranges on the left bank are painted with alternating horizontal stripes of black and white, and on the right bank - in red. The signs of the left bank are equipped with green light, and the signs of the right bank with red one (Figures 3.6, 3.7).

Figure 3.6 Visual sign on the left bank

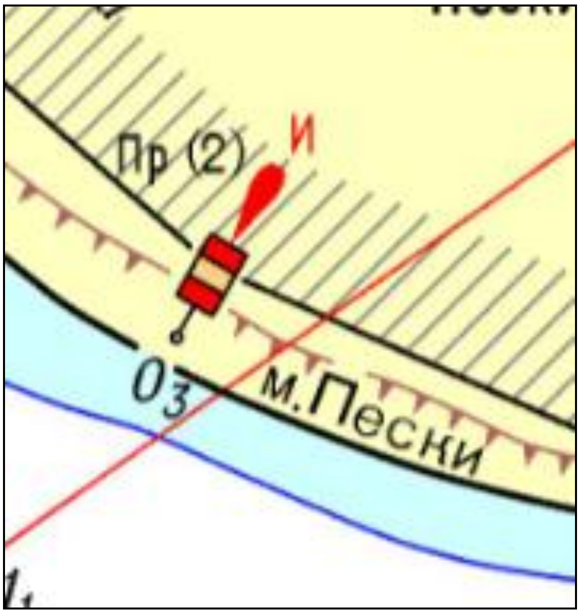


Figure 3.7 Visual sign on the right bank

The list of signs is given in Table 3.2.

Table 3.2 - List of Visual signs

Visual sign				
No.	**km**	**Bank**	**Light**	**Light type**
1	1359.35	right	lighted	Fixed red
2	1350.0	right	lighted	Fixed red
3	1343.45	left	lighted	Fixed green
4	1339.15	right	lighted	Fixed red
5	1337.55	left	lighted	Fixed green
6	1336.95	left	lighted	Fixed green
7	1335.7	left	lighted	Fixed green
8	1332.1	right	lighted	Fixed red
9	1328.55	left	lighted	Fixed green

There are 6 times less of them than range signs, but they are all lighted, which is a plus during the navigation extension period.

3.1.3 Information signs

The main signs included in this group:

- sign "Do not drop anchor";
- sign "Passing and overtaking are prohibited";
- sign "Do not exceed air draught";
- roadside mark (road stead range lines);
- sign "Place of turn of ships";
- distance sign

Let's consider each sign in more detail.

The sign "Do not drop anchor" is used to designate the zone of underwater passage of cables and pipelines laid on the bottom. This sign is most often found within the boundaries of St. Petersburg. In total 173 signs have been installed on the Neva River (the range lines are counted as one sign, differ in the characteristics of the lights - 2 range yellow). The list of signs is given in Table 3.3.

Table 3.2 - List of signs "Do not drop anchor"

Do not drop anchor									
No.	**km**	**Bank**	**Light**	**Light type**	**No.**	**km**	**Bank**	**Light**	**Light type**
1	1384.25	left	lighted	2 vertical yellow	37	1379.0	left	lighted	2 vertical yellow
2	1384.25	right	lighted	2 vertical yellow	38	1378.95	left	lighted	2 vertical yellow
3	1383.6	left	lighted	2 vertical yellow	39	1378.9	right	lighted	2 vertical yellow
4	1383.6	right	lighted	2 vertical yellow	40	1378.65	left	lighted	2 vertical yellow
5	1383.5	left	lighted	2 vertical yellow	41	1378.65	right	lighted	2 vertical yellow
6	1383.4	left	lighted	2 vertical yellow	42	1378.45	right	lighted	2 vertical yellow
7	1383.35	right	lighted	2 vertical yellow	43	1378.45	left	lighted	2 vertical yellow
8	1382.2	left	lighted	2 vertical yellow	44	1378.3	right	lighted	2 vertical yellow
9	1382.15	right	lighted	2 vertical yellow	45	1378.25	left	lighted	2 vertical yellow
10	1382.1	left	lighted	2 vertical yellow	46	1378.25	right	lighted	2 vertical yellow
11	1381.5	right	lighted	2 vertical yellow	47	1378.15	left	lighted	2 vertical yellow
12	1381.45	left	lighted	2 vertical yellow	48	1378.15	right	lighted	2 vertical yellow
13	1381.2	left	lighted	2 vertical yellow	49	1378.1	left	lighted	2 vertical yellow
14	1381.2	right	lighted	2 vertical yellow	50	1378.1	right	lighted	2 vertical yellow
15	1381.15	left	lighted	2 vertical yellow	51	1377.5	right	lighted	2 vertical yellow
16	1380.8	right	lighted	2 vertical yellow	52	1377.4	right	lighted	2 vertical yellow
17	1380.8	left	lighted	2 vertical yellow	53	1377.35	left	lighted	2 vertical yellow
18	1380.75	right	lighted	2 vertical yellow	54	1376.95	right	lighted	2 vertical yellow
19	1380.75	left	lighted	2 vertical yellow	55	1376.9	left	lighted	2 vertical yellow
20	1380.4	right	lighted	2 vertical yellow	56	1376.7	right	lighted	2 vertical yellow
21	1380.4	left	lighted	2 vertical yellow	57	1376.7	left	lighted	2 vertical yellow
22	1380.35	left	lighted	2 vertical yellow	58	1376.6	right	lighted	2 vertical yellow
23	1380.25	left	lighted	2 vertical yellow	59	1376.6	left	lighted	2 vertical yellow
24	1380.2	right	lighted	2 vertical yellow	60	1375.9	right	lighted	2 vertical yellow

25	1380.15	left	lighted	2 vertical yellow	61	1375.9	left	lighted	2 vertical yellow
26	1380.1	right	lighted	2 vertical yellow	62	1375.7	right	lighted	2 vertical yellow
27	1380.1	left	lighted	2 vertical yellow	63	1375.6	left	lighted	2 vertical yellow
28	1379.85	right	lighted	2 vertical yellow	64	1375.65	right	lighted	2 vertical yellow
29	1379.8	left	lighted	2 vertical yellow	65	1375.65	left	lighted	2 vertical yellow
30	1379.75	left	lighted	2 vertical yellow	66	1375.5	right	lighted	2 vertical yellow
31	1379.7	right	lighted	2 vertical yellow	67	1375.5	left	lighted	2 vertical yellow
32	1379.7	left	lighted	2 vertical yellow	68	1375.35	right	lighted	2 vertical yellow
33	1379.3	left	lighted	2 vertical yellow	69	1375.3	left	lighted	2 vertical yellow
34	1379.2	right	lighted	2 vertical yellow	70	1375.25	right	lighted	2 vertical yellow
35	1379.2	left	lighted	2 vertical yellow	71	1375.2	left	lighted	2 vertical yellow
36	1379.1	right	lighted	2 vertical yellow	72	1375.05	left	lighted	2 vertical yellow

Table 3.3 continued

Do not drop anchor									
No.	**km**	**Bank**	**Light**	**Light type**	**No.**	**km**	**Bank**	**Light**	**Light type**
73	1374.85	left	lighted	2 vertical yellow	113	1368.9	right	lighted	2 vertical yellow
74	1374.8	right	lighted	2 vertical yellow	114	1368.9	left	lighted	2 vertical yellow
75	1374.75	left	lighted	2 vertical yellow	115	1368.87	left	lighted	2 vertical yellow
76	1374.7	right	lighted	2 vertical yellow	116	1368.85	right	lighted	2 vertical yellow
77	1374.7	left	lighted	2 vertical yellow	117	1368.85	left	lighted	2 vertical yellow
78	1374.6	right	lighted	2 vertical yellow	118	1367.85	right	lighted	2 vertical yellow
79	1374.6	left	lighted	2 vertical yellow	119	1367.85	left	lighted	2 vertical yellow
80	1374.5	right	lighted	2 vertical yellow	120	1366.7	right	lighted	2 vertical yellow
81	1374.5	left	lighted	2 vertical yellow	121	1366.7	left	lighted	2 vertical yellow
82	1373.9	right	lighted	2 vertical yellow	122	1366.35	left	lighted	2 vertical yellow
83	1373.25	right	lighted	2 vertical yellow	123	1366.3	right	lighted	2 vertical yellow
84	1373.25	left	lighted	2 vertical yellow	124	1366.15	right	lighted	2 vertical yellow
85	1373.23	right	lighted	2 vertical yellow	125	1366.0	right	lighted	2 vertical yellow
86	1373.23	left	lighted	2 vertical yellow	126	1366.0	left	lighted	2 vertical yellow
87	1373.15	right	lighted	2 vertical yellow	127	1365.95	left	lighted	2 vertical yellow
88	1372.9	left	lighted	2 vertical yellow	128	1365.85	right	lighted	2 vertical yellow
89	1372.8	right	lighted	2 vertical yellow	129	1365.25	right	lighted	2 vertical yellow
90	1372.8	left	lighted	2 vertical yellow	130	1365.15	left	lighted	2 vertical yellow
91	1372.5	right	lighted	2 vertical yellow	131	1365.05	right	lighted	2 vertical yellow
92	1372.5	left	lighted	2 vertical yellow	132	1365.05	left	lighted	2 vertical yellow
93	1372.35	right	lighted	2 vertical yellow	133	1364.95	left	lighted	2 vertical yellow
94	1371.8	right	lighted	2 vertical yellow	134	1364.75	right	lighted	2 vertical yellow

95	1371.8	left	lighted	2 vertical yellow
96	1371.78	left	lighted	2 vertical yellow
97	1371.75	right	lighted	2 vertical yellow
98	1371.55	left	lighted	2 vertical yellow
99	1371.5	right	lighted	2 vertical yellow
100	1371.5	left	lighted	2 vertical yellow
101	1371.4	right	lighted	2 vertical yellow
102	1371.4	left	lighted	2 vertical yellow
103	1371.25	left	lighted	2 vertical yellow
104	1371.05	right	lighted	2 vertical yellow
105	1371.0	left	lighted	2 vertical yellow
106	1370.95	right	lighted	2 vertical yellow
107	1370.8	left	lighted	2 vertical yellow
108	1370.6	right	lighted	2 vertical yellow
109	1370.55	right	lighted	2 vertical yellow
110	1370.55	left	lighted	2 vertical yellow
111	1369.35	right	lighted	2 vertical yellow
112	1369.35	left	lighted	2 vertical yellow

135	1364.75	left	lighted	2 vertical yellow
136	1350.15	left	lighted	2 vertical yellow
137	1350.0	left	lighted	2 range yellow
138	1348.9	left	lighted	2 range yellow
139	1348.8	right	lighted	2 range yellow
140	1348.6	left	lighted	2 range yellow
141	1348.5	right	lighted	2 range yellow
142	1345.65	left	lighted	2 range yellow
143	1345.5	right	lighted	2 range yellow
144	1345.3	left	lighted	2 range yellow
145	1345.25	right	lighted	2 range yellow
146	1344.0	left	lighted	2 vertical yellow
147	1343.9	left	lighted	2 vertical yellow
148	1342.55	left	lighted	2 range yellow
149	1339.35	right	lighted	2 vertical yellow
150	1339.15	right	lighted	2 vertical yellow
151	1335.0	left	lighted	2 vertical yellow
152	1334.8	left	lighted	2 vertical yellow

Table 3.3 continued

Do not drop anchor									
No.	**km**	**Bank**	**Light**	**Light type**	**No.**	**km**	**Bank**	**Light**	**Light type**
153	1330.8	right	lighted	2 vertical yellow	163	1322.95	left	lighted	2 range yellow
154	1329.8	right	lighted	2 vertical yellow	164	1322.8	right	lighted	2 range yellow
155	1329.55	right	lighted	2 vertical yellow	165	1322.8	left	lighted	2 range yellow
156	1327.8	left	lighted	2 range yellow	166	1322.7	left	lighted	2 range yellow
157	1327.6	left	lighted	2 range yellow	167	1322.6	right	lighted	2 range yellow
158	1325.6	right	lighted	2 range yellow	168	1321.3	right	lighted	2 range yellow
159	1325.55	left	lighted	2 range yellow	169	1321.15	left	lighted	2 range yellow
160	1325.4	right	lighted	2 range yellow	170	1320.75	right	lighted	2 range yellow
161	1325.3	left	lighted	2 range yellow	171	1320.6	left	lighted	2 range yellow
162	1323.2	left	lighted	2 range yellow	172	1315.5	right	lighted	2 vertical yellow
					173	1315.3	right	lighted	2 vertical yellow

Based on the analysis of the data in Table 3.3, it can be noted that the distribution of range signs along the Neva River is rather uneven, the main part of the signs is located in the city of St. Petersburg, which is logical due to the large number of infrastructure facilities (Figure 3.8).

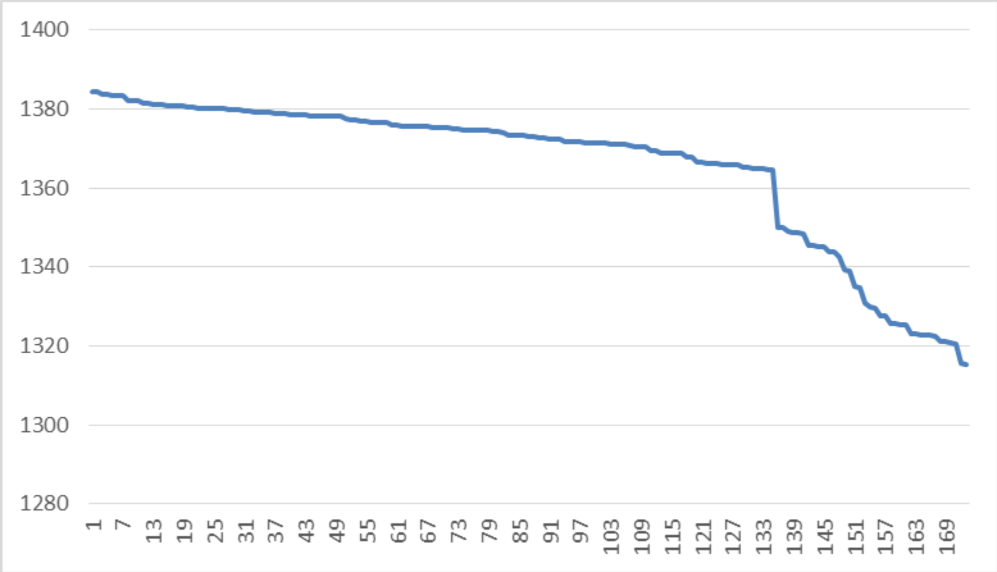


Figure 3.8 Distribution of signs "Do not drop anchor"

During the extended navigation period masters shall take this factor into account since special care will be required when anchoring in these areas. The ratio along the banks is approximately equal.

Signs “Passing and overtaking are prohibited” (Figure 3.9) are located in a rather small area, which is difficult for navigation, the master shall be especially careful here, especially during extended navigation period.

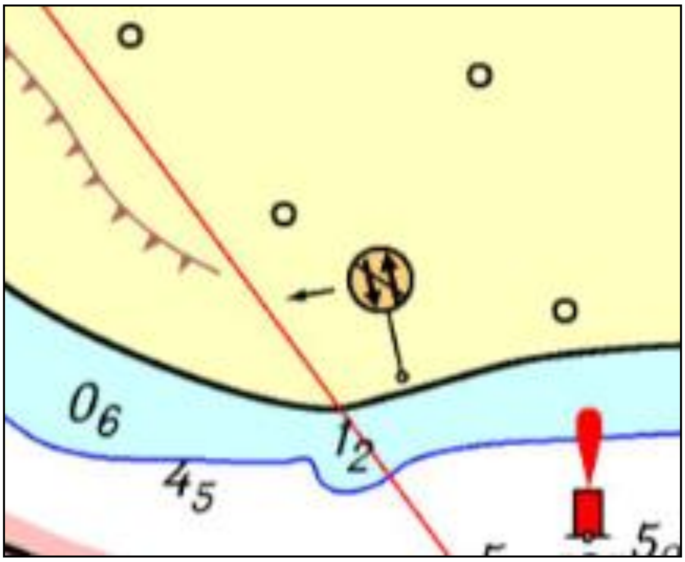


Figure 3.9 Sign "Passing and overtaking are prohibited"

The list of signs "Passing and overtaking are prohibited" is given in Table 3.4.

Table 3.4 Sign "Passing and overtaking are prohibited"

Passing and overtaking are prohibited				
No.	**km**	**right**	**Light**	**Light type**
1	1359.8	right	unlighted	-
2	1357.45	right	unlighted	-
3	1345.1	right	unlighted	-
4	1334.0	right	unlighted	-

It should be noted that all of them are unlighted, which requires special attention, at the same time, dispatch control is mandatory in these areas.

The signs "Do not exceed air draught" (Figure 3.10) are used to indicate the places of overhead crossing.

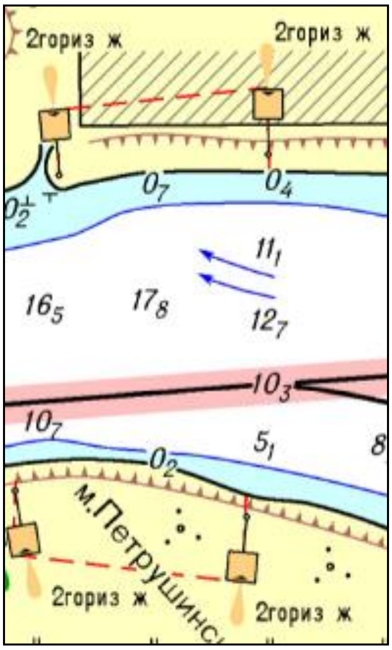


Figure 3.10 Sign "Do not exceed air draught"

Distributed evenly along the river outside St. Petersburg, the list is given in Table 3.5.

Table 3.5 Sign "Do not exceed air draught"

Do not exceed air draught				
No.	**km**	**Bank**	**Light**	**Light type**
1	1366.85	right	lighted	2 horizontal yellow
2	1366.8	left	lighted	2 horizontal yellow
3	1366.6	right	lighted	2 horizontal yellow
4	1366.6	left	lighted	2 horizontal yellow
5	1360.05	right	lighted	2 horizontal yellow
6	1360.05	left	lighted	2 horizontal yellow
7	1359.85	left	lighted	2 horizontal yellow
8	1359.7	right	lighted	2 horizontal yellow
9	1337.55	left	lighted	2 horizontal yellow
10	1337.5	right	lighted	2 horizontal yellow
11	1337.35	left	lighted	2 horizontal yellow
12	1337.3	right	lighted	2 horizontal yellow
13	1327.3	right	lighted	2 horizontal yellow
14	1327.3	left	lighted	2 horizontal yellow
15	1327.05	right	lighted	2 horizontal yellow
16	1327.05	left	lighted	2 horizontal yellow
17	1320.6	left	lighted	2 horizontal yellow
18	1320.4	left	lighted	2 horizontal yellow

These navigation signs are usually located in small settlements, installed in groups of 2-4 signs (highlighted in gray in Table 3.5). All signs are lighted.

Signs roadside mark (road stead range lines) (Figure 3.11).

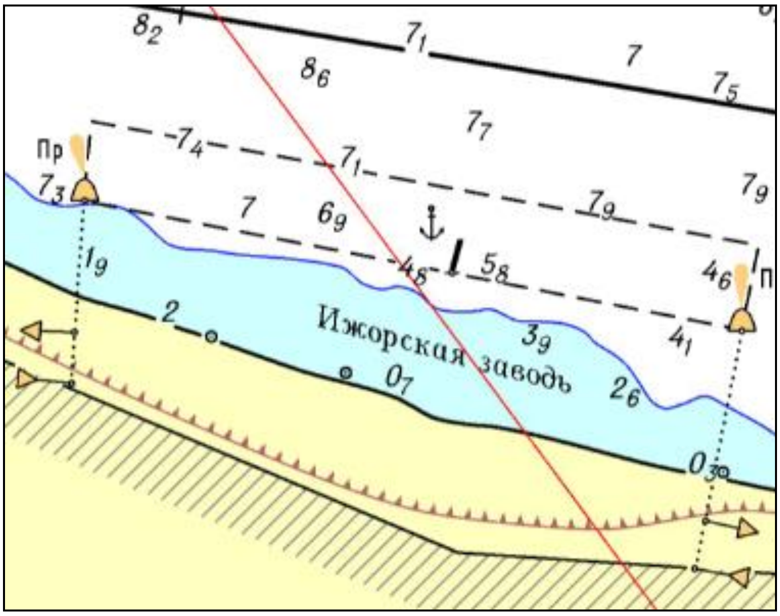


Figure 3.11 Roadside mark

Roads on the Neva River are marked with 52 range signs and are usually located near areas difficult for navigation: Krivoye Koleno (1359.8–1357.5) and Ivanovskiye Porogy (1349.0-1334.0). The list is given in Table 3.6 (pairs of characters are marked with gray fill).

Table 3.6 – Roadstead range signs

Roadstead range signs									
No.	**km**	**Bank**	**Light**	**Light type**	**No.**	**km**	**Bank**	**Light**	**Light type**
1	1378.1	right	unlighted	-	27	1355.05	left	unlighted	-
2	1378.05	right	unlighted	-	28	1355.05	left	unlighted	-
3	1377.45	right	unlighted	-	29	1354.5	left	unlighted	-
4	1377.45	right	unlighted	-	30	1354.5	left	unlighted	-
5	1372.35	left	lighted	Fixed green	31	1354.4	right	unlighted	-
6	1372.35	left	lighted	Fixed green	32	1354.4	right	unlighted	-
7	1371.9	left	lighted	Fixed green	33	1353.5	right	unlighted	-
8	1371.9	left	lighted	Fixed green	34	1353.5	right	unlighted	-
9	1363.1	left	unlighted	-	35	1345.75	right	lighted	Fixed red
10	1363.1	left	unlighted	-	36	1345.75	right	lighted	Fixed red
11	1362.8	left	unlighted	-	37	1345.55	right	lighted	Fixed red
12	1362.8	left	unlighted	-	38	1345.55	right	lighted	Fixed red
13	1361.3	left	unlighted	-	39	1324.2	right	unlighted	-
14	1361.3	left	unlighted	-	40	1324.2	right	unlighted	-
15	1361.3	right	lighted	Fixed red	41	1323.2	right	unlighted	-
16	1361.3	right	lighted	Fixed red	42	1323.2	right	unlighted	-
17	1360.55	right	lighted	Fixed red	43	1320.2	right	unlighted	-
18	1360.55	right	lighted	Fixed red	44	1320.2	right	unlighted	-
19	1360.45	right	unlighted	-	45	1320.0	left	lighted	Fixed red
20	1360.45	right	unlighted	-	46	1320.0	left	lighted	Fixed red
21	1360.4	left	unlighted	-	47	1319.25	left	lighted	Fixed red
22	1360.4	left	unlighted	-	48	1319.25	left	lighted	Fixed red
23	1357.1	right	lighted	Fixed red	49	1319.15	right	lighted	Fixed red
24	1357.1	right	lighted	Fixed red	50	1319.15	right	lighted	Fixed red
25	1355.7	right	lighted	Fixed red	51	1317.9	right	lighted	Fixed red
26	1355.7	right	lighted	Fixed red	52	1317.9	right	lighted	Fixed red

At the same time, the ratio along the banks indicates a significant prevalence of signs located on the right bank (Figure 3.12). Therefore, most of the raids are located on the right bank. This must be taken into account during extended navigation period, since the weather at this time is highly changeable and the need to anchor at the roadstead increases.

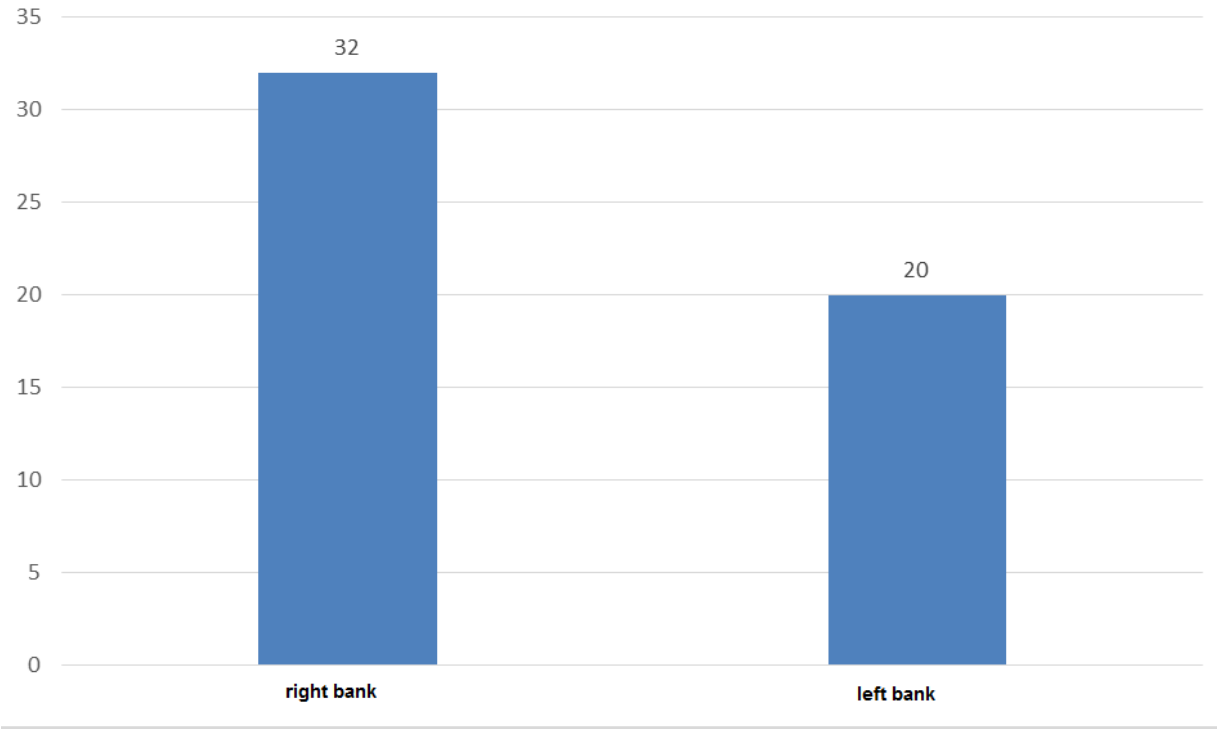


Figure 3.12 Distribution of signs by bank

The ratio of lighted and unlighted signs is shown in Figure 3.13.

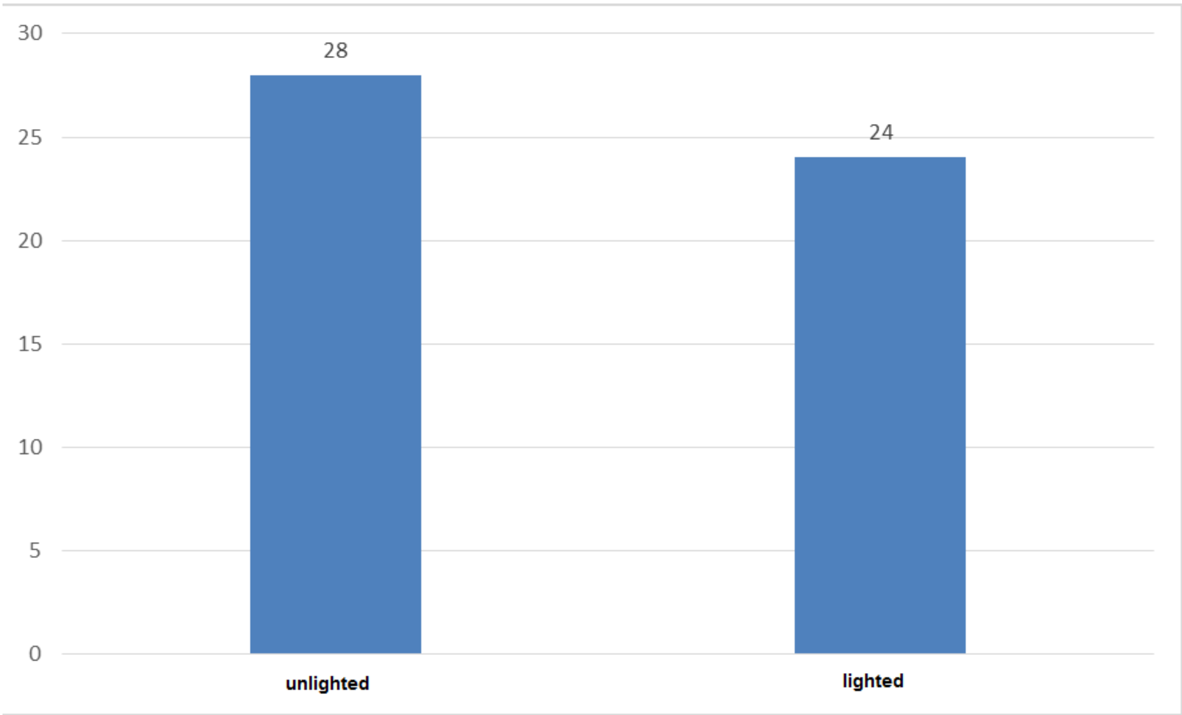


Figure 3.13 Distribution of signs by bank

It should be noted that more than half of the signs (54%) are unlighted, the master shall take these data into account during the navigation extension period.

Only one sign “Place of turn of ships” is installed on the Neva River (Figure 3.14).

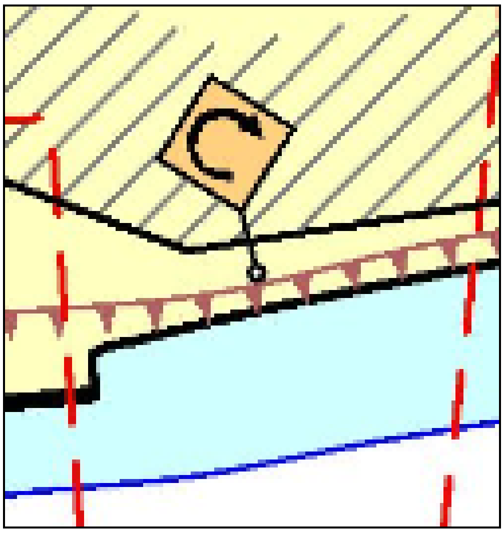


Figure 3.14 Sign "Place of turn of ships"

It is installed at 1362.6 km, unlighted.

The distance signs are installed outside St. Petersburg 5 km apart from each other (Figure 3.15).

Figure 3.15 Distance sign

The list of signs is given in Table 3.7.

Table 3.7 – Distance signs

Distance signs				
No.	**km**	**Bank**	**Light**	**Light type**
1	1375.0	right	unlighted	-
2	1370.0	right	unlighted	-
3	1365.0	right	unlighted	-
4	1360.0	right	unlighted	-
5	1355.0	right	unlighted	-
6	1350.0	right	unlighted	-
7	1345.0	right	unlighted	-
8	1340.0	right	unlighted	-
9	1335.0	right	unlighted	-
10	1330.0	left	unlighted	-
11	1325.0	right	unlighted	-
12	1320.0	right	unlighted	-
13	1316.0	left	unlighted	-

Distance signs have an important function in helping to identify the section of the route on which the vessel is located. In addition to the ENC this will be one of the main navigation aids during the navigation extension period.

3.2 Ice marks

During the inter-navigation period, not all floating navigation signs are removed, special ice buoys remain in their regular places. During the navigation extension period, the navigator is recommended to use them as one of the navigation aids. Let's consider them in more detail. These navigation aids are cigar-shaped buoys.

Ice signs during the main navigation period are installed as duplicate ones (Figure 3.16), and during the extended navigation period serve as the main floating navigational signs.

Figure 3.16 Ice mark on the Neva River

On the Neva River ice buoys of the H-2 type are installed with the topside silhouette in the form of a truncated cone (Figure 3.17).

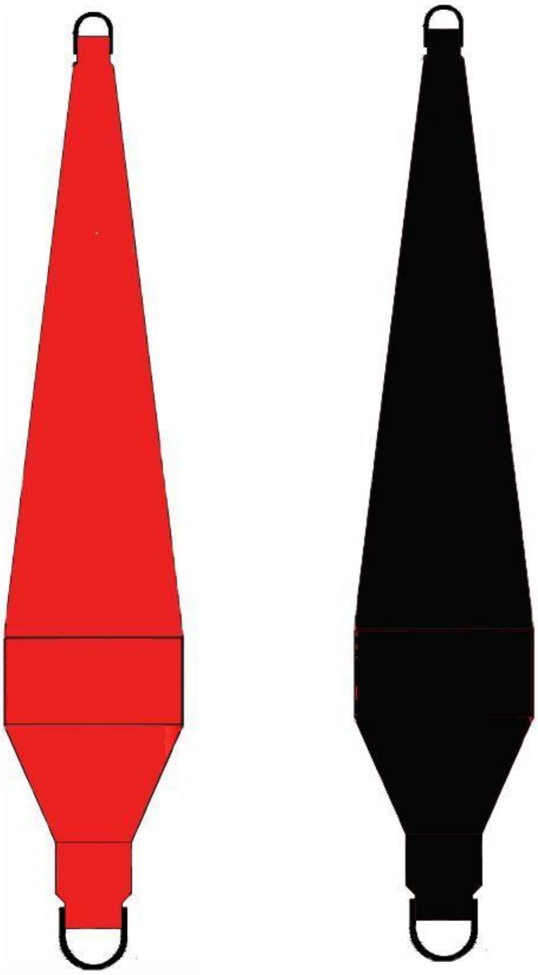


Figure 3.17 Ice buoys H-2

The characteristics of ice buoys are shown in Table 3.8.

Table 3.8 - Characteristics of ice buoys

Characteristic	Value
Dimension size	Н-2-П
Type (topside silhouette)	Truncated cone
Bouy body color	Red or black (as per specification)
Bouy body material	Polyethylene
Installation depth, m	3-20
Buoy overall height (with lamp), m	3.5 – 4.5
Buoy overall diameter, max, m	0.9 – 1.0
Buoy overall height (topside silhouette), m	2
Maximum draft. m	2 – 2.5
Anchor chain caliber (maximum), mm	22
Buoy mass without equipment and anchor gear, kg	550-600

Ice buoys are a one-piece sealed structure with ballast located in the buoy body and molded sleeves for connecting the anchor and lifting eyes. Unsinkability in case of a breakdown is ensured by filling the float with special grade polyurethane foam with a minimum water absorption coefficient.

Both metal and plastic ice buoys have been installed on the Neva River; currently, mainly plastic signs are purchased.

The body material of such a buoy is a special grade of linear low or medium density polyethylene for processing by rotational molding.

The buoy body is made by rotational molding. The thickness of the buoy body walls is not less than 1.5 cm. The used grades of polyethylene are resistant to high and low temperatures, do not fade and do not change color under the influence of sunlight and precipitation during the entire service life. Suitable for winter use.

The buoy body is made of a one-piece hollow sealed element (one-piece design of the surface and underwater parts), made using seamless technology. In the buoy body, 2 bushings are hermetically molded (one in the upper part of the buoy, and another in the lower part of the buoy) for the possibility of installing brackets to install/remove the buoys and attach the buoy to the anchor device. The largest diameter of the buoy body is from 900 mm to 1,000 mm.

The strength of each (any one) eyebolt ensures the carrying out of loading and unloading and installation operations together with the anchor cargo applied to this type of buoys. In the upper part of the buoy there is a sealed valve that can be opened during the summer period when the buoys are stored on the shore and when the buoy is repeatedly closed afloat.

The lower part design provides for the possibility of connecting a chain and an anchor (all this shall be fixed to the buoy body through a molded bushing).

The buoy design provides the buoy ability to submerge under the ice during the freeze-up period and to surface out from under the ice in the water lead. Due to its design and the body material the buoy does not freeze into the ice.

The buoy buoyancy is ensured by the body tightness, the unsinkability - by filling it with light floating elements or foam materials with low water absorption.

All metal elements of the buoy have a corrosion-resistant paint and varnish coating, the overmolded bushings are made of stainless steel. The ballast is housed in a hollow, one-piece buoy body and securely fixed.

The underwater part of the body is sealed and does not have any connections through flanges, bolts or sealant. The color of the buoy body is made of a uniform material from which the buoy is made, and corresponds to GOST 26600-98.

The cigar color corresponds to the color of the buoy it is paired with; after the end of the navigation period the main buoys are uninstalled (Figures 3.18, 3.19).

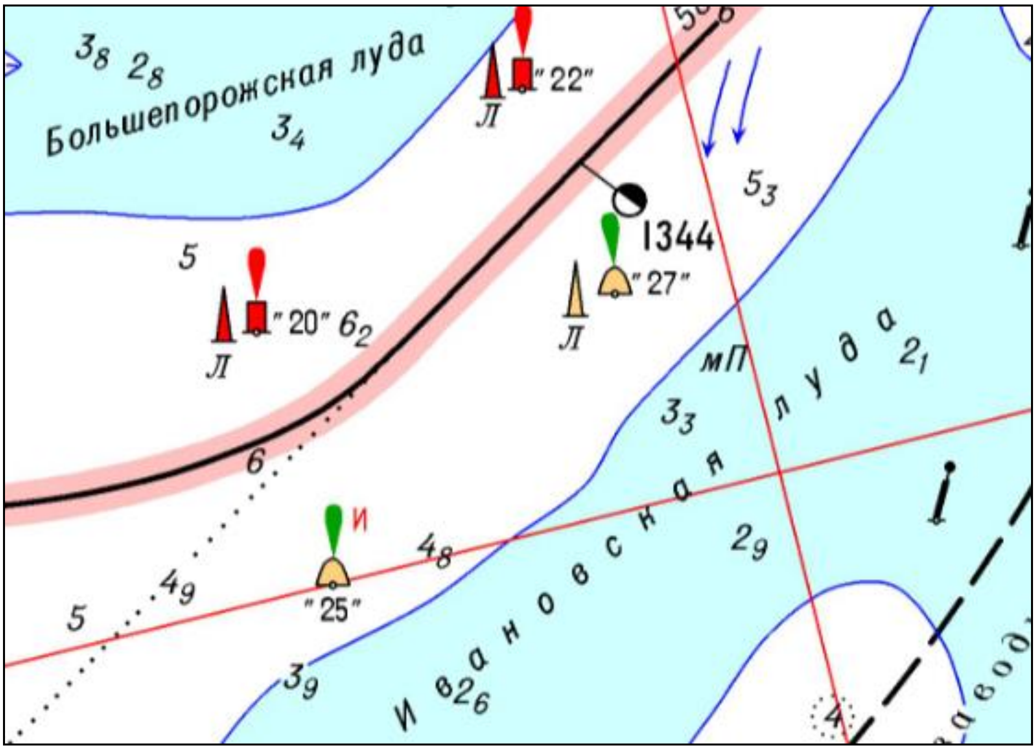


Figure 3.18 Ice buoys-cigars of the left and right edges of the fairway

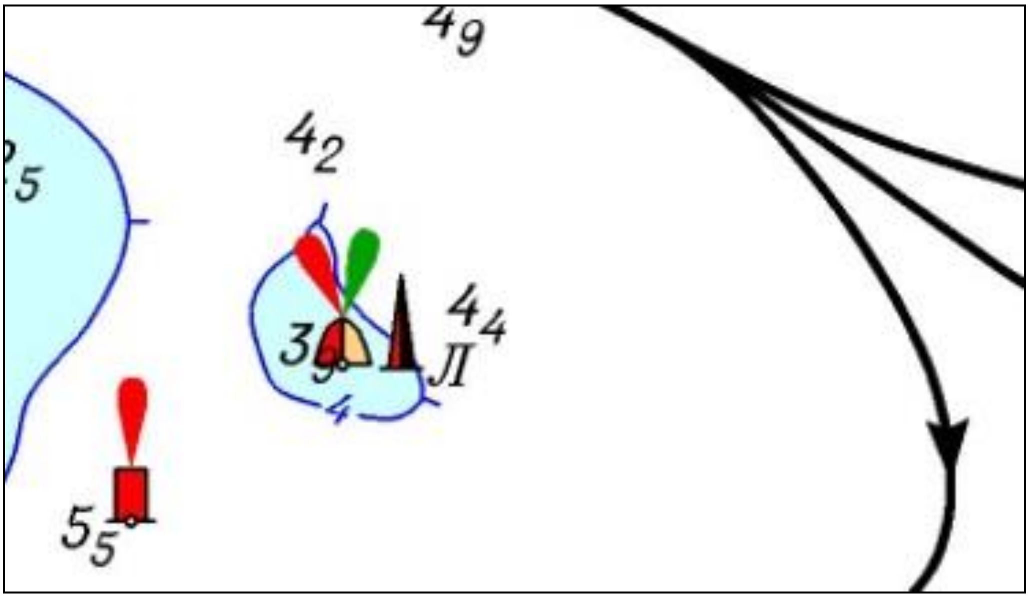


Figure 3.19 Pivot Cigar Buoy

The list of ice marks is given in Table 3.9.

Table 3.9 - List of ice marks

Ice marks				
No.	**km**	**Fairway side**	**Light**	**Light type**
1	1382.85	right	unlighted	-
2	1347.85	right	unlighted	-
3	1346.3	left	unlighted	-
4	1346.1	right	unlighted	-
5	1344.3	right	unlighted	-
6	1344.1	left	unlighted	-
7	1377.0	right	unlighted	-
8	1341.15	right	unlighted	-
9	1340.05	left	unlighted	-
10	1338.5	left	unlighted	-
11	1334.6	left	unlighted	-
12	1316.85	right	unlighted	-
13	1316.65	right	unlighted	-

As can be seen from the graph of the distribution of ice marks on the Neva River, they are installed in the most dangerous sections of the fairway, a dense arrangement is observed in the area of the Ivanovskiye Porogy rapids and the Koshkinsky fairway (Figure 3.20).

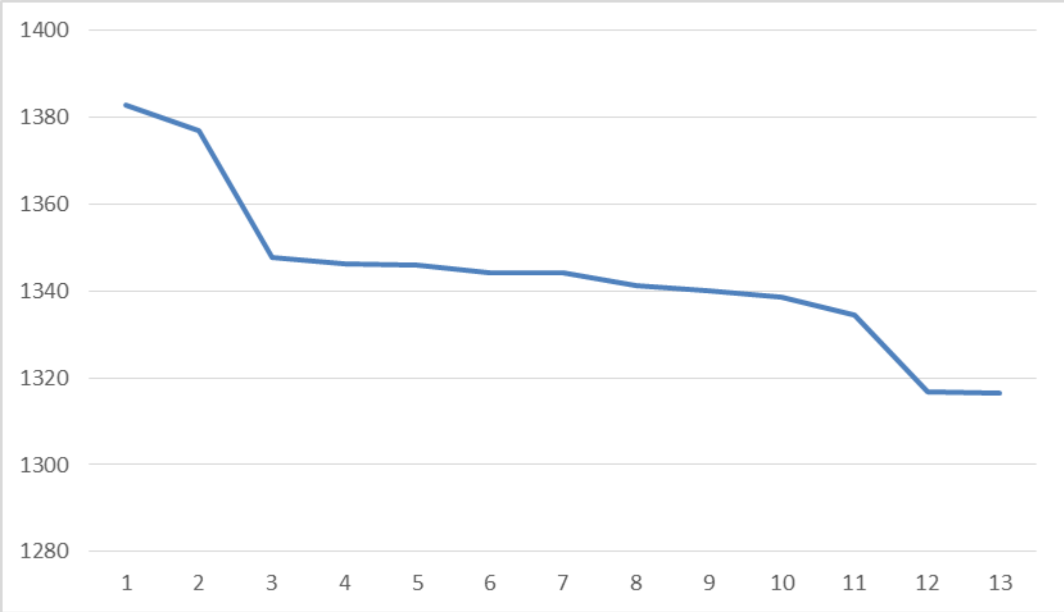


Figure 3.20 Schedule of distribution of ice marks on the Neva River

3.3 Basic recommendations for ensuring ice channeling of ships in the water area of the Neva River

It is recommended (Figure 3.21) for navigators to use ENCs as their primary navigation aids and coastal navigation signs as an additional aids. Ice buoys are installed in the most difficult navigation areas.

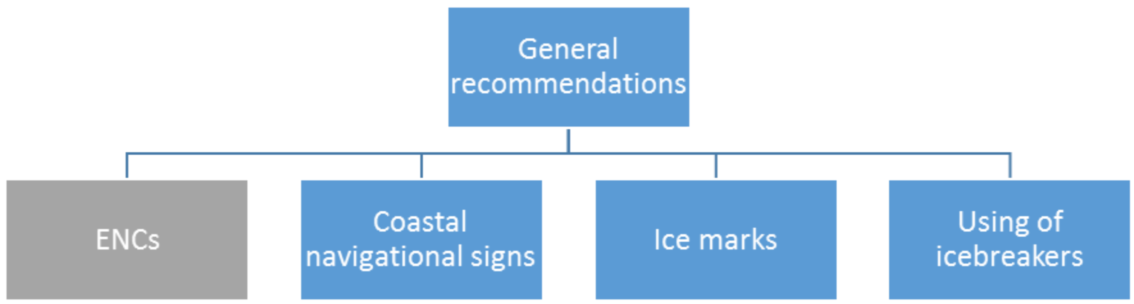


Figure 3.21 General recommendations for ice channeling

In case of ice coverage escorting will be carried out using icebreakers.

4. PREPARATION OF CONCLUSION ON THE RESULTS OF DEVELOPMENT OF SCIENTIFICALLY BASED RECOMMENDATIONS ON INFORMATION AND NAVIGATION SUPPORT FOR NAVIGATORS DURING THE NAVIGATION EXTENSION PERIOD

4.1 River Information Service

Currently masters receive information about changes in the ice situation via the radio channel through coastal radio stations and through the dispatch service. To ensure the safety during the extension navigation period, it is necessary to develop a special service for prompt provision of the entire range of data to navigators via the Internet. To solve the problem the River Information Service (RIS) or, at the first stage, its elements shall be developed and created.

River Information Services (RIS) are harmonized information and communication services that facilitate the management of cargo and vessel traffic in inland navigation, including, where technically possible, interconnection with other modes of transport. The RIS shall at minimum shall include the following:

- fairway information service;
- vessel traffic information service;
- vessel traffic regulation service;
- logistics service;
- logistics service;
- service of charges for the use of waterways;
- disaster control service.

When operating the RIS, it is necessary to ensure:

- providing RIS users with all data important for planning voyages on inland waterways in an accessible electronic format;
- user access to electronic pilotage charts suitable for navigation purposes;
- access for competent authorities to messages with the necessary information about vessels in electronic form;
- provision of messages to masters in the form of standard, coded and downloadable messages.

In addition, it is necessary to ensure continuity in relations with the services that provide information services and, first of all, with the services that deal with the regulation of traffic on other modes of transport, especially the regulation of traffic in maritime navigation. RIS applications shall be able to interact with the transport and business management systems of companies involved in the transport of goods and passengers.

Potentially RIS can be both public and private. Both public and private RIS shall meet the general requirements.

From the point of view of this work, we are primarily interested in the Fairway Information Service (FIS). It will allow to promptly bring navigational information to the navigators, and is critically important during the navigation extension period.

Table 4.1 - Functional composition of the Fairway Information Service

No.	RIS service RIS subservice RIS function	Information level	Users							
			Navigator	**VTS operator**	**Gateway / bridge operator**	**Waterway Administration**	**Terminal operator**	**Emergency center**	**Superintendant**	**Shipper**
	Information:									
FIS.1.	Geographic data of the shipping area and clarifications	FIS	X	X	X	X		X	X	X
FIS.2	Navigation aids and signs regulating the movement of ships	FIS	X	X	X	X		X		
FIS.3	Fairway depth profile	FIS	X	X	X	X	X	X		X
FIS.4	Long-term obstructions in the fairway	FIS	X	X	X	X		X	X	X
FIS.5	Updated meteorological information	FIS	X	X		X		X		
FIS.6	Temporary obstructions in the fairway	FIS	X	X		X		X		X
FIS.7	Existing and expected water levels at measuring posts	FIS	X	X		X		X	X	X
FIS.8	Condition of rivers, canals, locks and bridges in the RIS area	FIS	X	X	X	X		X		X
FIS.9	Restrictions caused by floods and ice	FIS	X	X	X	X		X	X	X
FIS.10	Malfunction of the navigation aids	FIS	X	X		X				
FIS 11	Short-term changes in the opening hours for locks and bridges	FIS	X	X	X	X				X
FIS 12	Short-term changes in the operation of navigation aids	FIS	X	X		X				
FIS.13	Typical opening hours for locks and bridges	FIS	X	X	X	X		X	X	X
FIS.14	Physical restrictions on waterways, under bridges and at locks	FIS	X	X	X	X		X	X	X
FIS.15	Navigation rules	FIS	X	X	X	X		X	X	
FIS.16	Infrastructure fee rates	FIS	X			X			X	X
FIS.17	Rules and guidelines for pleasure craft	FIS	(X)			X		X		

The traditional channels for CIFs are, for example, visual navigation aids, notices to masters in print, by radio and landline telephone at locks. GSM cell phones have expanded the possibilities for voice communication and data transmission, but GSM is not available everywhere and not always. CIF services created specifically for waterways can be obtained through:

- radiotelephone service on inland waterways;
- the Internet;
- service for providing electronic navigation charts.

The types of fairway information are listed in Table 4.1.

Fairway information includes static and dynamic information as well as urgent fairway information. Dynamic and static information shall be transmitted according to a specific schedule. Urgent information needs very frequent updates and/or needs to be transmitted in real time (for example, in a voice form on VHF or through electronic data exchange channels, over the Internet).

Safety-related fairway information shall be provided by or on behalf of the competent authority.

Fairway information for the international river sector shall be transmitted through a single information distribution point, where data from the relevant competent authorities are received.

Safety-related data shall be verified as closely as possible by the competent authority upon receipt.

The values of various parameters shall be given only with an indication of the accuracy with which they were obtained.

Fairway information services shall use approved communication means (for example, notices to navigators via the Internet or VHF) and, where possible, provide their services tailored to the customer needs.

To ensure navigation in conditions of poor visibility with radar, the fairway shall be equipped with buoys and signs with radar reflectors; radar reflectors shall also be installed in front of bridge supports. This item is closely related to navigation and hydrographic support and will be considered at the next stage of work.

From the point of view of extended navigation, the main emphasis shall be placed on the promptness of bringing information to the navigators. Let's consider what information is advisable to bring to using various technical means.

The radiotelephone service allows direct and fast communication between masters, waterway authorities and port authorities. It is best suited for transmitting urgent information in real time.

It is recommended to transmit voice information about the fairway in the service "navigation information" (shore/ship) in the following cases:

- in the presence of urgent information that requires frequent updates and shall be transmitted in real time;

- for the regular daily transmission of dynamic information.

Urgent and dynamic information transmitted by radiotelephone may concern, for example:

- temporary obstacles in the fairway, malfunctions of the navigation aids;

- short-term changes in the opening hours for locks and bridges;

- navigation restrictions due to floods and ice;

- existing and expected water levels at measuring posts.

The RIS area shall be completely covered by the signal of VHF base stations for the transmission of navigation information.

In the service "navigation information", notices to navigators can be transmitted to "all users" in the form of:

- regular messages at certain times of the day on the state of waterways, including messages on water levels at water measuring posts;

- urgent messages in special cases (for example, the order of movement after an accident).

The operator of the RIS center shall be able to answer specific questions from the masters upon their request and receive messages from them.

Data transmission over the Internet.

It is recommended to post the following types of fairway information on the Internet:

- dynamic navigational information about the state of waterways, which shall be transmitted no more often than once a day. This information can be in the form of notices to navigators;

- dynamic hydrographic information on existing water levels, expected water levels, waterway depths (if available), forecasts and messages on ice events and floods. This information can be presented in the form of regularly updated tables and charts;

- static information (e.g. physical restrictions on waterways, normal opening hours of locks and bridges, navigation rules). This information can be presented in the form of static sites on the Internet.

For dense and/or extended waterway networks, dynamic information can be organized in interactive databases (content management system) to facilitate data access.

In addition to posting on the Internet, notices to navigators can be transmitted through:

- subscriber e-mail to computers on board vessels and in offices;

- subscriptions for the transmission of short messages to mobile phones;

- displaying pages on the screens of mobile devices.

In order to facilitate the route planning for the navigator, it shall be possible, upon the user's request, to display on one page all the information about the fairway required on the way from the port of departure to the port of destination.

Notices to navigators posted on the Internet or transmitted as part of the exchange of data between competent authorities shall have an agreed format in order to allow them to be automatically translated into other languages, which will be promising taking into account the plans for the development of international navigation on inland waterways.

4.2 Running modification of ENCs

One of the important tasks during the extended navigation period is to provide masters with up-to-date correction data for the ENC.

The transmission of corrections under these conditions shall be realized exclusively using wireless data transmission channels. For these purposes, you can use:

- cellular communication channels;

- service channels of the basin administrations for the transmission of the ENC correction information.

Transmission via cellular channels (HSDPA, 4G) is technically easy to implement, but has a significant drawback in that the channel is entirely owned by a private provider company and is not controlled by the basin administration in any way. This channel can be switched off or switched to service mode at any time.

The construction of an own channel for the transmission of ENC correction data implies the creation of access points on certain sections of the waterway, where the navigator's ECDIS can automatically connect and download updates.

The coastal remote transmission station (RTS) ENC is autonomous and includes: a device for a network connection, an industrial computer (server, usually without a monitor) and a powerful Wi-Fi router with an extended-range antenna (Figure 4.1).

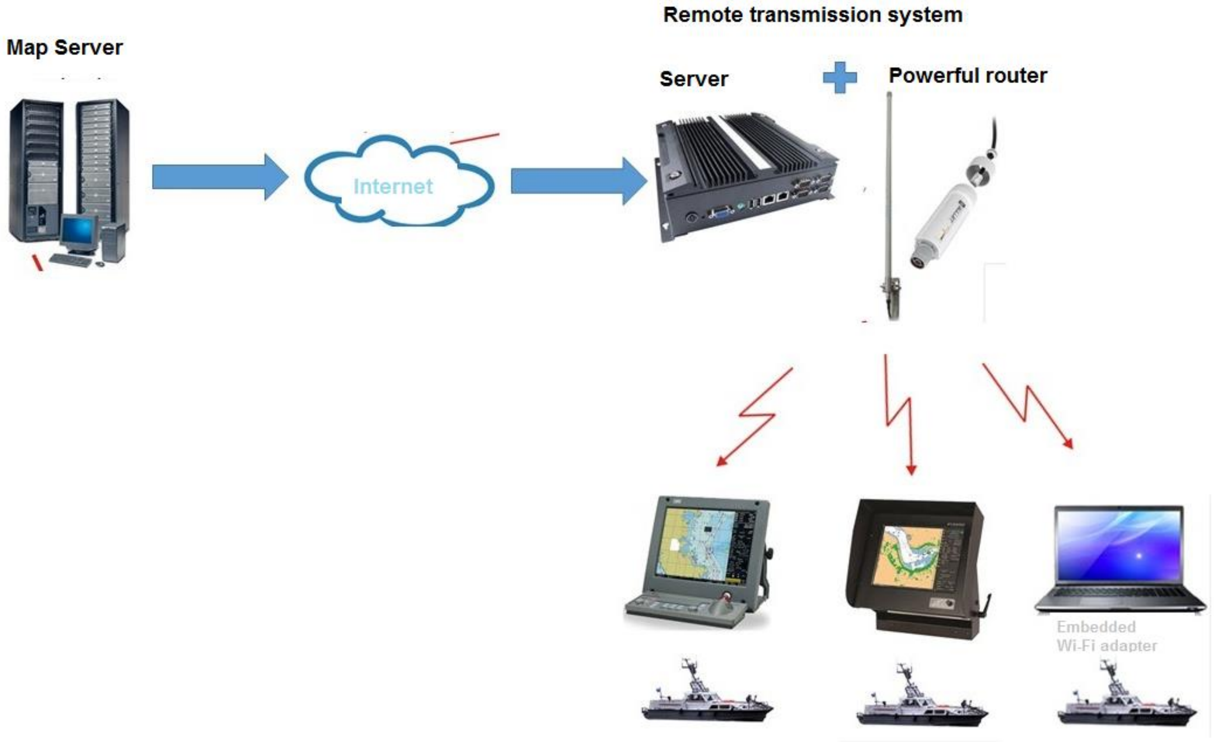


Figure 4.1 - Schematic diagram of the ENC control system

It is planned to use the Internet to communicate with the map server; for use in hard-to-reach places, the connection can be made via a satellite data transmission channel. The satellite terminal can be implemented in two versions.

When the complex is stationary, large-sized equipment is used that works with geostationary satellites of the Yamal series. In the case of the portable version, during the temporary deployment of the coastal station, compact equipment is used that works with satellite systems Inmarsat, etc.

The software deployed on the server maintains a set of maps and updates for a given area, downloads updated versions of ENCs from a map server, provides maps and updates via Wi-Fi to passing ships.

It is planned to use industrial computers (monitorless stations) as a server. If technically possible, the server can be connected to a local Internet provider without using satellite data transmission channels, which will significantly reduce the cost of its operation.

The complex is deployed on the shore, taking into account the maximum range of the Wi-Fi antenna of 800-1,500 meters. If necessary, the antenna and router can be moved from the server to a closer distance to the shore.

The placement of such a complex on the Neva River seems reasonable in the Shlisselburg area. If two complexes are installed, it is recommended to install the second one within the city in the area of Perevoznaya embankment (Figure 4.2).

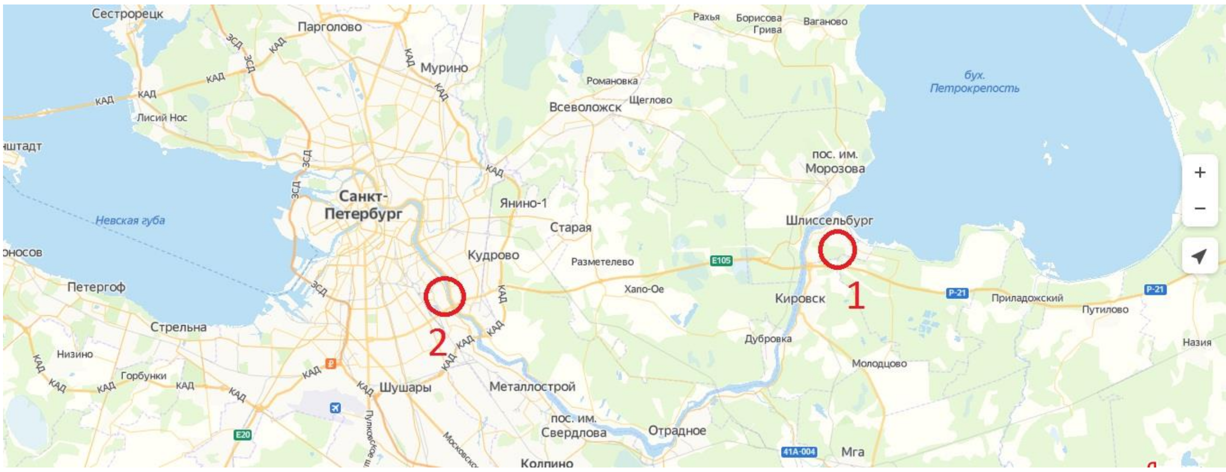


Figure 4.2 - Recommended locations of the ENC control system

4.3 "Print on demand" technology

For completely paperless navigation, the minimum requirement is two independent ECDIS on board. In the conditions of inland waterway transport, this solution is not always feasible, therefore, the obligatory presence of a paper map on board, even when using ENC for navigation purposes as the main means, remains. In conditions of extended navigation, special requirements are imposed on such maps in terms of the promptness of data updating. Data on the waterway state are provided by various sources (for more information on this information, see Section 1 of this work), they must be promptly plotted on the navigation map. One of the possible options is to manually apply corrections to the map sheets, but in case of a large amount of changes, using the map becomes difficult. The way out of this situation is to use the "print on demand" technology.

"Print on demand" - PoD - a publishing technology in which new copies of cards are printed only upon reception of a request from the buyer.

This publishing technology was first introduced in February 1997 in Stockholm, but widespread use of the technology became possible with the development of digital printing, since it was economically unprofitable to print single copies using traditional offset printing technology.

For navigation maps, the "print on demand" technology has been working for more than 10 years, while absolutely all state navigation maps for inland waterways until 2012 were printed by typographic method, the circulation was stored in the warehouse, this map did not change until the next edition (at least 5-9 years). To inform navigators about the current navigational situation on the waterway section, the maps were regularly updated. It is good if the correction was made in a timely manner by placing graphic inserts on the map sheets, but more often the correction was made over the existing image. There was a situation when many sheets of the map were overloaded with correction information, while a large number of sheets remained unchanged.

With the help of “print on demand” technology it became possible to create paper analogs on the basis of a single database of digital cartographic information and print them on demand in the required quantity taking into account constant updating.

The state paper navigational maps created in this way retain the same functional yield as electronic navigation maps, have the same accuracy and allow the navigator to quickly take bearings in the locality due to the presence of a geographic grid.

The first experience in the implementation of the "print on demand" (PoD) technology of state navigation maps of inland waterways in the Russian Federation was the creation of a map of the Volkhov River.

Its original version had a cutting of the map sheets, oriented strictly to the north (a complete analogue of the electronic navigation map of the S-57 standard) with full preservation of the geometry of all cells and the translation of conventional signs into signs that meet the requirements of the Guidelines for the publication of paper maps of inland waterways.

On each sheet of the map, in addition to the required attributes, the number of the corresponding ENC cell was also indicated.

In general, the proposed technology for creating paper navigation maps of inland waterways was approved, but for ease of use by navigators, it was decided to traditionally cut the map sheets "along the channel", even though Volkhov has a fairly convenient geographical location, i.e. flows almost strictly to the north (Figure 4.3).

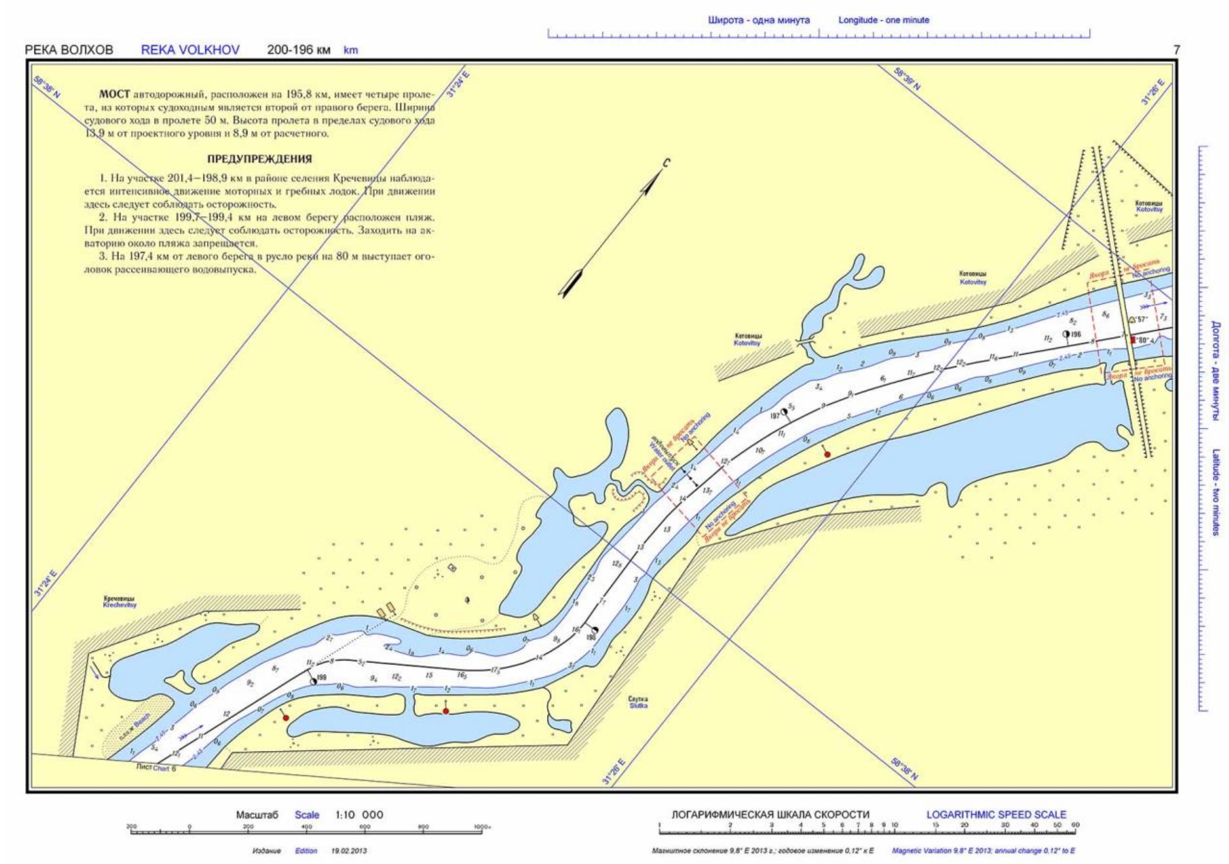


Figure 4.3 An example of a navigation map published using the PoD technology

All inscriptions on the map are duplicated in English (proper names are given in transliteration), this was done due to the fact that the Volkhov River is a model map for all future editions of state navigation maps of inland waterways using the PoD technology.

This version of the map is currently issued by Volgo-Balt Administration. The map sheets printed in color on special paper are stapled into a single folder.

Therefore, the PoD technology of IWW maps has the following advantages:

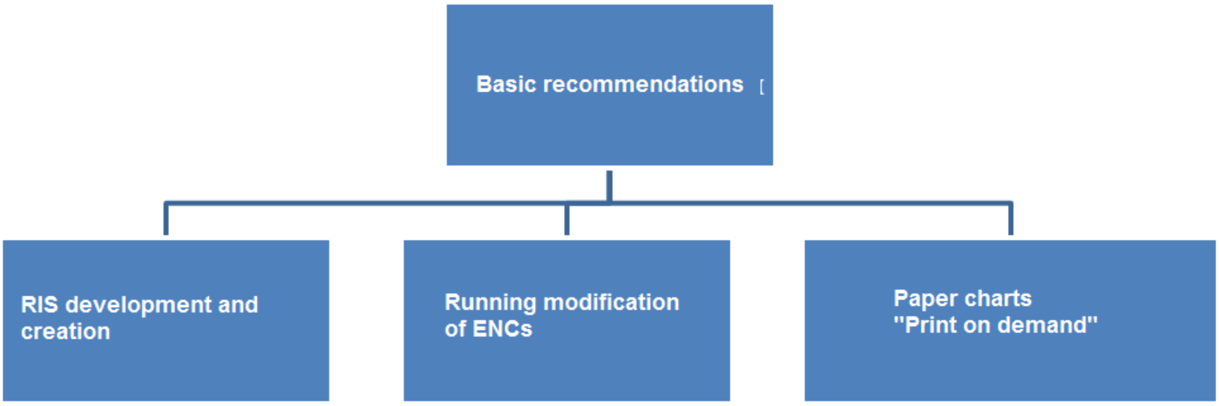
- high accuracy of paper navigation charts;
- there is no need to store the published circulation;
- making corrections directly to the pre-print file;
- prompt communication of all changes to the consumer.

Along with the abovementioned advantages, the presented technology has a number of disadvantages, the main of which is the price of one copy of the map for the consumer. The price turns out to be higher for the consumer than the price of a map produced using offset printing technology. However, it should be noted that for the payback of a map published using offset printing technology, the publisher shall sell the entire circulation (at least 500-1,000 copies), which is practically unrealistic for non-main waterways. For a basin organization Print on Demand is a way to print a publication at a fixed price per copy regardless of the order size. While the unit price for each physically printed copy is higher than with traditional offset printing methods, for small circulations the average cost per print circulation is lower because the cost of deploying and maintaining the equipment is significantly lower.

Therefore, in the event of significant changes requiring a large amount of corrections, a new map sheet with the corrected data already entered will be printed out to the navigator. This will improve both the quality of the cartographic material and reduce the workload on the navigator, since the introduction of a large amount of corrections seems to be a rather labor-intensive task. The use of PoD technology during the navigation extension period seems to be one of the mandatory decisions.

4.4 Conclusion on the results of development of scientifically based recommendations on information and navigation support for navigators during the navigation extension period

Three main directions for information and navigation support for masters have been formed, which shall be implemented and maintained during the navigation extension period (Figure 4.4).



4.4 The main directions on information and navigation support for navigators during the navigation extension period

The features of the implementation of each direction and its advantages in navigation and information support of navigators are considered.

5. JUSTIFICATION FOR THE SELECTION OF SITES FOR ICE BUOYS TESTS

Testing a river ice buoy on the Neva River within the INFUTURE project

Abstract

The river ice buoy is supposed to be installed on the Koshkinsky fairway of the Neva River, 1,316.6 km, on the right edge of the fairway in the area of buoy No. 54.

Brief description of the area of the proposed installation of the river ice buoy and justification of the location.

The Koshkinsky fairway is one of the most difficult sections for ships to navigate. The fairway leads from the middle of the Petrokrepost Bay of Lake Ladoga to the source of the Neva River in the Shlisselburg harbor. The Koshkinsky fairway is the only fairway serving to enter the Neva River from the lake. The fairway has six bends and is 9 miles long. The shallowest depth in the fairway is 4 m, the fairway width along the bottom is 85 m.

The location was chosen so that the river ice buoy was tested in the most severe conditions on the extremely difficult section of the Koshkinsky fairway for navigation. The distance of 1,316.6 km is perfect for this purpose. This is the fifth reach of the Koshkinsky fairway - the narrowest and shallowest place. The bottom is rocky. The current speed in this area is 6 knots.

The buoyage system of the Koshkinsky fairway is represented by lateral navigation signs according to the system adopted on the inland waterways of the Russian Federation. The left edge of the fairway is fenced with white buoys, the right edge of the fairway is fenced with red buoys.

In ice conditions the buoys are uninstalled and partly replaced by winter ice buoys - cigars. Since the test ice buoy will enclose the right edge of the fairway, it shall be painted red.

The selected installation site is located within the coverage area of a coastal radar station and a video surveillance system, a dispatch control point for ship traffic in Shlisselburg.

Testing a sea ice buoy in Lake Ladoga within the INFUTURE project

Abstract

The sea ice buoy is supposed to be installed in the area of the Sukhskaya bank near Island Sukho in the southwestern part of Lake Ladoga.

Brief description of the area of the proposed installation of the sea ice buoy and justification of the location.

Lake Ladoga is the largest body of water in Europe with depths suitable for navigation. Its length from south to north stretches for 219 km, the maximum width is 125 km. The lake area without islands is 17.9 thousand km². The coastline length is more than 1 thousand km. The average depth of the lake is 50 meters, the maximum depth (in the area of Valaam Island) is 233 meters.

More than 35 rivers flow into Lake Ladoga, the largest of which is the Svir River, and the only flowing river is the Neva River.

On Lake Ladoga, not only the Rules for the Navigation of Vessels on Inland Waterways, but also the Rules for the Movement and Mooring of Vessels in the Volga-Baltic Basin of Inland Waterways, are effected. Vessels shall only move out to Lake Ladoga with the permission of the traffic dispatcher of the Nevsko-Ladozhsky region area of waterways and shipping office, upon the master's report on the readiness of the vessel (convoy) to passage the lake, taking into account the restrictions on the wind-wave regime according to the Register documents.

In Lake Ladoga, vessel traffic separation systems are used and recommended routes are in effect, which lead from the Petrokrepost Bay and Svirskaya Bay to the most significant cities and points located on the shores of Lake Ladoga. Vessels move in accordance with the traffic separation systems and recommended routes both during the day and at night.

To fencing navigational hazards in Lake Ladoga, cardinal signs of the International Association of Lighthouse Authorities (IALA) region A are used.

The navigation of ships along the shore is ensured by the lighthouses and luminous coastal signs. Navigational hazards located near shipping routes are protected by floating navigation aids. Floating navigation aids are deployed to their regular places at the beginning of navigation, as the lake clears from ice, and operate during the navigation period until ice conditions occur. Usually ice appears at the end of the first - beginning of the second decade of November, first in the shallow southern part and then in the deeper northern part of the lake. Usually the breaking up of ice on Lake Ladoga occurs at the end of March in the reverse sequence of freezing. In winter period the buoys are removed and partly replaced by winter ice buoys - cigars.

According to the current governing documents, the exit of vessels to Lake Ladoga is allowed:

- with serviceable navigation aids and radio communication;
- with a complete set of corrected maps and manuals for the navigation area;
- with the crew according to the certificate of minimum manning and crew list;
- with compensated and defined residual deviation of the magnetic compass;

Monitoring and control over the fleet movement on Lake Ladoga is assigned to traffic dispatchers of the Nevsko-Ladozhsky region of waterways and shipping - a branch of the FBI Volgo-Balt Administration.

The location, size and configuration of the lake is due to a complex wave regime. Strong winds, often observed during the navigation period, especially in autumn, cause significant and sometimes even strong waves in places. In the deep-water parts of the lake, which are located in the center and in the north, gently sloping waves with a length of about 25 m and a height of no more than 3.5 m are usually observed. The highest waves are observed here near Island Valaam. Their height reaches 4.5 m, but their repeatability is not great.

In the southeastern part of Lake Ladoga, the frequency of occurrence of waves with a height of more than 0.8 m is 50%. The height of the waves in this part of the lake is higher than in the northwestern one. At strong northerly winds, waves up to 6 m high can be observed here. The waves in the southeastern part of the lake during strong winds are often chaotic and turn into a windlop. In the gulfs and bays of the southern part of the lake, the wave height is significantly lower than in the open part. Individual waves 1.5-2.0 m high can be observed when exposed to strong northerly winds. In the summer and autumn period, windlop is often observed, the intensification of which, as a rule, indicates the beginning of storm winds, from the direction from which the windlop comes.

Sukho Island lies 9 miles north of Voronov Cape. Sukho Island is bordered by a rocky sand bank with a depth of less than 5 meters, protruding from the northern coast of the island by 3 miles, from the southern coast by 1.5 miles, and from the east and west - at a distance of 7 cbl to 1 mile. Behind Sukho Island it is possible to take shelter from the western, northern and eastern winds.

There is a passage between Sukho Island and the Varetskiye banks, the depth of which is 6-9 meters. The Sukho lighthouse is installed on Sukho Island.
Sukhskaya Bank is rocky with a depth of 2.6 meters and is located 3 miles north of Sukho Island.

6. MATHEMATICAL SIMULATION OF SAFE MOVEMENT ONLY USING RADAR AIDS AND ECDIS OF THE ESTIMATED VESSEL ON SECTIONS DIFFICULT FOR NAVIGATION IN TERMS OF EXTENDING NAVIGATION IN THE WATERS OF THE NEVA RIVER USING THE NT PRO NAVIGATION SIMULATOR

6.1. Navigation simulator composition

To assess possible solutions ensuring the required level of navigation safety, the method of mathematical simulation was used using a modern navigation simulator, Navi-Trainer 4000, developed by Transas and installed at the Department of Inland Waterways Navigation. Transas navigation simulators are certified by international classification societies such as the Russian Maritime Register of Shipping, Lloyd's Register, Det Norske Veritas and Germanischer Lloyd. Transas also has a certificate of conformity for the version of the navigation simulator Navi-Trainer Professional (NT Pro) 4000 by the Ministry of Transport of the Russian Federation.

The NTPro 4000 navigation simulator provides the following types of training in accordance with international and national standards:

Organization of navigational watch;

Ship maneuvering and control;

Training in maneuvering and steering of vessels equipped with two full-turn electric steerable thrusters;

Training in the use of navigation bridge resources (BRM);

Radar surveillance and plotting;

Use of Automatic Radar Plotting Aids (ARPA);

Use of radars on inland waterways;

Use of ECDIS;

Use of ECDIS on inland waterways.

The Navi-Trainer Professional 4000 navigation simulator provides an opportunity to practice and evaluate the following skills and abilities:

Passage planning and execution and position determination;

Organization of safety of navigational watch;

Using of radar/ARPA to maintain the navigation safety;

Working with ECDIS;

Ship maneuvering;

Passage planning and execution;

Ensuring the navigation safety using radar, ARPA and other modern navigation aids that ensure decision-making in a dangerous situation;

Maneuvering and control of the vessel in any conditions [11].

Therefore, the simulator includes the whole range of training areas required for a master to navigate a ship along the IWW. This allows to use it for mathematical simulation of the movement of the estimated vessel along the section under consideration.

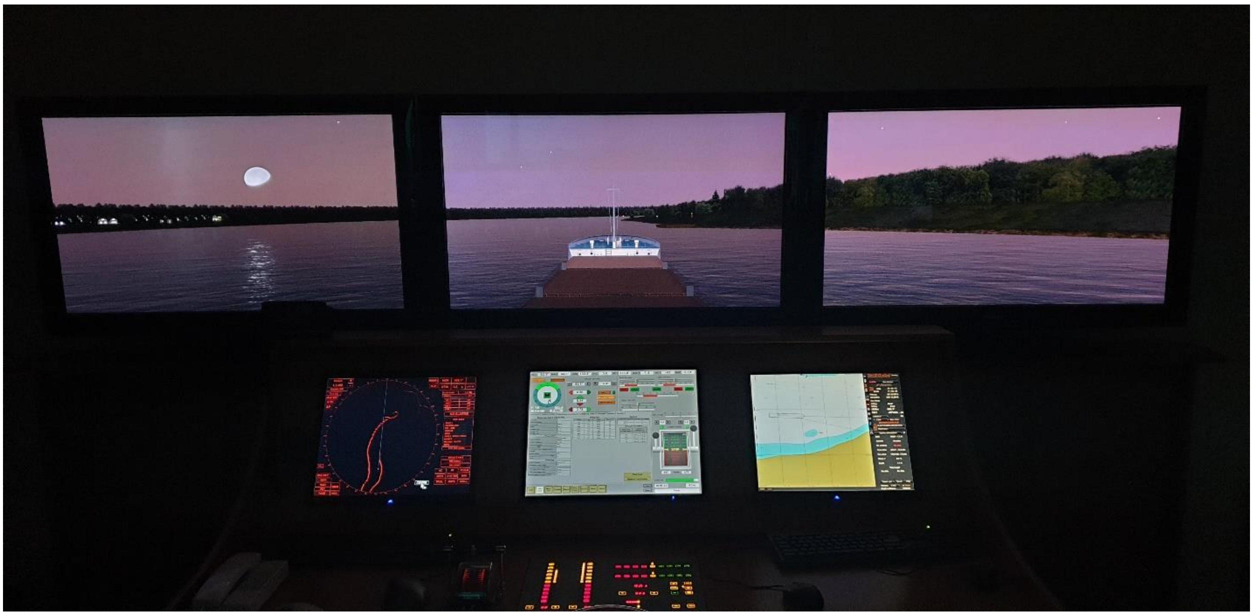


Figure 6.1. General view of the navigation bridge of the Transas NTPro 4000 navigation simulator

The simulator consists of an instructor station and one or several navigation (pilot) bridges and is a modular structure that allows to create a system of any type from a radar/ARPA simulator or electronic mapping to a full-scale integrated navigation bridge simulator.

The Instructor Workstation provides instructors with the tools to effectively development, execute, and analysis exercises.

Figure 6.2. Engine telegraph and control panels of the vessel of the Transas NTPro 4000 navigation simulator

Exercise development is a stepwise process that allows to exclude accidental errors during direct implementation and includes the following steps:

- navigation and hydrographic study of the modeling area;
- selection of the estimated vessel;
- exercise planning;
- preliminary playback of created exercises;
- carrying out exercises.

Navigational and hydrographic study of the modeling area for the purpose and learning of the navigation features of the areas to select the one that is most suitable for modeling the controlled movement of the estimated vessel. For example, for some rivers, the main navigational equipment is linear sections, which lead equidistant from dangerous isobaths enclosing the fairway edges. When navigating a vessel only with the use of radar in such a section, the main radar landmarks will be the shores, which will require the navigator to have good knowledge of special pilotage, in particular, the location of navigational hazards. In the presence of a sufficient number of signs of floating navigation aids, the main landmarks when navigating a vessel using radar will be navigation floating signs, which are displayed to clarify the position of navigational hazards in winding sections, where it is difficult to estimate the position of the fairway along the sections.

Therefore, to carry out mathematical simulation of the controlled movement of the vessel, it is necessary to select such sections, the complexity of which is due to a combination of reasons. Among the main reasons most typical for IWW can be identified as follows: a sharp change in the directions of the navigable pass straight sections, alternation of narrow and wide sections, effect of cross currents, significant current velocities, the currents variability depending on the water level and location.

Due to the special importance of this section for shipping purposes, as well as the complexity and variability of navigation conditions, recommendations were developed for navigators, which shall be guided directly for safety when navigating a vessel.

Selection from the database of a simulator of vessels, the characteristics of which are the same or are sufficiently consistent with the characteristics of vessels operating in the specified area.

To assess the similarity of vessels operated in the area and available in the simulator complex, it is advisable to make a comparison using certain criteria.

In case of main vessel dimensions, speeds and draughts vary significantly, it is not possible to divide all the vessels into groups for different water levels so that the error is within certain fixed limits;

In case of main vessel dimensions, draught and speed differ slightly, then drift angles and maneuvering lane width will be within certain limits, and hence does not matter what criterion to be used to combine groups of vessels.

One of the optimal criterion for combining vessels into groups is the drift angle, because it depends on external factors and on the dimensionless characteristics of the vessel;

However, the navigational safety of a vessel piloting will be determined by the width of the maneuvering lane to a large extent determined by the vessel dimensions and the amount of stores, therefore, the criterion for assessing the ability of the vessel to navigate safely along a particular section of the waterway is the width of the maneuvering lane.

Taking into account that the maneuverability lane will be affected by the vessel maneuverability, master experience of handling a specific vessel, the ability of the master to assess the vessel location and movement using the navigation signs, the maneuverability lane width can be taken as the final criterion to combine vessels into groups.

It should be noted that the estimated vessel does not have to be the largest in its dimensions, since special rules for piloting may apply to such vessels and, accordingly, special restrictions may be introduced. Along with the vessel dimensions the following criteria shall be taken into account: maneuverability, sail area, hazard of transported goods.

Planning exercises and navigation conditions, emergency scenarios, equipment and system failures, etc.

Preliminary playback of created exercises;

Carrying out exercises.

In the process of carrying out mathematical simulation, the simulator complex for maneuvering and control allows real-time control over the progress of the runs of the estimated vessel.

Control of surface and air targets (course, route, speed, lights, signals, malfunctions, etc.)

Tug control (manually or automatically), mooring, towing, working with anchors.

Management of environmental conditions (illumination, visibility, sea waves, wind strength and direction, drift, ice conditions, changes in water level, currents, clouds, etc.)

Introduction of errors and malfunctions into any control and monitoring system of the environment and ship systems.

For the subsequent analysis and analysis of exercises, the training complex includes:

1) Recording, archiving and documenting the exercises performed.

2) Reproduction of any episode of the exercise in time scale at the stations of the exercise analysis, as well as on any navigation bridge. This makes it possible to exclude the influence of systematic errors that can be caused by insufficient viewing angles, equipment ergonomics, various settings of navigation equipment directly on the navigation bridge.

3) The ability to "replay" the situation from any moment in time with the original or changed conditions.

Navigation simulators of the Navi-Trainer Professional (NTPro) series allow for simulator training and certification of watch officers, chief officers, masters working on sea, river and fishing vessels, in accordance with the International Convention on the Training, Certification of Seafarers and Watchkeeping, as amended (STCW) and model courses 7.01, 7.03, 1.22, as well as conduct simulator training for pilots and VTS operators.

Navigation simulators allow teaching skills of working with modern radar/ARPA. In this case, both computer simulators and real radar indicators can be used. Using its own cartographic database, Transas can create radar scenes for any area of waterways, both inland and estuarial areas of large rivers. The simulators use an accurate mathematical model of radar signal propagation, which increases the realism of perception and the effectiveness of visual observation.

A significant advantage of the Navi-Trainer 4000 is the application of the method of mathematical simulation for assessing the navigation safety, which makes it possible to take into account all the components of the navigation system: the navigator, the vessel, the external environment.

The method for assessing the navigation safety in difficult conditions, which allows both to assess the degree of influence of external factors on navigation safety, and to assess the navigator actions, is the method of mathematical simulation of the controlled movement of the vessel.

Among the functional features of the NTPro 4000 simulator, it is necessary to highlight the following:

1) Processing and displaying information from external sensors on one screen;

2) Receiving of information in digital and analog formats;

3) Possibility of developing an individual imaging of information on the display;

4) Extensible database of units of measurement;

5) Built-in recording function.

Displayed information

The standard Navi-Conning 3000 system provides four basic viewing modes:

current vessel coordinates, course, speed;

rudder position, telegraph repeater, etc.;

state of navigation lights;

sounder readings, wind and route data.

6.2. Procedure for carrying out simulated runs of the estimated vessel

Ship maneuvering is the skill most commonly used by masters when navigating along inland waterways or when moving at relatively low speeds. On the high seas or at full speed, the vessel is usually steered by an autopilot, while in the port waters or in narrow areas, the vessel is manually controlled.

In such a navigation area, the depths are usually limited, the traffic density is higher, in addition, among other things, the presence of banks, shoals, artificial hazards to navigation, as well as anchored vessels should be expected. Under these conditions, the vessel will be forced to maneuver, slow down, stop, turn around and moor using own resources or with the help of tugs.

The movement of a maneuvering vessel was simulated on the basis of a mathematical model of movement, which, being installed on a computer, reproduced the behavior of the vessel during maneuvering as accurately as possible. When assessing the possibilities of applying a specific mathematical model, the main attention was focused on its adequacy and practical application of the model for computational work. Justification of the selected mathematical model was carried out in the first part of the research report "Feasibility study of the possibilities of extending navigation on the routes of inland waterways and canals".

In order for the models to be used for assessing the navigation safety in confined navigation conditions, they shall provide simulation of all modes of the vessel movement and maneuvering at low speeds. Simulation of the vessel movement at full speed is less important. The model shall simulate a complete stop of the vessel, lateral movement, and forward and astern movement, and also take into account the following:

- shallow water effect (and, accordingly, the changing parameters of the vessel maneuvering due to changes in depth),
- hydrodynamic interaction between vessels (with vessels under way and stopped vessels),
- canal effect,
- propeller type, - fixed or adjustable pitch of the propeller,
- influence of tugs thrust,
- impact of external factors: wind, waves and currents,
- influence of thrusters and other means for the vessel maneuvering.

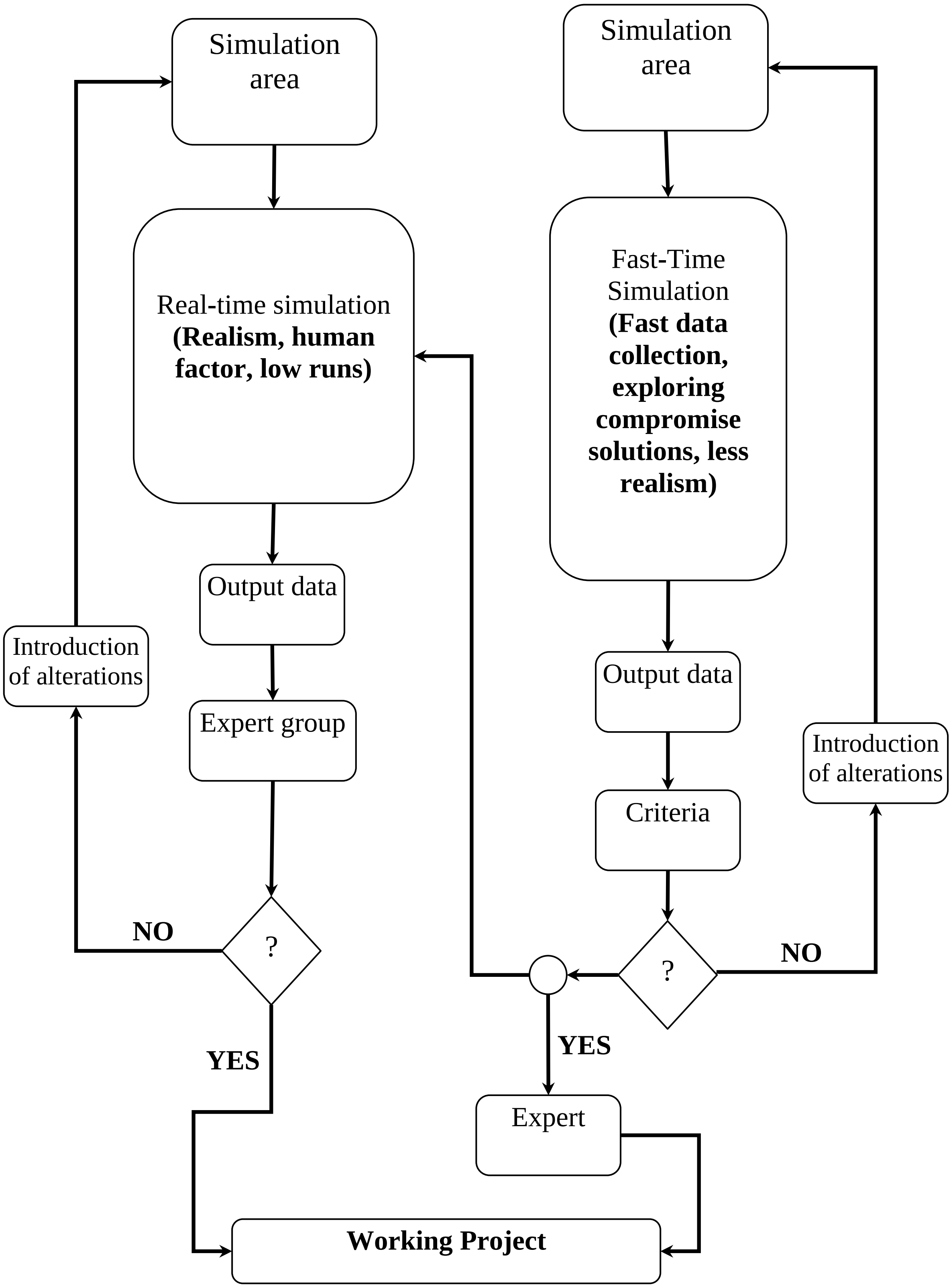


Figure 6.3. Schematic representation of real-time and fast-time simulation

In addition, it is necessary to ensure the ability of a human operator (developer and navigator) to intervene in the simulation process, as well as to completely control the model movement.

Mathematical simulation of the controlled movement of the vessel can be carried out by the following methods:

– real-time simulation method;
– fast- time scale modeling (Figure 6.3).

Real-time simulation

Real-time simulations typically use full-scale simulators (i.e. simulators with full-scale equipment and visualization). Navigators act both as participants in simulator training and as consultants.

The parameters of the investigated section of the waterway are entered into the simulator model, and the navigators guide the vessel along this section. Guided by their experience of working in real conditions and knowing the peculiarities of the vessel control in the appropriate conditions, navigators give their commentary on the specifics of a vessel maneuvering in relation to specific circumstances and navigation conditions.

This procedure usually consists of the following main steps:

- initial familiarization with the training equipment;
- simulation of maneuvers by one or several navigators on models of vessels of assumed types (or on models of similar types);
- detalization and analysis of the results of simulated maneuvers after each run;
- observation and registration of the key parameters of the movement of vessels and the state of external objects of the model.

Initial familiarization with the training equipment

Some masters may not be familiar with the functionality of real-time simulators. In such cases, it will take some time for familiarization and getting used to.

Trial, introductory simulations can be performed both in the modeled section of the researched waterway, and in a special "model water area". Allow at least a day for the familiarization period, as it will take time to answer questions and overcome the natural distrust of the simulator as a whole.

Familiarization will also be required for the expert group, if they are pilots, in order to study in detail the navigation area of interest. In the event that researchers are considering a new section of the waterway or new schemes for installing navigation equipment that were not previously used, then experts will need time to collect and familiarize themselves with new information and data, such as, for example, the features of the effect of wind and current on the vessel.

During the familiarization period, no simulation of situations was carried out in order to fix values or take readings, which can then be used when making certain decisions. Such simulations were carried out only from the moment when all participating masters were fully familiar with the simulator and the model.

After all the navigators were familiar with the simulator, a transition was made to the specific maneuvers and guidance of the vessel through the considered water area. Often, navigators were enthusiastic about the tasks of playing maneuvers and this enthusiasm was correctly used by the project manager. The work adhered to the agreed and specified plan of action, but not excluding a flexible approach in the event that the conditions for the estimated vessel runs change during exercises. Special attention is paid to ensure that only one parameter is changed at a time.

During each run, the work of the navigators was supervised by the project manager (responsible executor) on the bridge, and the corresponding registration of events was also kept. In addition, the project manager clearly understood that replaying the piloting in the simulator in difficult navigational conditions of inland waterways can be a tedious task for navigators. In reality, the master, as a rule, conducts vessel maneuvering in the same section once a day or less often. In the simulator he can repeat this piloting every hour. If at the end of the day errors caused by fatigue appeared, then the work on the simulator was suspended, or an additional number of navigators were added to the group. Naturally if studies on the effect of master fatigue are being carried out, then the above does not matter.

The analysis of each stage of the maneuvers was thorough. Peer groups of navigators were formed. All team members took part in the discussions after the planned amount of modeling, in order to obtain a more objective assessment of the situation and develop an optimal solution. Successful planning of each subsequent run depends largely on the thoroughness with which the previous run was analyzed. Errors arising during the run were analyzed and sorted out, trying to find the cause. These errors were eliminated on subsequent runs.

After each run, the trajectories of the model vessels, event log, as well as all corresponding maps, navigational study of the area, etc. were recorded.

During the run, key parameters of movement were recorded and an event log was kept. Registration, as a rule, was performed automatically in the simulator. The obtained parameters were used later to analyze the situation. The event log is also an important element of registration, since it was used to identify manifestations of increased stress, fatigue or other factors of the human condition experienced by navigators during the training of maneuvers on the simulator and which may be directly related to navigational-hydrographic or hydrometeorological conditions when carrying out a separate run. If these factors lead to errors in vessel control, then it may be necessary to make changes in the process of conducting model runs and to accept certain restrictions on the piloting of vessels.

The checklist for the tasks performed on the real-time navigation simulators used in this study is presented in Table 6.1.

Table 6.1

The checklist for the tasks performed on navigation simulators

Verification criteria		Tested
1. Design speed	- Too high?	
	- Is it safe?	
	- Too slow?	
2. Rudder displacement	- Mean value	
	- Maximum value	

	- Displacement frequency	
3. ME maneuvers	- Frequency of starts	
	- Number of starts	
4. Evaluation of the vessel movement along a given trajectory and positioning	(a) did you manage to keep the vessel on the specified trajectory (following your side of the fairway in two-way traffic)?	
	- easy?	
	- experiencing some difficulties?	
	- very hard?	
	(b) Were you able to determine the vessel position relative to geographic objects, as well as relative to other vessels in the traffic?	
	(1) in the daytime	
	(2) at night	
	(3) in poor visibility conditions	
	- easy and fast?	
	- with some difficulty?	
	- with significant difficulties?	
5. Fairway curvature radius	- Appropriate?	
	- Too sharp?	
	- Too stretched?	
6. Navigation Aids	- location of buoys and distance between them?	
	- characteristics of lights and color of NA?	
	- range lines?	
7. Stopping and turning	- Is there enough space to perform these maneuvers?	
	- how many tugs are required and what size/power?	
	- ME operation and maneuvers?	
	- influence of the worst wave and current conditions?	
8. Emergency termination of the maneuver	- position of the point of the last moment when it is possible to safely stop the maneuver?	
	- position of the point of no return?	
	- presence of an area where the vessel should go in case of the maneuver termination?	
9. Visibility	- minimum, to maintain a given speed of the vessel?	
	- visibility restrictions for turning the vessel?	
	- view from the bridge?	
10. Is it safe to control the vessel?	- was there a “ship feeling” during the run?	
	- if not, why not?	
	- did you feel that the area is safe for piloting?	
	- if not, why not?	

The operating parameters that can be checked and compared against various criteria after the runs are usually the following:

- Rudder displacements, including the mean rudder displacement angle, rudder standard deviation, maximum rudder displacement angle, number of rudder transitions through the CL.

- The value of transverse vessel displacement from the trajectory along the course line.

- Changes in movement speed.

- Course changes.

- Changing the angular speed of the vessel.

The process of data analysis and reruns on the simulator is repeated until enough data is obtained to make a reasonable assessment of the navigation safety for the area on which they have to navigate the ships. They shall feel that the required level of traffic safety will be provided when the estimated vessel is piloted.

In the course of work on the simulator, the adequacy of the fairway width (along its entire length) was determined both by the navigators and the expert group, and based on the results of the runs, certain restrictions can be adopted, for example, in regard to hydrometeorological regime. By using this parameter adjustment method, masters are considered as experts.

The location and types of navigation aids was also the subject of a separate study, in the process of simulation of maneuvers. The visualized area can be quickly and easily switched, thus showing different lights and navigation signs. At the same time, the characteristics of all navigation aids corresponded to GOST 26600-98.

Restrictions on wind, current and level fluctuations may be imposed to ensure navigation safety. The value of the restriction is determined by expert judgment - the master indicates the places within the considered area, where, in his opinion, he loses the ability to control the vessel. These values shall also be selected taking into account commercial and other factors affecting shipping. If the these values are unacceptable, restrictions shall be introduced. These restrictions can also be used to include in the "Peculiarities of movement and anchorage of vessels on inland waterways" for the corresponding basin.

For some ports, it is necessary to define a vessel “maneuver/movement stop point”. After passing this point, the vessel will inevitably fall in conditions in which it will not be able to turn back if it becomes impossible to continue moving.

The case of movement in conditions of limited visibility requires a separate study. In low visibility conditions, as a rule, radar is used, and therefore the channel configuration shall be planned with the use of radar navigation aids.

Fast-time scale modeling

The fast-time scale modeling allows to perform a large number of runs in a short period of time, and this property is its main advantage as a design tool.

This method does not exclude the involvement of an expert group. However, the differences between real-time simulations and fast-time scale simulations are so considerable that expert recommendations cannot always be made. A common practice in such a situation is the joint application of professional knowledge and some experimental criteria to decide whether the canal design meets the required parameters and whether the navigation safety is ensured. These criteria can also be used in real-time simulations, as described above, but in this case there is a possibility that the studies will take a very long period of time.

There are several ways of fast-time scale modeling:

– multiple runs
– single runs
– human control
– vessel control with piloting
– control on the plan or visualization from the navigating bridge.

The multiple runs method is usually combined with the method of vessel control with piloting and involves performing a specified number of predetermined maneuvers and analyzing the results of those runs. The control with piloting model is essentially a human-controlled automated model, into which perceptual delay, random error in heading perception, lateral displacement, etc. are introduced.

Such a probabilistic approach to assessing the navigation safety makes it possible to determine the correspondence between the width of the fairway and curved sections based on the dispersion of trajectories of the models after multiple runs. At the same time, the probability is calculated that under the influence of control and external disturbances, such as wind, waves and current, the vessel will move beyond the fairway boundary (and, accordingly, get on the ground). The resulting probability can then be compared with the acceptable level of risk of a vessel aground.

A series of ship trajectories can also be used to determine the optimal curvature and width of the fairway.

Single runs performed in wind, wave and current conditions can be used to determine the suitability of the fairway dimensions based on previous experience and provide a result for the development of vessel steering criteria. These criteria can be obtain from the rudder actions, as in the case of real-time simulations, and then compared against the same obtained criteria.

The steering criterion is not an effective indicator that the fairway dimensions are sufficient, partly due to the very issue of steering and how the rudder is used to achieve certain steering goals, and partly due to the characteristics of the navigator and his personal habits in steering the ship. Therefore, this criterion shall be applied with caution.

The fast-time scale modeling allows also to determine wind, wave and current limits. These values strongly depend on the subjective assessment of the master, who shall determine for himself at what point in time he will lose or have already lost control of the vessel. Sometimes the loss of control is obvious, but in some cases it is very difficult to understand where the poor control still remains, and where the control of the vessel has already been lost and if in doubt, repeated runs shall be carried out.

Most simulators operating on an fast-time scale allow to observe the area of interest on a map scale, while others generate a visualization of the navigation area from the navigation bridge. An adequate computer image visualizing the navigation area can take too long, slowing down the modeling process and, as a consequence, depriving the fast-time scale modeling method of its main advantage. The use of visualization with the night time imitation and, accordingly, only visible navigation lights, to some extent, solves the problem. Most of the runs are performed using a plan of the area, some of the maneuvers require visualization with perspective, since the perception of the channel only with visible navigation aids differs significantly from its perception in the plan view, and this discrepancy can affect the vessel control.

The fast-time scale modeling shall be accompanied by human judgment and experience. A person perceives the fast-time and real-time modes differently, especially when the movement in real time is too slow (for example, the start of a tanker turn). The right and correct perception of such movement is one of the problems in ship handling.

All fast-time modeling activities shall be supported by real-time simulations, or the fast-time simulations shall be thoroughly reviewed by navigators with recent practical experience in the specified area or vessels.

6.3. Familiarization with the estimated vessel

Estimated vessel - a vessel accepted as a reference vessel for mathematical modeling in order to assess the navigation safety.

The choice of the estimated vessel was based on:

- the estimated cargo turnover;
- the analysis of current and future routes of ships;
- the analysis of the conditions of a particular port (natural conditions, limited size of the water area and territory, etc.).

At the same time the analysis of the current and predicted traffic was carried out.

The estimated vessel is not limiting in terms of its dimensions, since special rules of piloting may apply to such vessels and, accordingly, special restrictions may be introduced.

Along with the vessel dimensions the following criteria were taken into account:

- maneuverability;
- sail area;
- hazard of the transported goods.

Taking into account the maneuvering characteristics when solving problems of ship control is a prerequisite for ensuring navigation safety. The vessel maneuverability shall be taken into account when solving practically all vessel control tasks, in particular:

- when calculating the collision avoidance maneuver in case of passing of vessels;
- when carrying out mooring operations;
- when navigating and maneuvering in narrow areas and in confined waters;
- when anchoring the vessel and mooring buoys.

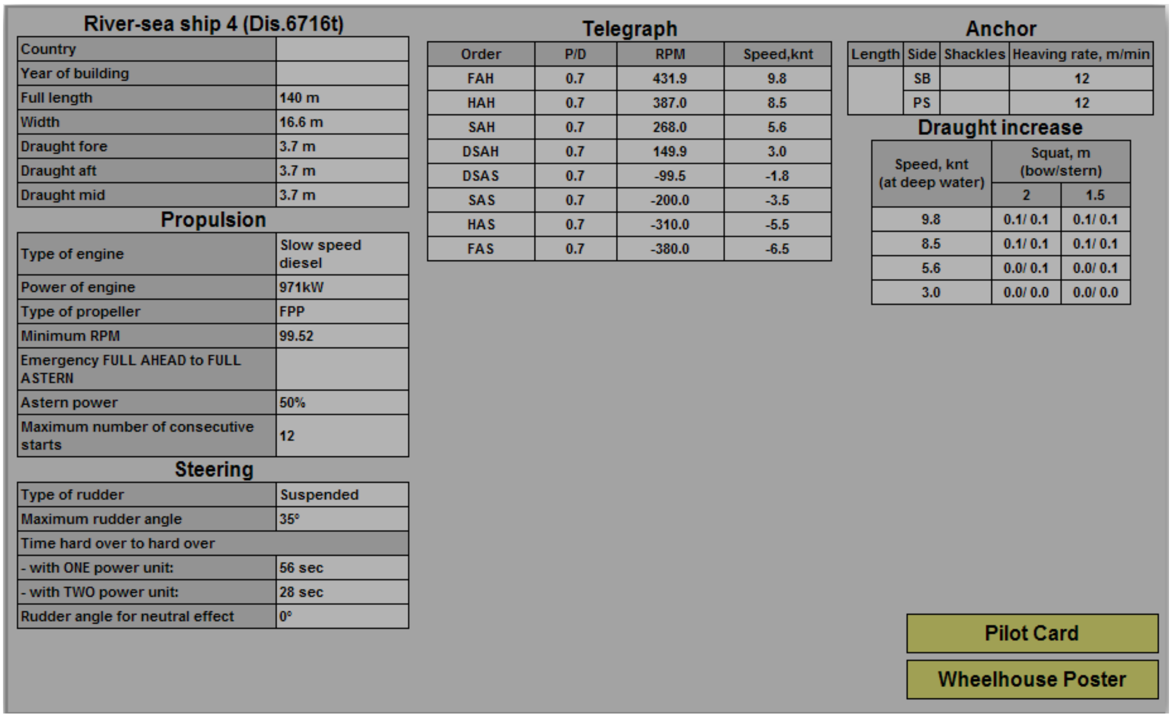
The main maneuvering characteristics of the vessel include:

- controllability characteristics;
- components of turning;
- way and time of vessel stopping.

These characteristics are determined based on the results of full-scale maneuvering tests of the vessel after its construction (acceptance tests) and in accordance with Resolution A.601(15) "Provision and display of maneuvering information on board ships" are drawn up in the maneuvering characteristics table located on the navigating bridge for two loading states: fully-loaded and in ballast.

The maneuvering characteristics table includes:

- the expected trajectory of the center of gravity circulation, as well as the trajectory of all other points of the vessel relative to the same center;
- these trajectories shall be in a rectangular coordinate system with the starting point of the rudder displacement;
- time and speed when changing course by 90, 180 and 270 degrees from the original course.



River-sea ship 4 (Dis.6716t)

Country	
Year of building	
Full length	140 m
Width	16.6 m
Draught fore	3.7 m
Draught aft	3.7 m
Draught mid	3.7 m

Propulsion

Type of engine	Slow speed diesel
Power of engine	971kW
Type of propeller	FPP
Minimum RPM	99.52
Emergency FULL AHEAD to FULL ASTERN	
Astern power	50%
Maximum number of consecutive starts	12

Steering

Type of rudder	Suspended
Maximum rudder angle	35°
Time hard over to hard over	
- with ONE power unit:	56 sec
- with TWO power unit:	28 sec
Rudder angle for neutral effect	0°

Telegraph

Order	P/D	RPM	Speed,knt
FAH	0.7	431.9	9.8
HAH	0.7	387.0	8.5
SAH	0.7	268.0	5.6
DSAH	0.7	149.9	3.0
DSAS	0.7	-99.5	-1.8
SAS	0.7	-200.0	-3.5
HAS	0.7	-310.0	-5.5
FAS	0.7	-380.0	-6.5

Anchor

Length	Side	Shackles	Heaving rate, m/min
	SB		12
	PS		12

Draught increase

Speed, knt (at deep water)	Squat, m (bow/stern)	
	2	1.5
9.8	0.1/ 0.1	0.1/ 0.1
8.5	0.1/ 0.1	0.1/ 0.1
5.6	0.0/ 0.1	0.0/ 0.1
3.0	0.0/ 0.0	0.0/ 0.0

Figure 6.4. An example of the presentation of estimated vessel data in the navigation simulator Transas NTPro 4000

For urgent stoppages, the following information is required:

- trajectory of deviation during stop maneuvers with the help of full reverse;

- diagram of stopping characteristics, including stopping distance, speed and time to stop corresponding to the speeds of the Forward Slow (FS), Forward Half (PS), Forward Full Maneuvering (FFM) and Forward Full (FF) speeds;

- Reverse Full speed (RF) maneuver from the rest state relative to the water shall be presented.

All information is provided for the full-loaded vessel.

If the following information is available, it is also included in the vessel maneuverability table:

- components of turning in ballast in deep water;

- components of turning of full-loaded vessel in low water for the ratio H/T1.2 and 1.5 under-keel clearance.

A sample maneuvering characteristics table is shown in Figure 6.4.

Deep water | Shallow water

9.8 knt | 8.5 knt | 5.6 knt | 3.0 knt

Heading	Time			
	-35	-15	+15	+35
10	00:40	00:55	00:55	00:40
20	00:56	01:20	01:20	00:56
30	01:10	01:42	01:42	01:10
40	01:24	02:02	02:02	01:24
50	01:37	02:21	02:21	01:37
60	01:50	02:41	02:41	01:50
70	02:04	03:00	03:00	02:04
80	02:17	03:19	03:19	02:17
90	02:31	03:38	03:38	02:31
120	03:13	04:36	04:36	03:13
150	03:57	05:34	05:34	03:57
180	04:41	06:33	06:33	04:41
270	06:54	09:31	09:31	06:54
0	09:08	12:29	12:29	09:08

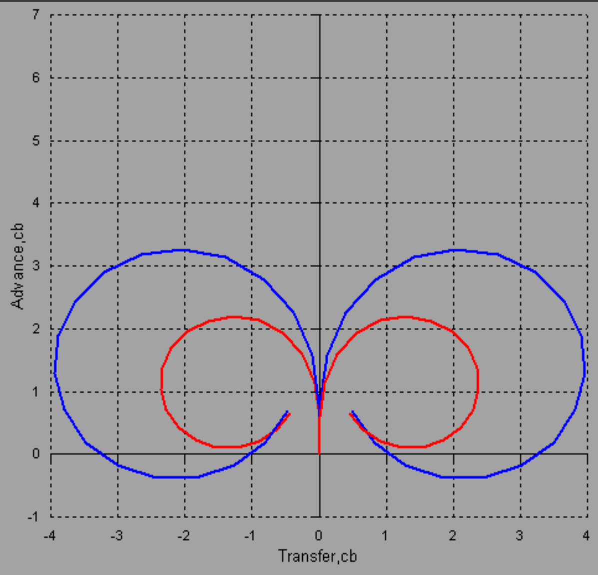
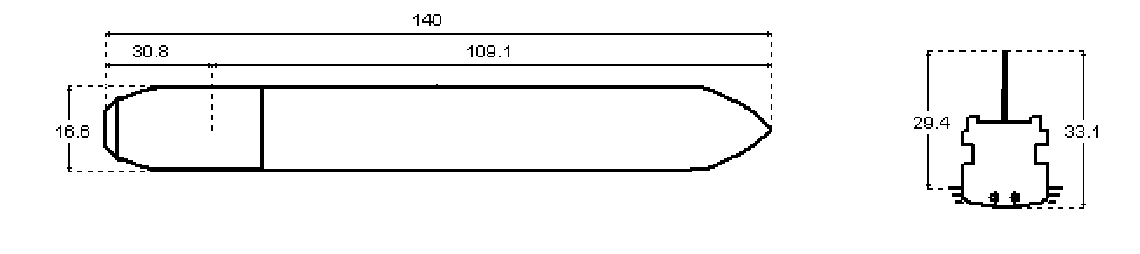


Figure 6.5. The controllability of the estimated vessel in the navigation simulator Transas NTPro 4000

PILOT CARD					
Ship name	River-sea ship 4 (Dis.6716t) v19			Date	18.2.2014
IMO Number		Call Sign		Year built	
Load Condition	Full load				
Displacement	6716 tones		Draft forward	3.7 m / 12 ft 2 in	
Deadweight	N/A tonnes		Draft forward extreme	3.7 m / 12 ft 2 in	
Capacity	N/A		Draft after	3.7 m / 12 ft 2 in	
Air draft	25.72 m / 84 ft 7 in		Draft after extreme	3.7 m / 12 ft 2 in	

Ship's Particulars			
Length overall	140 m	Type of bow	-
Breadth	16.6 m	Type of stern	-
Anchor Chain(Port)	14 shackles		
Anchor Chain(Starboard)	14 shackles		
Anchor Chain(Stern)	14 shackles	(1 shackle =27.5 m / 15 fathoms)	



Steering characteristics			
Rudder(s) (type/No.)	Suspended / 2	Number of bow thrusters	1
Maximum angle	35	Power	135 kW
Rudder angle for neutral effect	0 degrees	Number of stern thrusters	N/A
Hard over to over(2 pumps)	28 seconds	Power	N/A

Stopping			Turning circle	
Description	Full Time	Head reach	Ordered Engine: 100%, Ordered rudder: 35 degrees	
FAH to FAS	365.5 s	4.03 cbls	Advance	1.8 cbls
HAH to HAS	401.5 s	3.87 cbls	Transfer	0.83 cbls
SAH to SAS	582 s	3.67 cbls	Tactical diameter	1.91 cbls

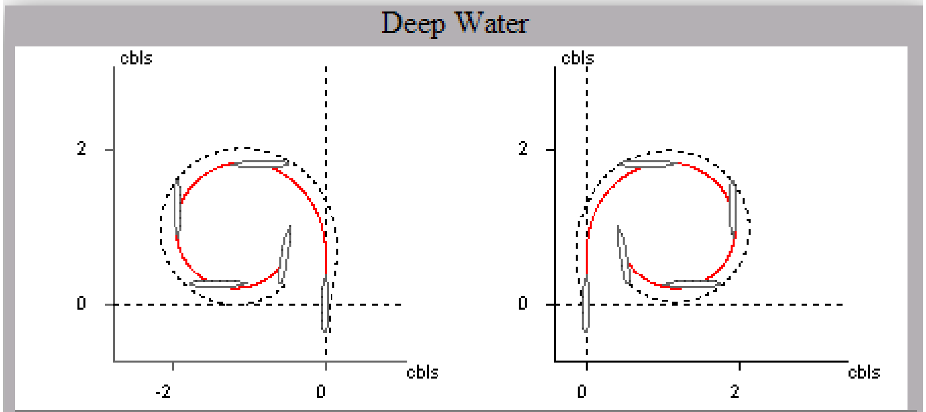
Main Engine(s)			
Type of Main Engine	Slow speed diesel	Number of propellers	2
Number of Main Engine(s)	2	Propeller rotation	Outward
Maximum power per shaft	2 x 971 kW	Propeller type	FPP
Astern power	50 % ahead	Min. RPM	99.52
Time limit astern	N/A	Full Ahead to Full Astern	20 seconds

Figure 6.6. The design vessel characteristics

Information on turning ability is given in the form of a graph and a table. The turning graph reflects the vessel position through 30° on the trajectory to the right and to the left with the rudder positions "hard rudder" and "half rudder". Similar information is presented in tabular form, but for every 10° change in the initial course in the range of 0-90°, for every 30° - in the range of 90-180°, for every 90° - in the range 180-360°. At the bottom of the table data on the largest turning diameter is placed.

Also in accordance with Resolution A.601(15) "Provision and display of maneuvering information on board ships" another way to provide maneuvering characteristics is a pilot card. It is filled out in by the master at the time of the pilot boarding in order to provide all the necessary information. The pilot card corresponds to the actual load, current maneuvering characteristics, any restrictions imposed by navigation conditions, as well as other necessary data.

A sample pilot card is shown in Figure 6.6.

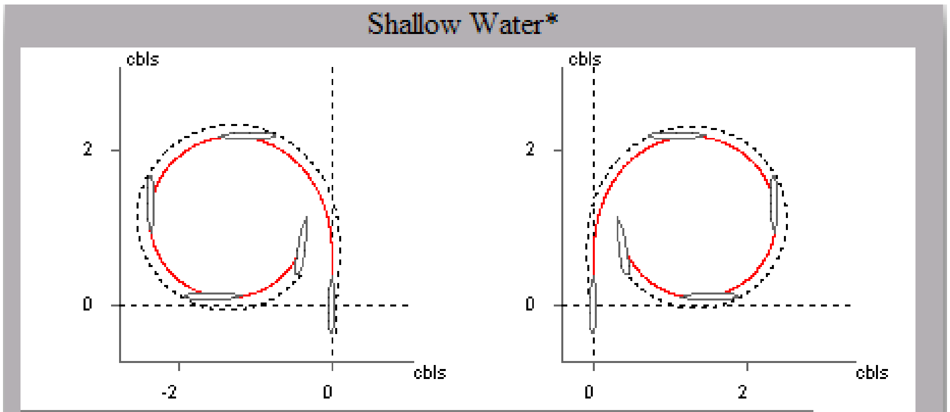


Eng.	Rudd.	Advance	Transfer	Tact. D	Final RoT	Final speed	Final time
100	35	1.8 cbls	0.83 cbls	1.91 cbls	53 deg/min	4 knots	384.5 s
100	-35	1.8 cbls	-0.83 cbls	-1.91 cbls	-53 deg/min	4 knots	384.5 s

Figure 6.7. The controllability of the estimated vessel in deep water

During the vessel operation under various external conditions, hull state and loading, the actual characteristics will differ from the construction ones. To clarify the maneuvering characteristics, it is advisable to periodically conduct sea trials by the crew. Current commercial vessel management methods do not always provide up-to-date data from crew tests. In this case methods of obtaining characteristics by the calculation method remain.

Along with the data of full-scale tests, the form of maneuvering characteristics shall also contain the calculated values of the components for various options for non-standard ship loading. The existing analytical methods for calculating the turning components for various loading options and rudder displacement angles have very low accuracy and are practically not used. Therefore, calculation methods are mainly used to obtain the characteristics of active and passive stopping. In this case, time and stopping distance are considered as the main characteristics.



Eng.	Rudd.	Advance	Transfer	Tact. D	Final RoT	Final speed	Final time
100	35	2.17 cbls	1.11 cbls	2.36 cbls	40 deg/min	4 knots	534 s
100	-35	2.17 cbls	-1.11 cbls	-2.36 cbls	-40 deg/min	4 knots	534 s

Figure 6.8. The controllability of the estimated vessel in shallow water

Maneuvering characteristics table. The maneuvering characteristics table shall contain the main features and details of the maneuvering characteristics of the vessel. It shall be in the wheelhouse at all times and shall be convenient to use. The maneuvering characteristics of the vessel may differ from those given in the table depending on external conditions, hull condition and vessel load.

The following data shall be included in the wheelhouse maneuvering characteristics table.

1. The vessel name, call signs, gross and net tonnage, displacement, deadweight, coefficient of fullness of displacement at full load draft according to summer load line.

2. Draft values at which information about maneuvering components was obtained.

3. Characteristics of steering arrangement.

4. Characteristics of anchor chain.

5. Characteristics of propulsion machinery.

6 Effect of the bow thruster under test conditions.

7. Increase in draft (loaded) due to squat and roll influence.

8. Turning at the maximum rudder angle (loaded and in ballast).

9. Stopping characteristics and maneuvers in an emergency (loaded and in ballast).

10. Maneuvering while rescuing a man overboard. Sequence of actions and recommended turning motion.

11. Dead zones.

12. Shadow sectors.

13. Vessel height (loaded and in ballast).

The inertial characteristics are presented in the form of line graphs built on a constant scale of distances and having a scale of time and speed values. The stopping distance from the forward speed to “Stop” is limited by the moment of the vessel control loss or the final speed equal to 20% of the initial one.

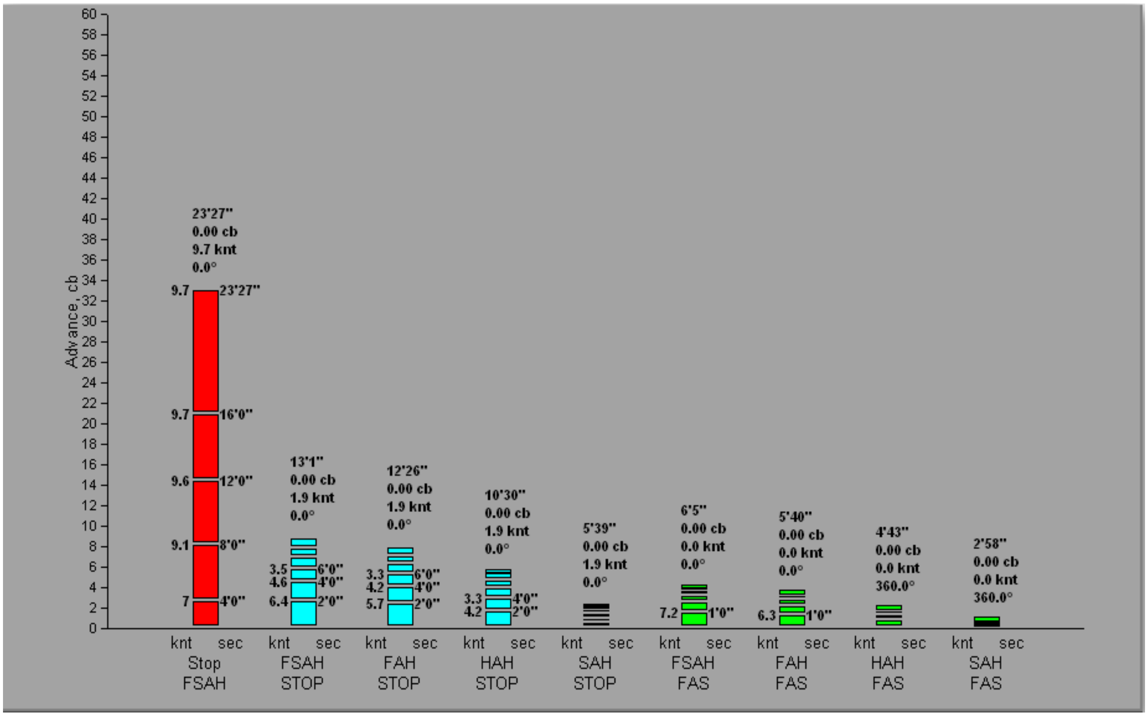


Figure 6.9. The controllability of the estimated vessel in the navigation simulator Transas NTPro 4000

On the graphs the most probable side of the vessel deviation from the initial path during the speed decrease is shown with an arrow.

The propulsion components are reflected in the form of a graphical dependence of the vessel speed on the propeller rotation frequency and supplemented with a table, where the propeller rotation frequency is indicated for each constant speed value.

6.4. Assessment of the influence of external factors on the mathematical model of the estimated vessel

Before carrying out the runs of the estimated vessel along the section under consideration, a navigation study of the route was carried out, with the help of which the expert group assessed the capabilities of control and monitoring of the position and movement of the vessel when using the radar, possible difficulties in controlling the movement of the vessel caused by the influence of hydrometeorological factors, navigation features of the water area.

Along the IWW, the vessel is controlled in such a way that the navigator knows the vessel position in the coordinate system at every moment of time, i.e. lateral deviation from the axis of the fairway and the distance to the turning point. It should be said that these two parameters will influence each other.

This means that in case of an excessively large deviation along the perpendicular to the fairway axis in the direction opposite to the turn, the turn shall be started in advance, since a delay in the turn beginning will also lead to a deviation to the undesirable side. When the vessel deviates in the turn direction along the perpendicular to the path line, it is necessary to start the turn with caution, avoiding excessive angular velocities in the turning direction, as this may cause further approach the vessel with navigational hazards. Then, as the vessel approaches the fairway axis, the angular velocity shall be increased in order to avoid the vessel deviation in the direction opposite to the fairway axis.

A feature of the considered water area is a complex combination of the combined influence of both hydrometeorological and navigational factors.

To confirm the conclusions made by the expert group, it is necessary to analyze the influence of hydrometeorological factors.

The main hydrometeorological factors that will affect the vessel will be wind, current and shallow water.

Forces from wind and current are usually interrelated as factors that the navigator cannot control. However, these two forces have a different effect on the vessel due to the difference in their nature. When the vessel is influenced only by the wind and moves relative to the water, its hull encounters underwater resistance, therewith a pair of forces arises, causing a moment that tends to turn the vessel forward to or down the wind. On the other hand, if the vessel movement is caused by the current, its surface practically does not experience air resistance. However, in the IWW conditions the current acts constantly and, therefore, has a much greater influence than the wind, especially on loaded vessels.

In the practice of maneuvering with the simultaneous effect of wind and current, masters use the principle of keeping the vessel on the line of the resultant external forces, or with a slight deviation towards the desired displacement.

With insignificant external influences, to assess and predict the vessel behavior, there is no need to accurately determine the points of application of aerodynamic and hydrodynamic forces, as well as their moments. The determination of the resultant force is made by the navigator visually and very approximately.

In the process of following sections difficult for navigation, navigators often have to reduce the vessel speed to ensure the required underkeel clearance. When traveling at a reduced speed, the degree of influence of external factors increases. The success of maneuvering in such circumstances depends, as a rule, on the navigator professional skills acquired in practice.

To assess the influence of hydrometeorological factors limiting the pilotage of vessels by virtue of the advantages mentioned, the vessel was controlled manually.

For this purpose, a method was used that involves the following actions:

1) Carrying out simulation of the vessel movement up and down one of the reaches of the considered area when exposed to wind of different directions, but with the same force;

2) Obtaining the dependences of operating parameters on time (in this case, such parameters as the rudder angle, the angular velocity of the vessel, the drift angle) are of interest;

3) The results were analyzed.

For the runs, a straight section was chosen, along which the Lobanovsky range leads. This is due to the fact that in one (upper) part of this rectilinear section, the current prevails, which coincides with the direction of the fairway axis. In this section, it is convenient to evaluate the vessel behavior in the wind, since it has a large length and sufficient width. The other (lower) part of this section is characterized by the presence of a significant cross current directed towards the right edge. In this section, it is convenient to assess the nature and degree of the current influence. A fragment of the navigation map of this area is shown in Figure 6.10.

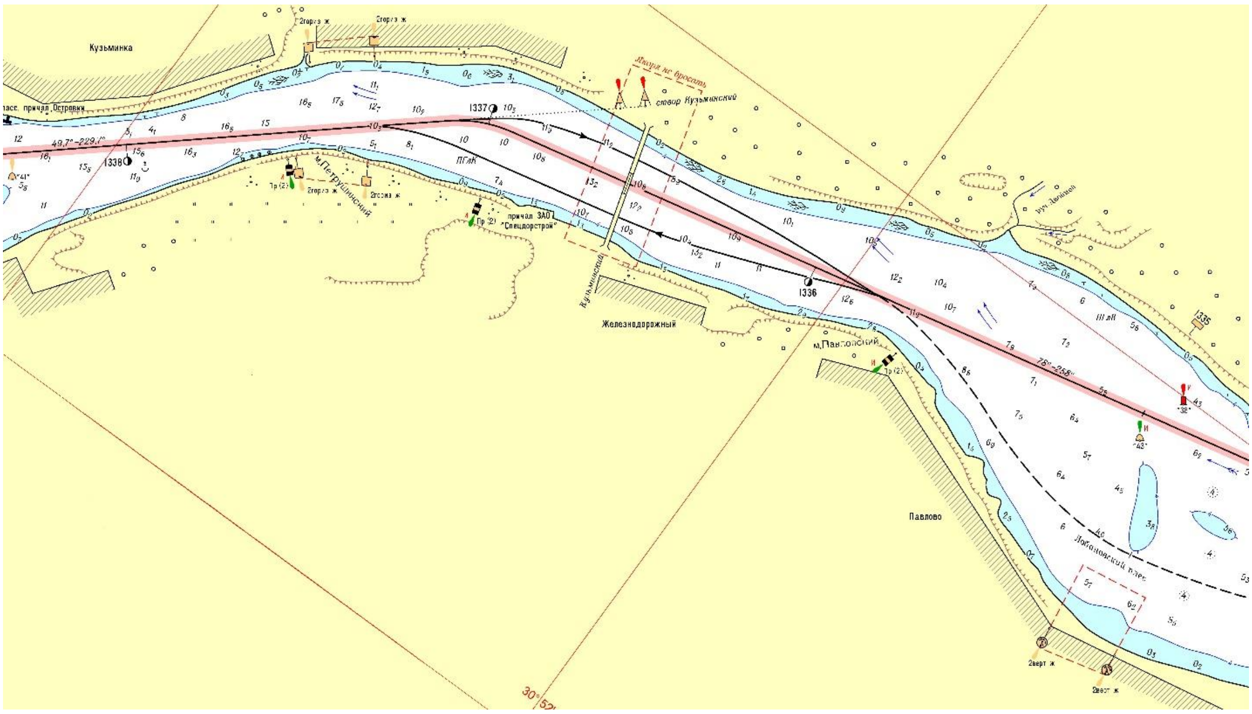


Figure 6.10. A fragment of the navigation map of the straight section Ivanovskye porogy rapids, indicated by the Lobanovsky range

Figure 6.11 shows the variability of the drift angle as a function of time. It is shown that when moving along the section where there is no cross current, the drift angle will be positive. As soon as drift is felt, the drift angle will change its sign, but despite this, the vessel deviates from the fairway.

Thus, after analyzing the change in the dependence of the drift angle as a function of time, certain conclusions can be drawn:

the value of lateral displacement of the vessel along the perpendicular to the fairway axis depends not only on the current speed, but also, to a large extent, on the gradient of the current speed in the direction of the vessel path line;

the vessel displacement along the perpendicular to the fairway axis will not be significant if the course change for its warning is carried out in a timely manner;

when approaching areas where significant currents are expected that do not coincide with the fairway axis direction, it is necessary to keep the vessel with a certain margin in a safe direction.

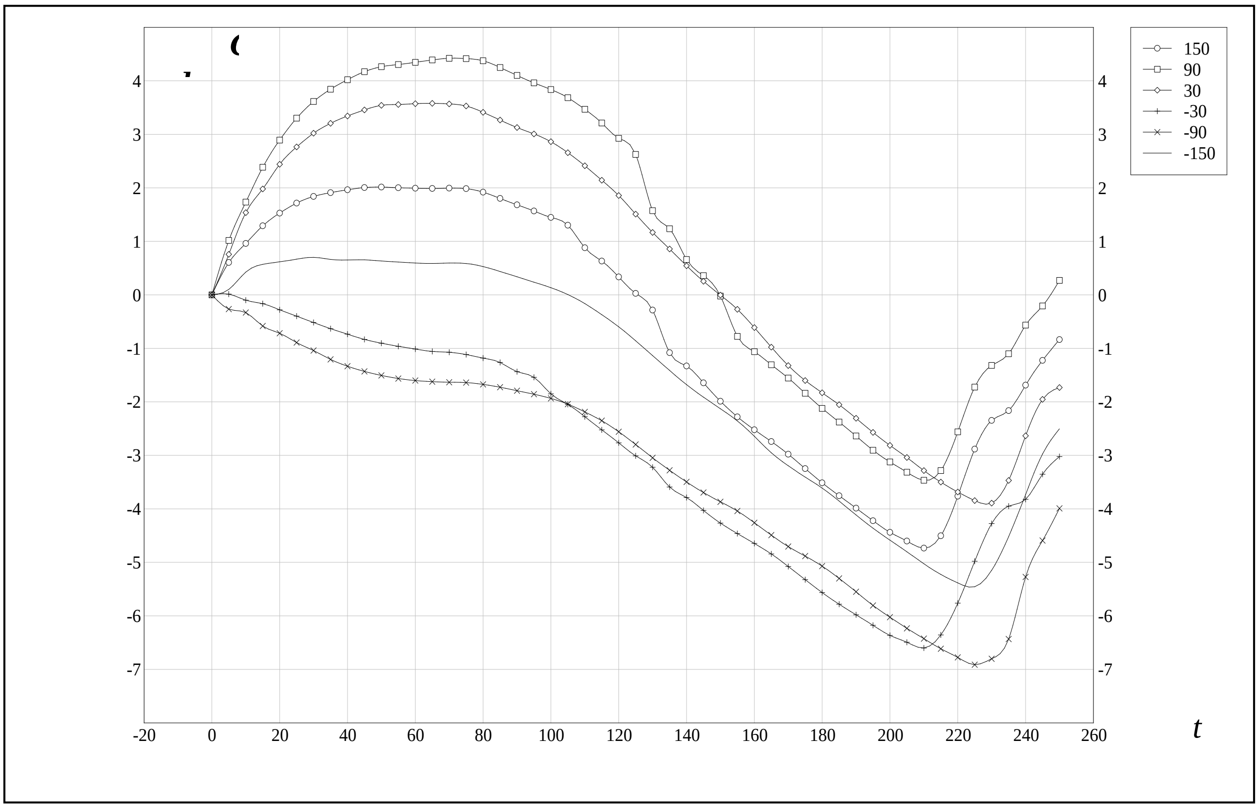


Figure 6.11. Dependence of the drift angle vs the wind and current C vs time t when moving downstream

Below are dependences of drift angle, rudder angle, angular speed of the vessel vs time for the course angles of the true wind 30°, 90°, 150° SB and PS and speed 20 m/s, as well as their analysis.

Figure 6.11 clearly shows the sign change of the drift angle with the wind from the starboard side and its sharp increase with winds from the opposite side.

The moment of the beginning in the drift angle change corresponds to the beginning of the cross current impact, the action of which does not cause a perceptible increase in the rudder displacement angle. Therefore, we can note one characteristic feature of the current influence on the vessel - the main negative factor of the current influence on the vessel is drift, while the pivoting moment is insignificant.

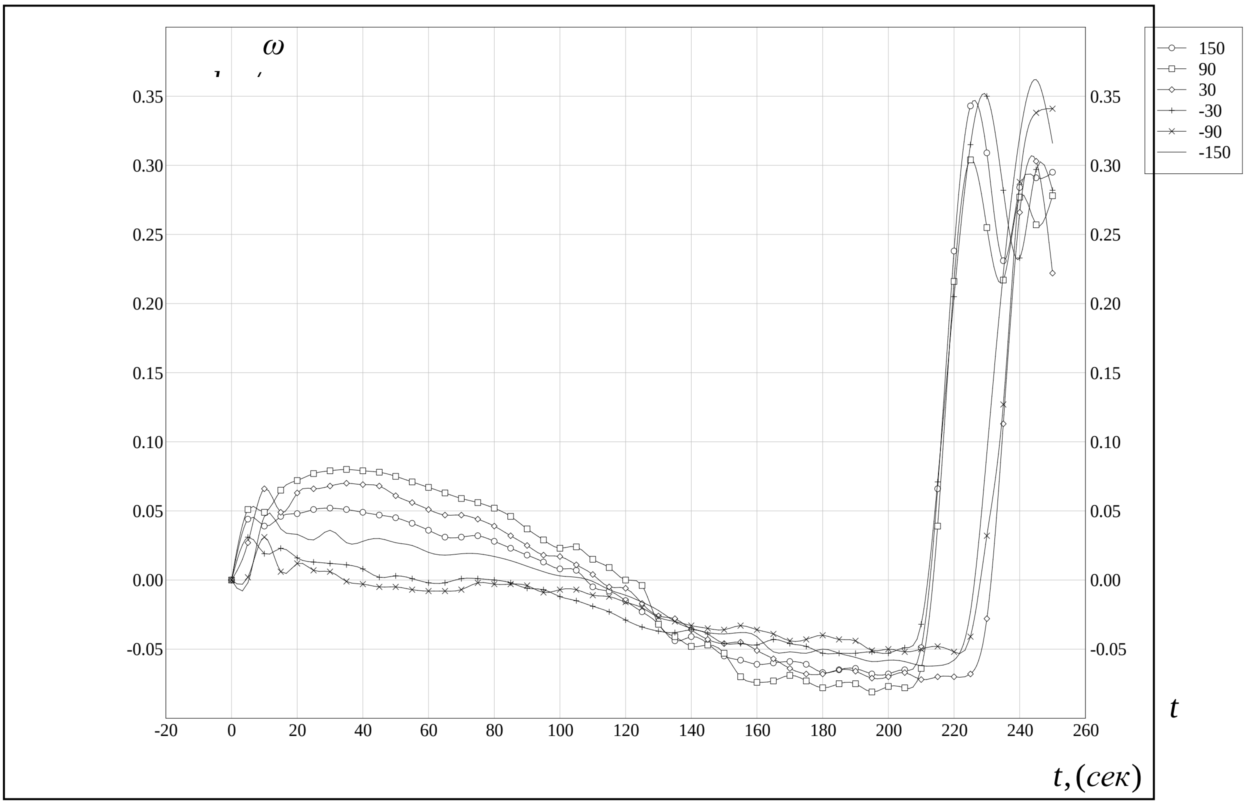


Figure 6.12. Dependence of the angular speed of the vessel on time when moving downstream

Analyzing the dependences of operating parameters on time when the vessel is moving downstream, presented in Figures 6.11 through 6.13. a number of conclusions were made that are important for the practice of vessel control.

1) When moving in a favorable current, the most unfavorable effect on the vessel will be from the traverse wind, as evidenced by the highest values of all selected parameters; the stern wind will be less dangerous; the quarter head wind will have an intermediate effect.

2) It should be noted that the point of application of the force from the current will be displaced to the vessel bow; points of application of aerodynamic

and hydrodynamic forces will correspond to the general laws known from the theory of vessel control; therefore, when the wind and current act onto one side (in this case, it is the portside), the moments from the wind and the current will have different signs, when the wind and current from different sides act, the moments caused by them will add up; Figures 6.12–6.13 show that the rudder angles and angular velocities will be greater with winds from the starboard side than with winds from the port side.

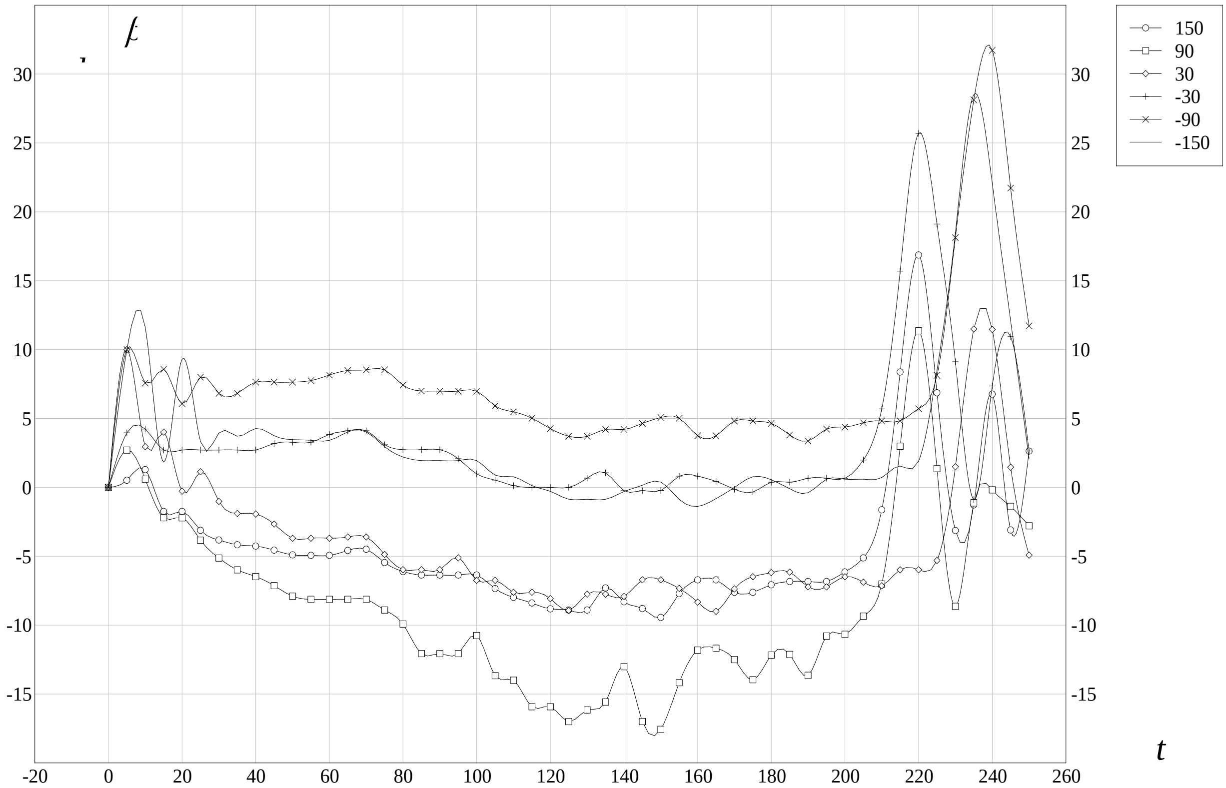


Figure 6.13. Dependence of the rudder displacement angle β on time t when moving downstream

The dependencies of the operating parameters shown in Figures 6.14–6.16 do not have any significant fundamental differences from the corresponding dependencies given for the downward sequence. However, there are some features that need to be emphasized.

It should be noted a significant reduction in the rudder displacement angle required to compensate for the turning moment from the wind; this is due to an increase in the relative speed of the vessel and a corresponding increase in rudder-lift force. Thus, the handling of the vessel is improved.

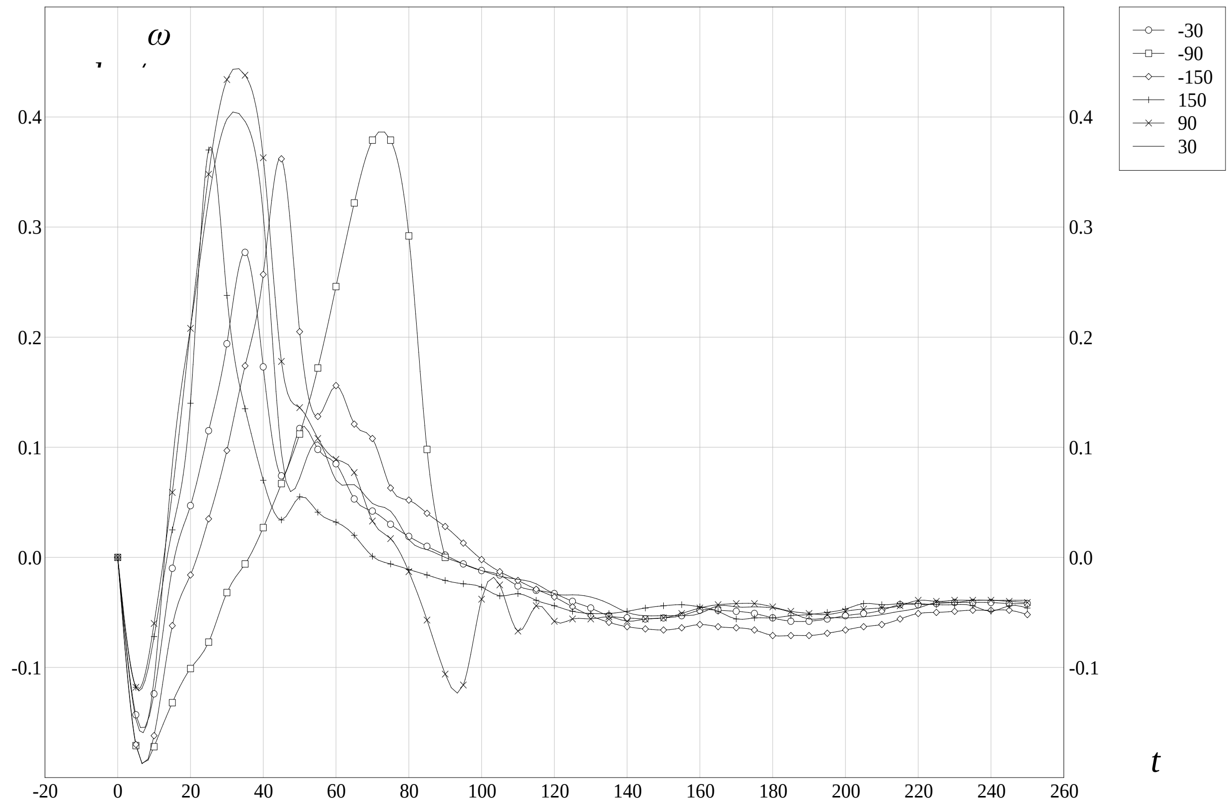


Figure 6.14. Dependence of the vessel angular speed ω on time t when moving upstream

When moving upstream, the degree of current influence on the vessel increases. In such conditions, the turning ability of the vessel in the existing circumstances is of great importance. This can be confirmed by paying attention to the dependence of the rudder displacement angle vs the angular speed at a relative wind direction of 90° PS presented in Figures 6.14–6.15.

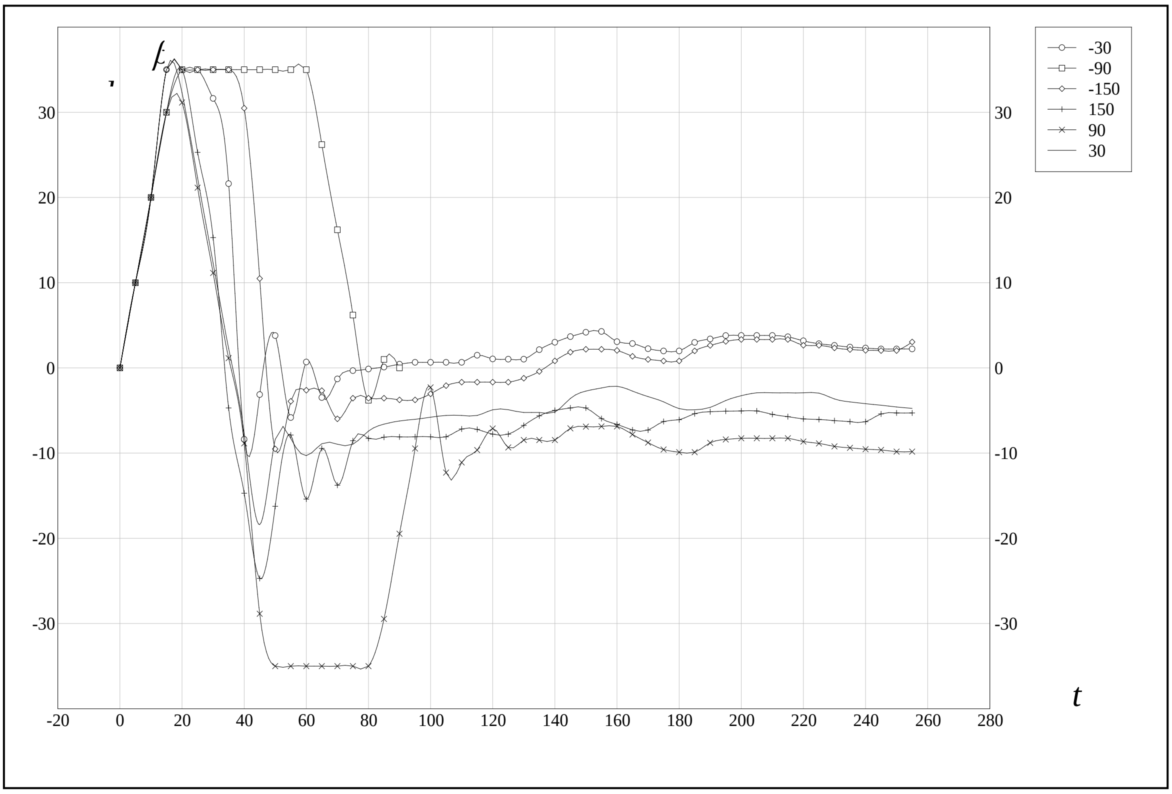


Figure 6.15. Dependence of the rudder displacement angle β on time t when moving upstream

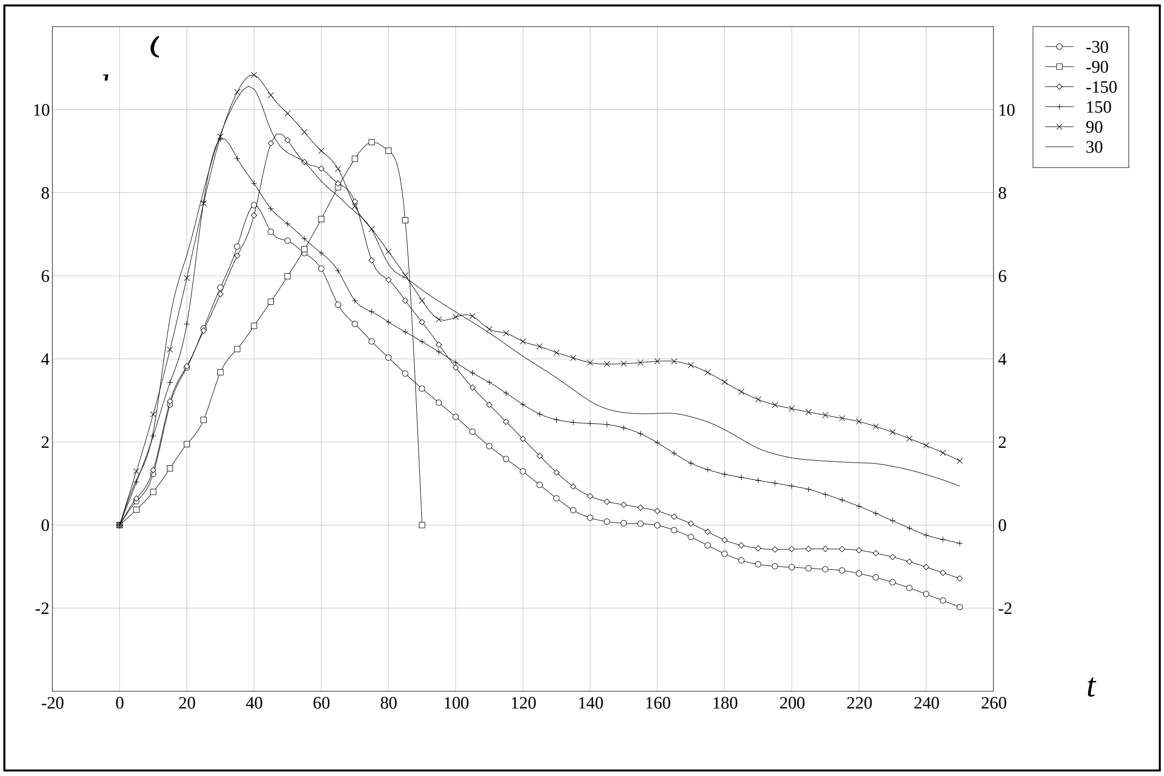


Figure 6.16. Dependence of the drift angle vs the wind and current C vs time t when moving upstream

The figures show that, despite the rudder displacement angle and its duration the angular speed will increase slowly. This leads to the fact that the vessel cannot change course in time and, under the influence of drift approaches the edge of the fairway.

With the combined action of wind and current, the worst case will be when the current and the wind act from different sides; this is due to an increase in the relative speed of the vessel, which causes an increase in the hydrodynamic force, respectively, the moment created by this force also increases.

Obviously, the data obtained as a result of preliminary runs showed the adequate operation of the mathematical model of the vessel, which is confirmed by the presented conclusions, which correspond to the general principles of vessel handling on the river.

6.5. Navigational study of the simulation site

When moving along the considered section, it is necessary to keep course strictly along the range lines, since the fairway edges quite steep and stony, and the depths behind the edges on the shallows are small. Passage from one range line to another shall be done smoothly almost everywhere. Following the section to keep the vessel course in such a manner to ensure its good control, especially when passing from one range to another.

In areas where no cross currents are observed, the current speed coinciding with the fairway direction is significant. This makes it necessary to consider the influence of the current on vessel control.

The current influence when the vessel moves downstream

The current is an external factor that constantly affects the vessel movement, especially directed at an angle to the center line (CL) of the vessel, which leads to a change in the vessel speed and trajectory. The value of the true speed of the vessel movement depends on the sum (or difference) of current and vessel speeds. The drift angle depends on the current direction relative to the vessel CL, current speed and vessel speed (the larger drift angle between the current and the vessel CL and the less vessel speed, the more drift distance).

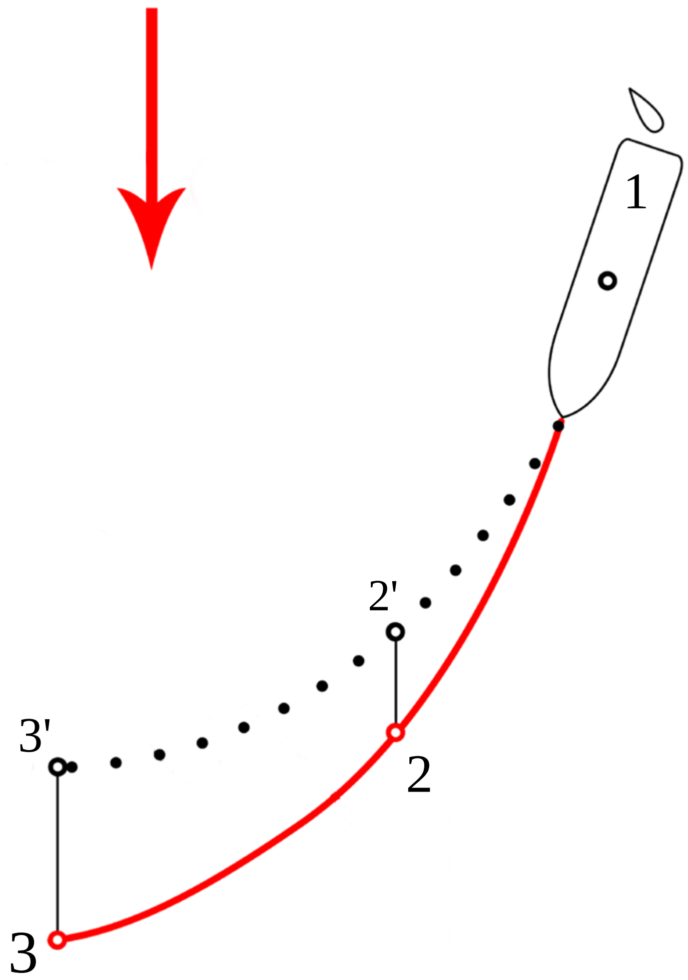


Figure 6.17. The vessel trajectory under the action of a favorable current at a small turning angle

Besides the general drift distance and change in vessel speed the current leads to a rotational motion of the vessel.

When the vessel passes the section upstream, nonlinear motion of the vessel will be characterized by the following features. When the vessel approaches the turn beginning point (Figure 6.17), after the rudder displacement to a certain angle sufficient for the turn (point 1), circulation (points 2,3) develops relatively slowly and the vessel moves for some time in downstream direction. This is due to the fact that the vessel speed relative to the water will be less, and, therefore, the vessel will respond more smoothly to rudder shift. In Figure 6.17 Point (1) denotes the starting point of the turn, and points (2') and (3') denote the position of the geometric center of the vessel, provided there is no current, and the dotted line denotes the corresponding trajectory.

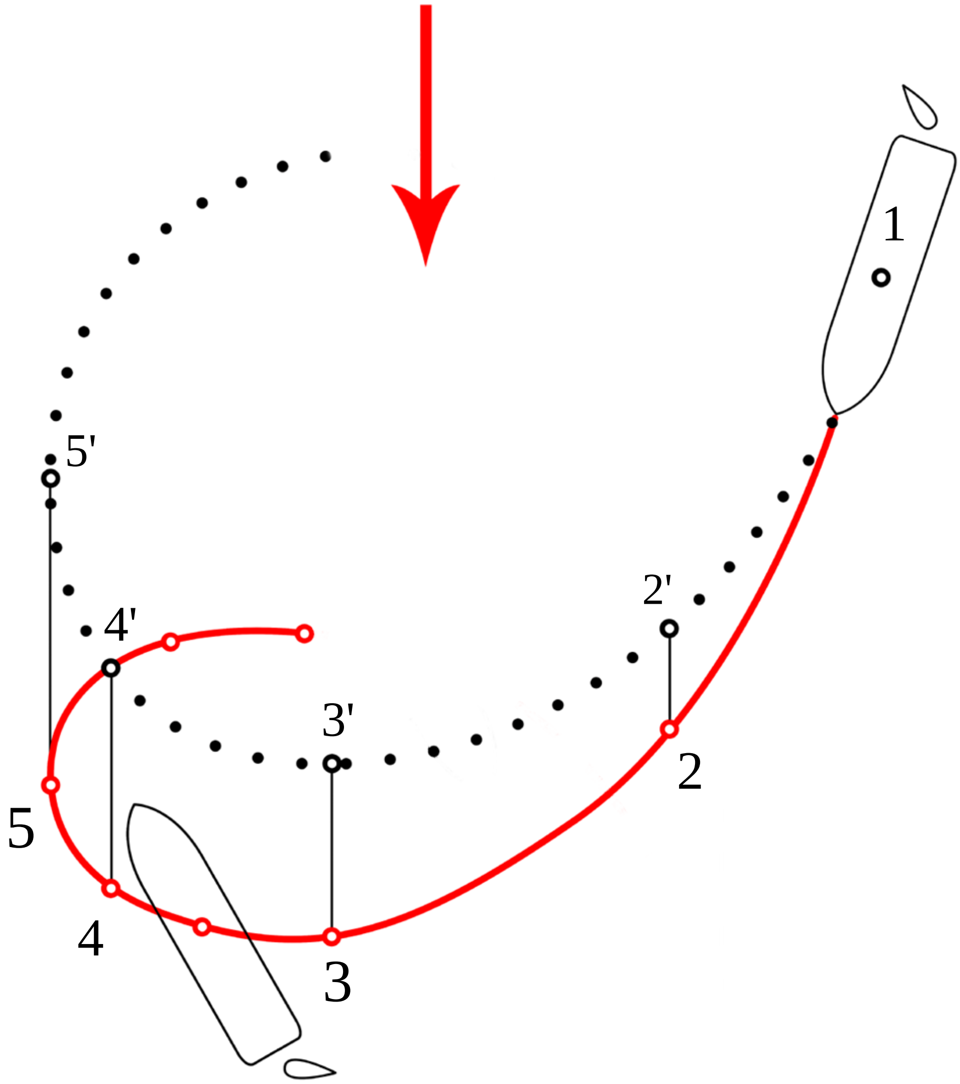


Figure 6.18. The vessel trajectory under the action of a favorable current at a significant turning angle

With a slow increase in the trajectory curvature, the vessel moves for some time in a direction almost perpendicular to the current (points 3, 4), and then abruptly and suddenly turns towards the rudder shift (points 4-5). The end of rotation in this case ends further down the river (downstream) than during turning without the current, which is shown in Figure 6.18 with a dashed line and dots 2'-5'. Additionally, turning downstream is accompanied by severe stern roll (high stern drift angle) and elevated total vessel drift under the current action.

The current influence when the vessel moves upstream

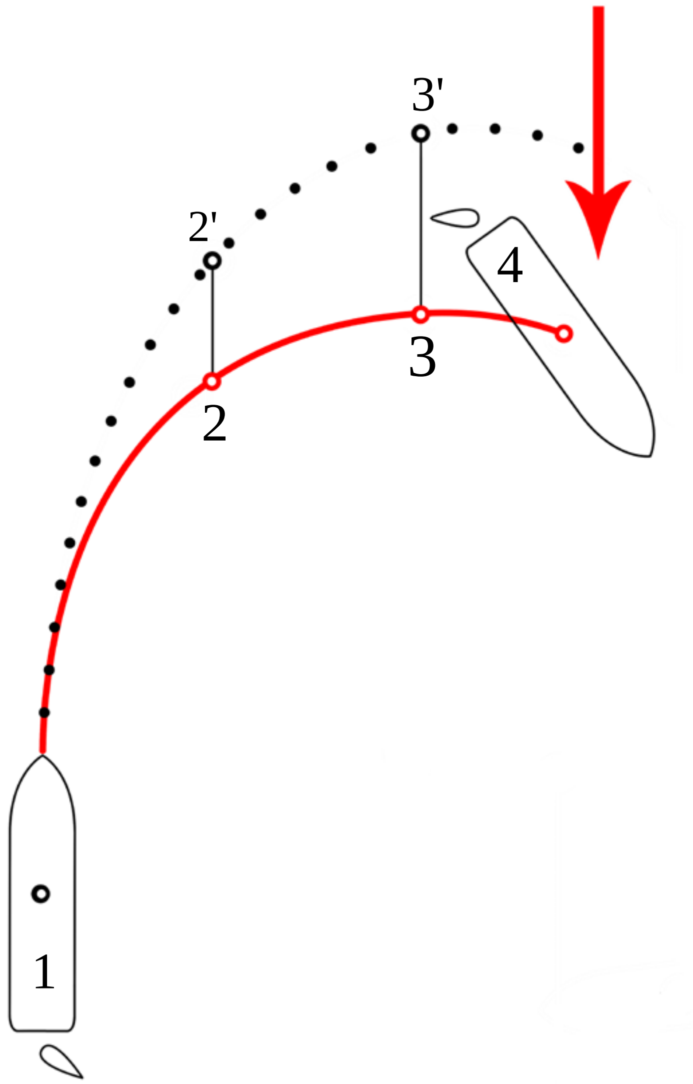


Figure 6.19. The vessel trajectory under the action of a counter current at a small turning angle

The curved trajectory of the vessel with slight changes in heading when moving upstream (compared to turning in the absence of current (Figure 6.19, points 2-3) is characterized by a relatively uniform development of the evolutionary period. The center of gravity of the vessel traces out a trajectory close to a circle.

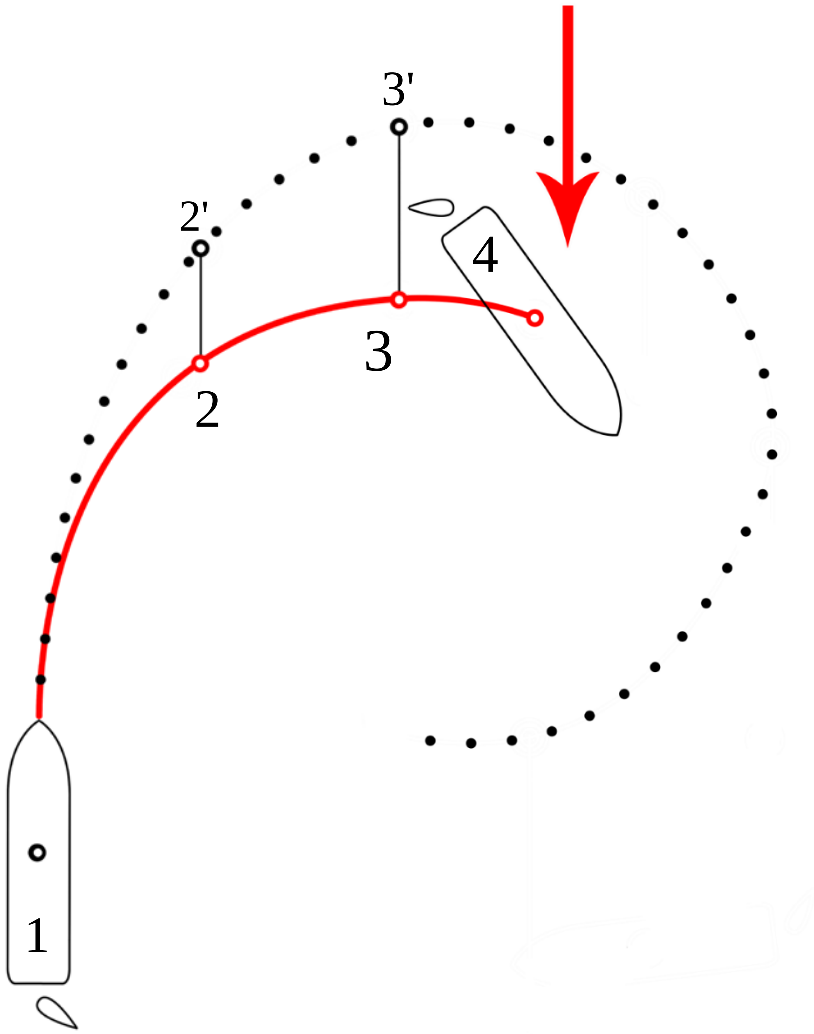


Figure 6.20. The vessel trajectory under the action of a counter current at a large turning angle

However, as the curved movement develops, the vessel will quickly overcome inertia and acquire curved movement. It should be borne in mind that when the course changes significantly (point 4), the vessel under the current influence will be subject to strong drift downstream. It should be remembered that at the beginning of the vessel turning, before its turning through an angle of approximately 90°, a relatively small stern roll is observed, and then the drift angle and the angular velocity of the vessel rotation increase sharply, reaching their maximum value after turning 180-270°.

Comparing the position of points 1 and 4 on the vessel turning circle downstream (see Figure 6.18) and upstream (see Figure 6.20), a conclusion that is especially important for the practice of navigation shall be made: from the vessel position at the moment of rudder shift (point 1) to the turn it 90° (point 3) a vessel performing turning downstream, requires a much greater distance in the previous course direction than in the turning upstream. Despite the fact that when moving along the considered section the vessel does not turn 180°, we should keep in view these significant differences in the vessel behavior when moving upstream and downstream, since when the turning starts with a significant rudder shift angle, the vessel angular speed can increase so quickly that it will be not possible to pullout in time.

The current has a direct effect on the vessel underwater part and an indirect effect, expressed in the inertia of motion, manifests itself after the vessel changes course or leaves the fairway. The vessel acquires inertia of motion in downstream direction, the action of which it is previously subjected to.

Summing up the assessment of the current influence on the vessel, it should be emphasized once again:

When moving upstream, the degree of current influence on the vessel increases.

In such conditions, the turning ability of the vessel in the existing circumstances is of great importance.

Thus, when carrying out mathematical simulation of the controlled movement of a vessel on a navigation simulator, attention should be paid to the dependence of the rudder angle and angular velocity. In view of the described features of the vessel controllability, in spite of the rudder shift value and the duration of its period, the angular velocity will not increase equally for cases of upstream and downstream movement. When navigating a vessel, this will lead to the fact that the vessel, with a certain combination of the relative wind angle, will not be able to change course in time and, under the drift influence, may exit or significantly approach the edge of the fairway.

The wind effects on the vessel

Forces from wind and current are usually interrelated as factors that the navigator cannot control. However, these two forces have a different effect on the vessel due to the difference in their nature.

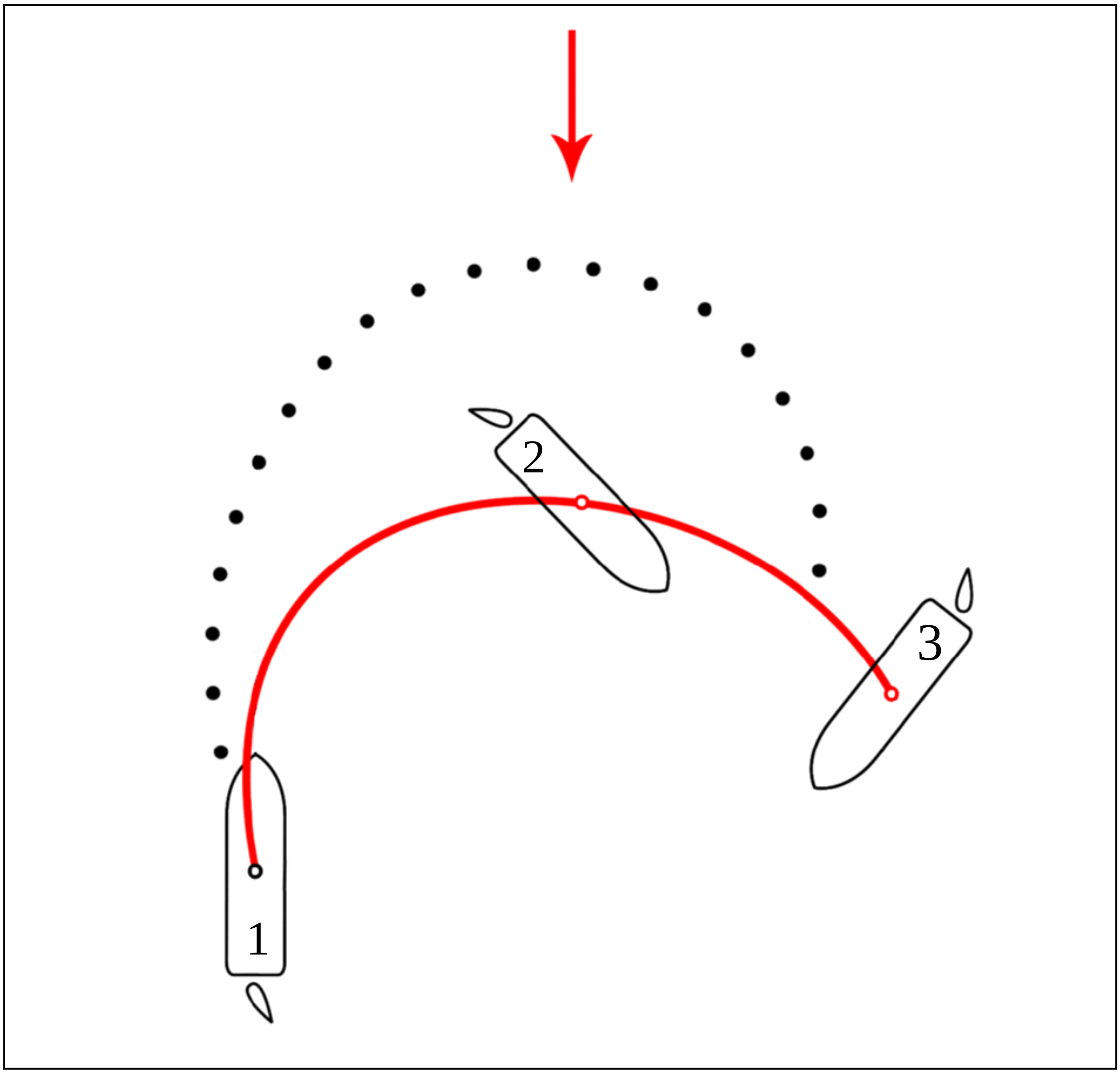


Figure 6.21. The vessel trajectory under the action of a counter current at a significant turning angle

When the vessel is influenced only by the wind and moves it relative to the water, its hull encounters underwater resistance, therewith a pair of forces arises, causing a moment that tends to turn the vessel forward to or down the wind. On the other hand, if the vessel movement is caused by the current, its surface practically does not experience air resistance. However, in the IWW conditions the current acts constantly and, therefore, has a much greater influence than the wind, especially on loaded vessels.

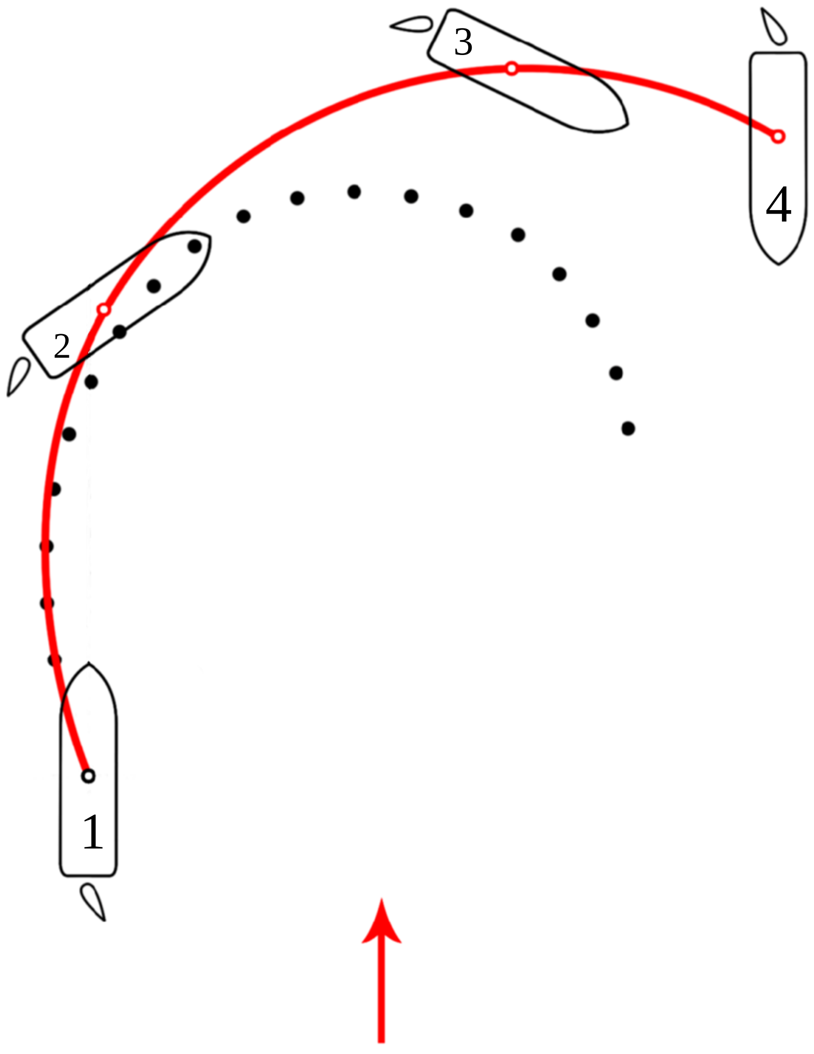


Figure 6.22. The vessel trajectory under the action of a favorable wind at a significant turning angle

Wind has the most adverse effect on the vessel movement and maneuvering, especially those with high freeboard and highly developed superstructures. The extent and nature of the wind impact on the vessel depend on many factors, the main of which are as follows:

sail area and the location of vessel center;

freeboard to draft ratio;

strength and direction of the wind relative to the vessel CL;

course and speed of the vessel relative to the wind direction.

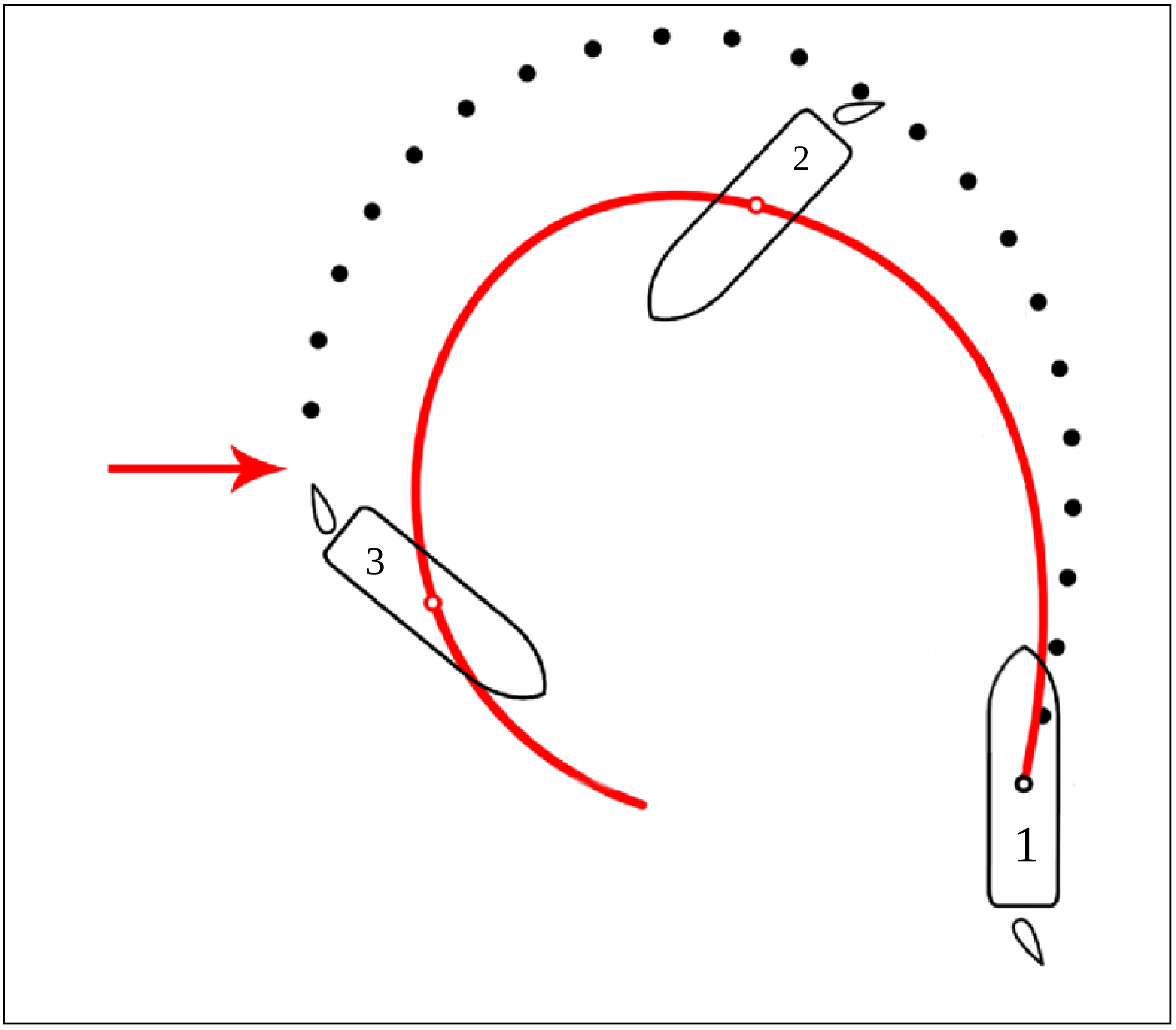


Figure 6.23. The vessel trajectory in the conditions of the side wind acting from the inner side with a significant turning angle

To solve problems concerning the wind effect on a moving vessel, it is necessary to distinguish between the true, actual wind from the apparent or relative one. An apparent wind is one that is felt on a moving vessel. When the vessel is moving, the true wind speed is geometrically added to the speed of the counter air flow, called the heading wind (the speed of the latter is equal to the vessel speed).

The greatest influence on the vessel is exerted by the wind directed perpendicular or at an angle to the vessel CL. In this case, there is a drift (side drift), roll, vessel turning to the wind or turning leeward, as well as a change in vessel speed.

Turning circle at wind is shown in Figure 6.21-6.24. When turning upwind (Figure 6.21), stopping distance usually decreases significantly, the diameter of turning circle increases slightly, and the turning trajectory shifts to leeward.

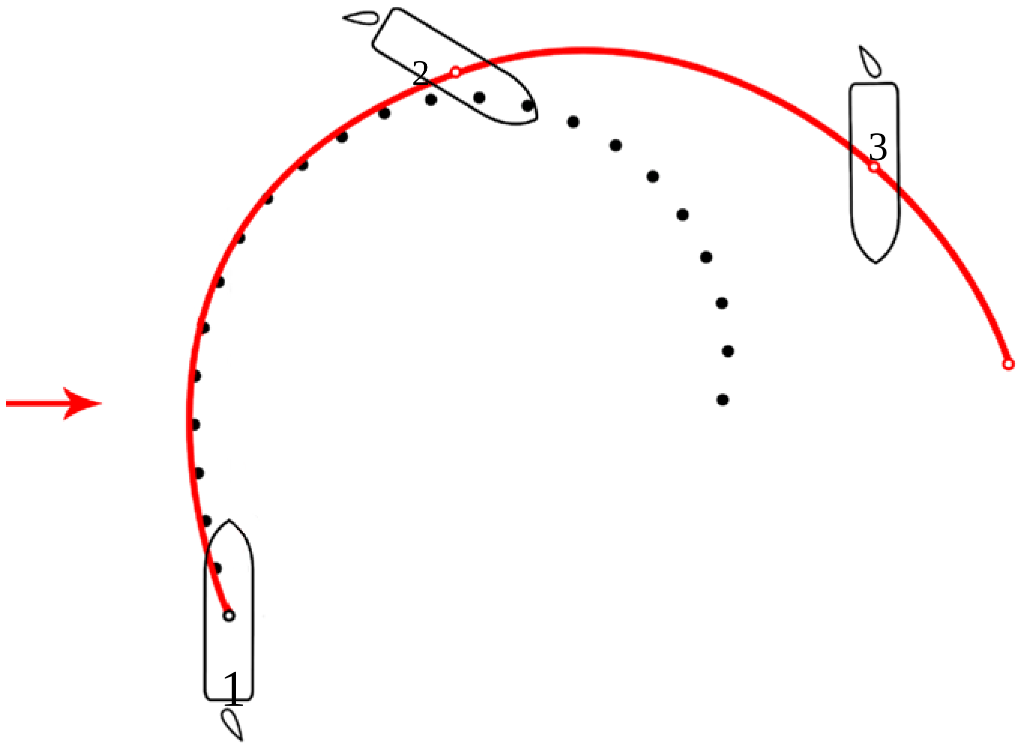


Figure 6.24. The vessel trajectory in the conditions of the side wind acting from the outer side with a significant turning angle

The vessel turning circle downwind (Figure 22), in most cases causes a significant increase in the stopping distance and turning circle diameter. The turning circle in the presence of a strong side wind (Figures 6.23-6.24) differs sharply from the turning circle in calm weather. It should be borne in mind that most vessels have much better turning parameters when turning windward than when turning leeward.

The dashed line in Figure 6.23 represents the vessel turning trajectory in the absence of wind.

When moving upstream, the rudder angle required to compensate for the turning moment from the wind is reduced.

With the combined action of wind and current, the worst case will be when the current and the wind act from different sides; this is due to an increase in the relative speed of the vessel, which causes an increase in the hydrodynamic force, respectively, the moment created by this force also increases.

The complexity of the Ivanovskiye Porogy rapids section is caused by a combination of reasons among which the main ones can be distinguished: a sharp change in the directions of the navigable pass straight sections, alternation of narrow and wide sections, effect of cross currents, significant current velocities, the currents variability depending on the water level and location.

Due to the special importance of this section for shipping purposes, as well as the complexity and variability of navigation conditions, before the model runs, the wind and current effects on the vessel were thoroughly analyzed and recommendations were developed for navigators, which shall be guided directly for safety when navigating a vessel.

Thus, the navigation recommendations contain both general and specific guidance. In general, keep in mind that regardless of the recommendations, masters shall take all the precautions required by the prevailing circumstances and navigation conditions, even given if forced to ignore the recommendations.

The theoretical foundations presented above have their value, since they were supplemented by the practical implementation of piloting on a navigation simulator, which confirms the correctness of this theory.

Hydrodynamic interaction between the hull and the edges of the fairway

When the vessel moves at a certain speed, a wave is created around its hull, which increases even more in shallow water due to the restriction of the water flow under the vessel bottom. The wave profile formed along the vessel side has a rise along the bow, decrease along the sides and an increase in the wave following the vessel. An increase in the longitudinal resistance of the water causes a loss of speed.

The created lowering of the water level along the vessel sides causes squat and further restricts the water flow and thus further reduces the speed. Model tests show that the squat is directly proportional to the vessel speed and width. When navigating in restricted conditions typical to the rivers of the RF IWW, an even greater limitation of the flow occurs, since the water flow is limited not only under the vessel bottom, but also along the sides, which leads to a different increase in hydrostatic pressure.

A vessel moving near the shore is experiencing a significant drop in water level on the shore side due to flow restriction. The difference in water levels along the vessel sides creates a pressure difference, which is the source of the shear force acting onto the vessel in the shore direction (Figure 6.25).

Figure 25 shows the hydrodynamic forces arising during the vessel movement near to the shore. In this case, the bow of vessel *2* under the action of the force P_2 of interaction with the shallow water area near the shore, will yaw out towards the area with great depths. The attractive force P_1 arising in the midship of the meeting vessel 1 also acts in this direction. The sum of the forces P_1 and P_2 will cause yawing the bow of vessel *2* to the meeting vessel 1.

At the same time, the stern of vessel 2 under the action of force P_3 will tend to approach the shore. The bow yawing forces $P_1 + P_2$ and attraction force P_3 of stern to the shore form a pair of forces that cause the rotational movement of the vessel with the moment M_{BP2}.

The moment of rotational motion in some cases can reach such a value that a vessel moving along the shore can lose controllability during crossing. In order to avoid this, it is necessary for both vessels to reduce their speed in advance and keep as much as possible at a greater traverse distance between the sides and to the shore. In this case, it is recommended to control the vessels with the help of not only rudders (nozzles), but also the appropriate maneuvering of the propellers.

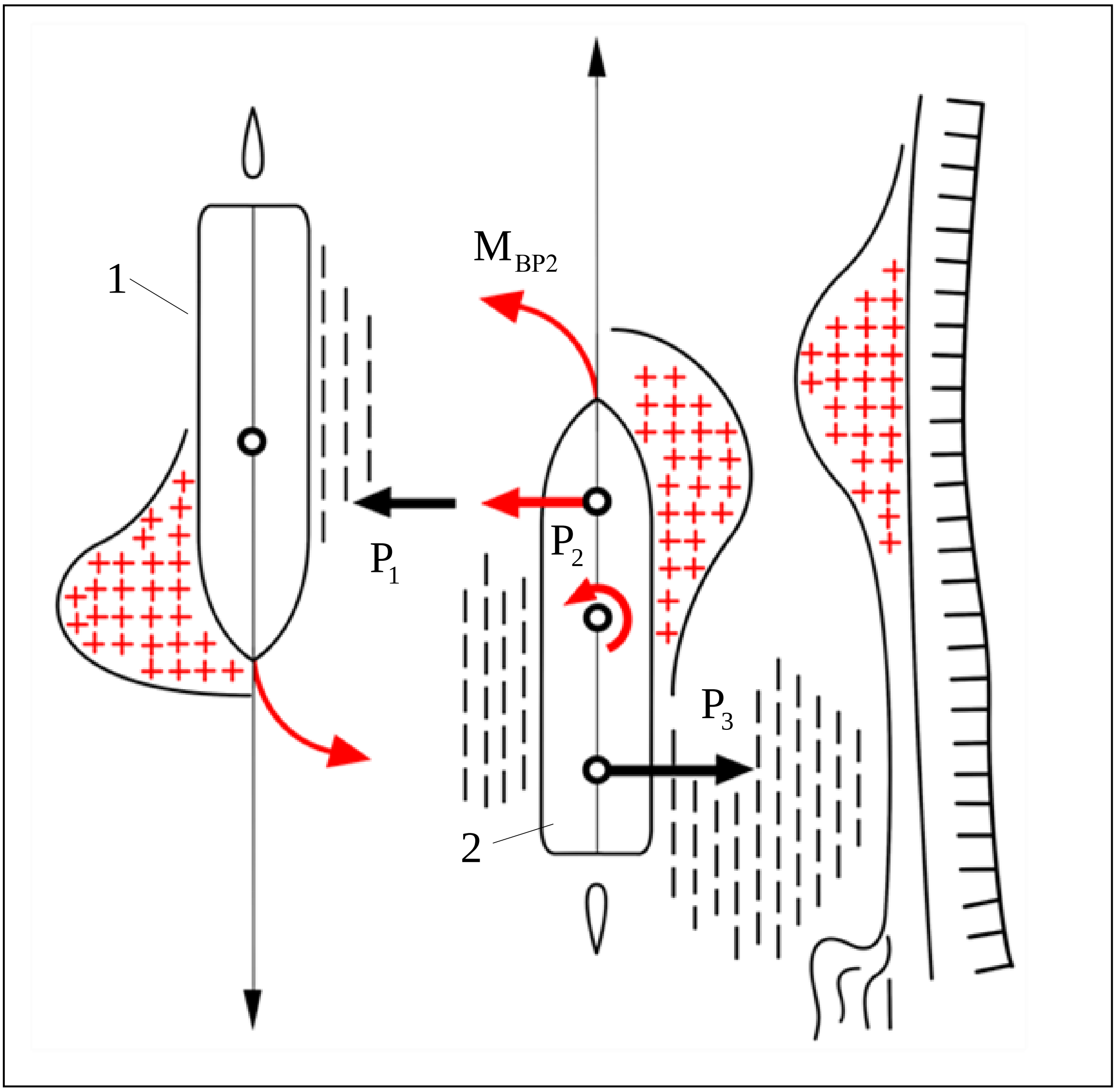


Figure 6.25 Forces arising between crossing vessels

(considering the proximity of the shore)

It should be borne in mind that the effect of hydrodynamic forces and moments on vessels in the process of their crossing will change both in nature and in intensity, depending on the position of the vessels relative to each other and the shore.

The point of application of this force is at the center of the application of hydrodynamic forces; the magnitude of the resulting shear force acting onto the vessel is directly proportional to the difference in water levels and, therefore, is directly related to the vessel speed. The center of turning should be at the vessel bow that means that the lateral force acting on the center of hydrodynamic pressure of the vessel should move the stern towards the shore. Moreover, when the vessel is moving at a fairly high speed, water rises in front of it, especially between the bow and the nearby shore. This results in a pressure difference in the vessel bow, between the side facing the shore and the opposite side, a force appears that pushes the bow away from the shore.

To keep the vessel on a constant course close to the shore, a balance shall be established between the rudder force and the forces acting onto the bow and stern. To keep the vessel on a straight course when moving close to one side of the fairway, it is necessary to shift the rudder towards the shore. And the closer to the shore, the more you need to shift the rudder to compensate for the shore effect. Since the efficiency of the rudder is higher at small shift angles, the greater the angle we shift the rudder, the less its efficiency increases, and the remaining shift margin decreases. The safest option to move along twisty fairways is to stay on the center line if vessel traffic allows it.

For a vessel experiencing the influence of the shore effect, the stern will be yawed, which will come even closer to the shore and as a result the attraction force will become stronger. In modern river-sea vessels, strong attraction force can be expected when moving in narrow fairways, or when approaching the fairway edges, because wide width causes additional yaw. The more vessel length, the more arm of the attraction force moment increases, in addition, in this case there is less space to prevent yaw. At lower speeds, the master has more time to control the weaker shore forces and, in addition, it is possible to increase the propeller speed to improve controllability.

A large wave in the forward part of the vessel increases the longitudinal resistance in the bow, which tends to displace the CoT to the stern. The water level near the shore rises higher than from the other side of the vessel, which leads to the cushioning of the bow from the shore. The area of increased pressure in the bow area creates a rotational motion similar to the attractive force, and its effect on vessels with a large draft that have a small under-keel clearance can be strong. The influence of the area of increased pressure in the bow end depends on the height of the bow wave, which in turn changes depending on the under-keel clearance, the distance to the shore, vessel draft, width and speed. Loaded vessels with a large draft and a relatively large part of their lateral underwater area ahead of the turning point are much more exposed to shore cushioning than in ballast.

For a vessel moving a narrow fairway, the hydrodynamic interaction between the extremities and the bottom topography does not greatly interfere, since it is either balanced by equal pressure on both sides when the vessel is on the fairway axis, or compensated by several degrees of rudder displacement if the vessel is off the axis.

When the vessel passes a branch of the fairway, the water rising from the corresponding side will enter this branch. At this moment, the area of hydrodynamic pressure in the way of the bow end from the other side begins to prevail, and if the navigator does not assess this moment in time, the vessel will yaw. As soon as yaw occurs, the attractive forces of the stern and bow form a rotating pair.

If yaw was not expected and the master is too late to take action, the situation may get out of hand; the increasing stern attractive force will turn the vessel across the fairway, despite the full rudder displacement to the appropriate side and full speed ahead.

When the loaded vessel is moved slowly, too much rudder displacement is not necessary to prevent the tendency of the vessel to turn, but moving at lower speeds requires appropriate attention from the master.

Overcome yaw

The first thing to do when the vessel is yawing under the influence of the coastal effect is to prevent the rudder from increasing turn, that is, shift it 20° or hard over depending on the situation. If at full rudder shift the vessel does not come on course, it is necessary to increase the speed of the propellers. With increasing stop and full rudder, it takes less time to stop the turn than to increase speed. The increasing stop will immediately increase the lateral force from the rudder action, while the longitudinal inertia prevents rapid acceleration. Attraction force depends on the vessel speed relative to the water, and it rises more slowly when the rudder is turned on board. When the vessel, under the action of the rudder shifted on board, and the increased engine speed, comes to a course, it is necessary to reduce the speed to the initial one and only then begin to gradually ease the rudder, since while the vessel is near the shore, it is exposed to the shore effect. If the vessel yawns across the fairway, the hydrodynamic pressure in the vessel bow, the action of which could prevent subsidence on the opposite shore, is not created because there is no rise of water level between the bow and the shore, as the vessel approaches the other shore at an angle.

6.6. Carrying out simulated runs of the estimated vessel using radar only

Mathematical modeling of the controlled movement of the estimated vessel was carried out along the considered section under the conditions listed below.

In accordance with clause No. 168 of the "Rules for the Navigation of Vessels on Inland Waterways of the Russian Federation" the movement of vessels in conditions of limited visibility is permitted if the vessel has and uses the following equipment in good working order:

radiolocation station;

an instrument indicating the vessel turning rate, or a compass;

vessel VHF radio communication device, which allows VHF radio communication between vessels and between the vessel and coastal dispatch control points of vessel traffic;

device for the emission of sound signals.

Since in accordance with the requirements of clause No. 174 of the "Rules for the Navigation of Vessels on Inland Waterways of the Russian Federation" in conditions of limited visibility, the passage of vessels and pushed convoys under bridges is allowed only on condition that the navigable spans have navigation equipment allowing the navigator to see these spans for at least for 500 meters and confidently navigate when approaching them (visually or with the help of technical means).

At the same time, the width of navigable spans for single vessels and single-line trains should be at least five times the width of the vessel (convoy), for other convoys - at least three times the convoy width.

Due to the fact that the Kuzminsky bridge is not equipped with the navigation equipment, allowing them to be observed during radar surveillance, the simulation of movement under the bridge was not carried out. The beginning of modeling for the case of vessel movement downstream was a straight section at the quay of ZAO Spetsdorstroy located at the left bank of 1,336.8 km. The estimated vessel movement along this section was simulated, the corresponding data are presented in section 3.4 “Assessment of the influence of external factors on the mathematical model of the estimated vessel” of this report.

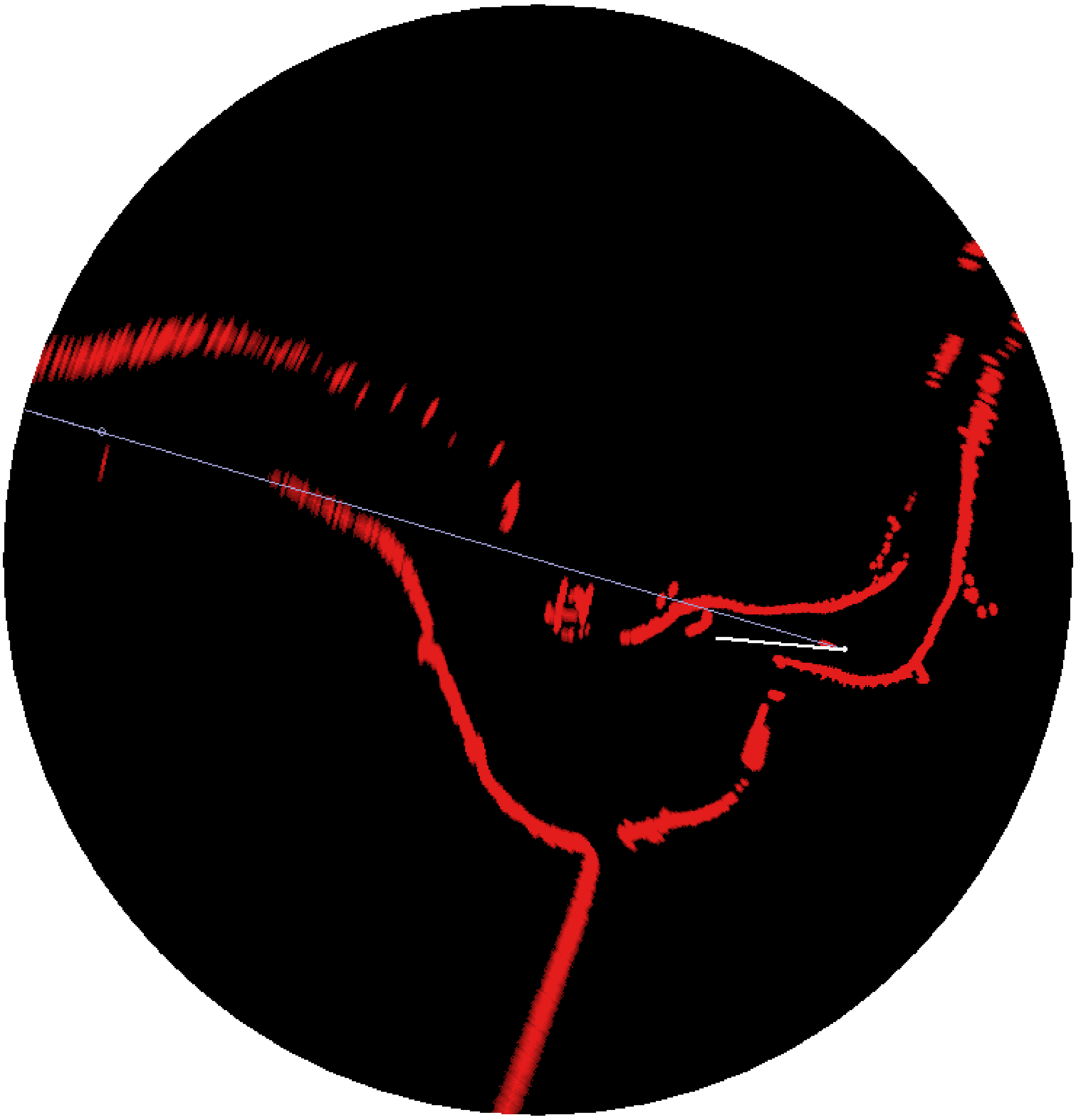


Figure 6.26. Display on the radar PPI of the vessel speed vector during nonlinear motion when turning to the stern Verkhny Pellovsky range line

In the extended navigation conditions, when there are no floating signs in their regular places, the axial lines are the main navigation aids.

Analysis of the special pilotage of the Ivanovskiye Porogy rapids section, which is difficult for navigation, shows that the sections are installed so that the water space available for the movement of the vessel is divided into asymmetric sections of irregular geometric shape. Thus, when navigating a vessel using only radar, the navigator will steer the vessel equidistant from the dangerous isobaths enclosing the fairway edges. When navigating a vessel only with the use of radar in such a section, the main radar landmarks will be the shores, which will require the navigator to have good knowledge of special pilotage, in particular, the location of navigational hazards.

When moving on the considered section using only radar for surveillance one shall correct the vessel course for reliable radar landmarks that can be considered as capes, ducts, characteristic shape of the shores. Since the fairway edges are steep and rocky, and the depths behind the edges on the shallows are small, the transition from one straight section to another almost everywhere should be done smoothly, which will ensure good controllability of the vessel and avoid delays and sudden changes in course.

When passing most sections, the vessel should follow a course so that it has a course angle corresponding to the range line direction. However, in the section from Verkhneporozhskaya Luda to Sverdlovskaya Luda, when navigating a vessel, it is necessary to take into account that, when entering a new rectilinear section, it is necessary to hold the correction for some time to compensate for the residual drift caused by the vessel inertia when turning, as well as by the action of a nonlinear current.

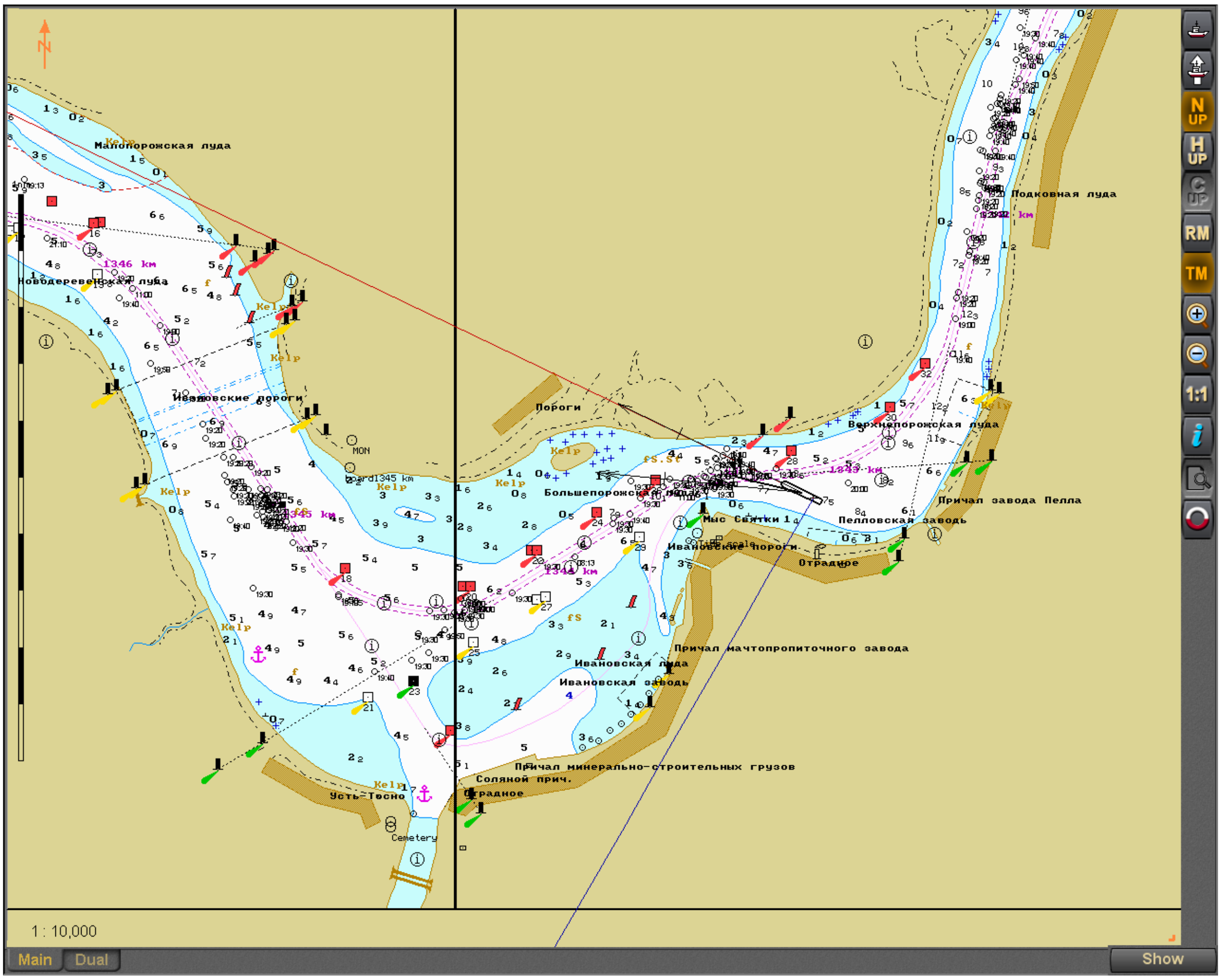


Figure 6.27. Display on the ECDIS window of the vessel speed vector during nonlinear motion when turning to the stern Verkhny Pellovsky range line

The east wind will be the most unfavorable, at which the turning moment created will prevent the vessel from turning. In this regard, the turn of the vessel must be started with a lead. When making a turn, it is enough to control the vessel position along the buoys of the right edge. This is because it is preferable to stay close to the convex edge when performing the turn, the stern rolls in the opposite direction.

The corresponding display on the radar PPI of the vessel speed vector during nonlinear movement in the process of rounding the Verkhneporozhskaya Luda and entering the stern Verkhny Pellovsky range line, i.e. at the entrance to the most difficult section of the Ivanovskiye Porogy rapids is shown in Figure 6.26, and in the ECDIS map view area in Figure 6.27.

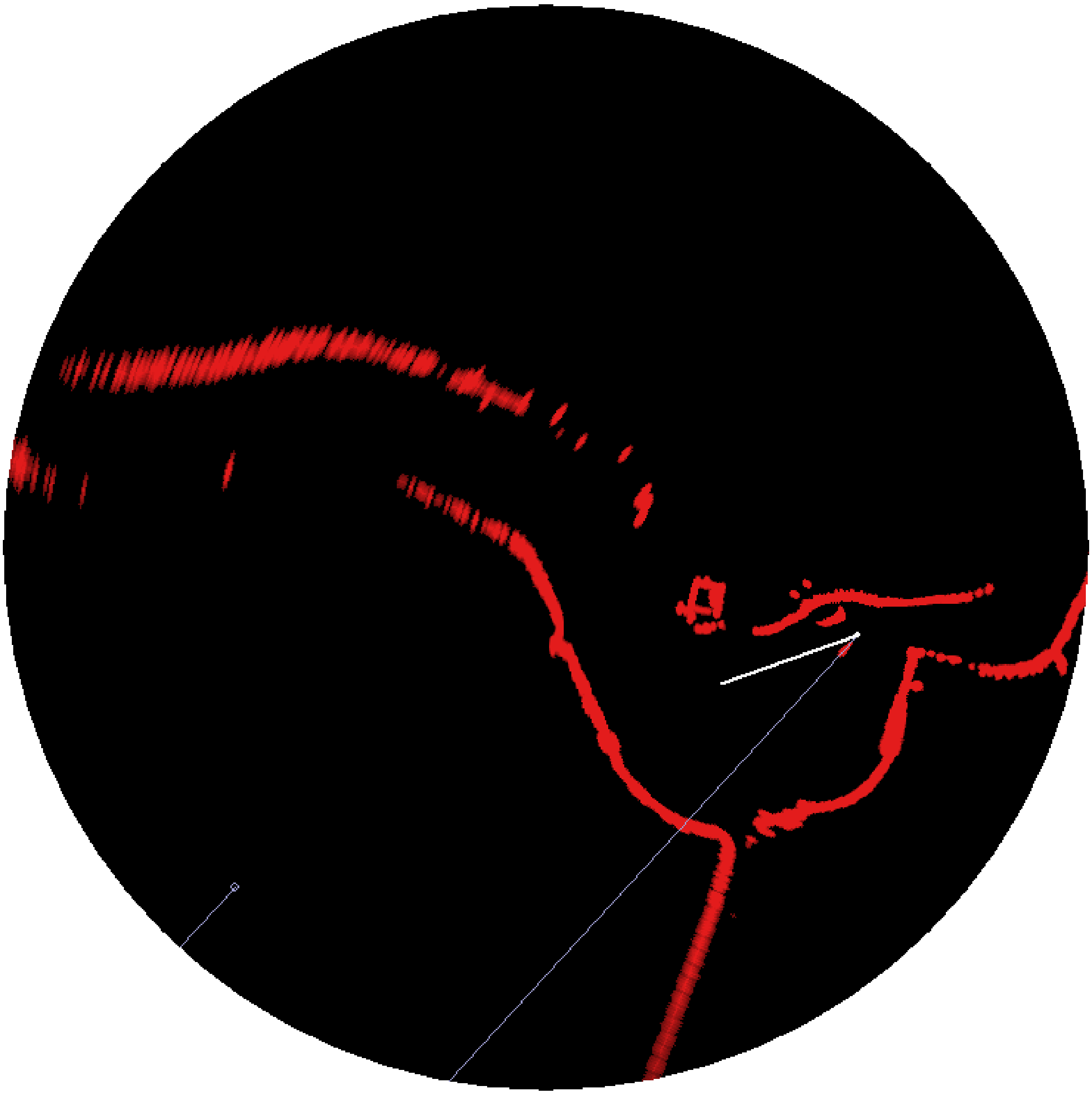


Figure 6.28. Display on the radar PPI of the vessel speed vector during nonlinear motion when turning to the stern Verkhneporozhsky range line

Strong cross currents act near curved sections, therefore their timely and accurate accounting will have a decisive effect on navigation safety when passing such sections.

When navigating the vessel during entering the straight section of the Verkhneporozhsky range line, where the river bed has a significant widening, it is also necessary to take into account the wind effect. Therefore, guided by the conclusions known from the course of vessel management, as well as the electronic navigation chart presented in ECDIS, we can say that the winds from the east and west will be unfavorable.

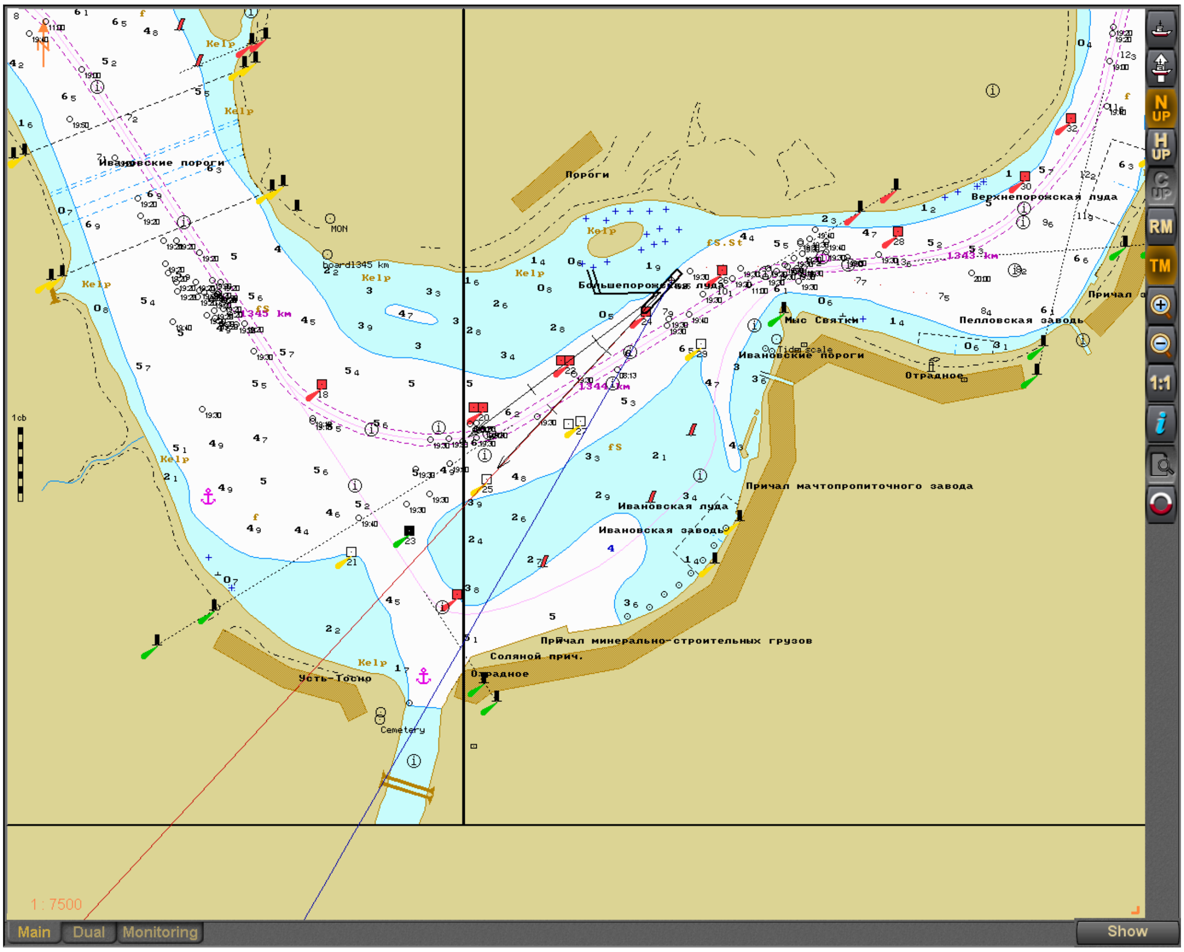


Figure 6.29. Display on the ECDIS window of the vessel speed vector during nonlinear motion when turning to the stern Verhneporozhsky range line

During the turns on this section in the conditions of the winds of the indicated directions, the vessel has a high angular velocity and, due to inertia, it will be not possible to pullout in time, which is clearly shown in Figures 6.28 through 6.29, respectively, where the velocity vector on the radar PPI and in the ECDIS window is displayed of a vessel in nonlinear motion while turning to stern Verhneporozhsky range line.

When passing this section, the reason for the vessel movement beyond the fairway edge may be not as much a cross current as a strong wind.

There are no cross currents on most straight sections but the current speed is significant.

Winds from the starboard side will be of great importance, because the turning moment they create will prevent the vessel from entering a new course. And when the vessel enters a new course due to a significant rudder shift, then during pullout, the turning moment from the wind can cause a sharp pullout and yawing in the direction opposite to the turn. In such conditions, the vessel turning ability will not be sufficient and even a slight delay in turning will not allow to get on the required course in time and, under the passing current influence the vessel will receive an unacceptable deviation from the fairway axis and get on the ground.

In the general case, when moving along the range line of the considered section, avoid a few to the right of the ranges, because they "lead over white buoys". With north winds, keep to the range lines, and the transition from one straight section to another shall be started in advance. On the contrary south winds will facilitate the vessel turn, therefore, when turning with northern winds, keep to the range lines, and the transition from the range line to the stern Tosnensky range line shall be started in advance.

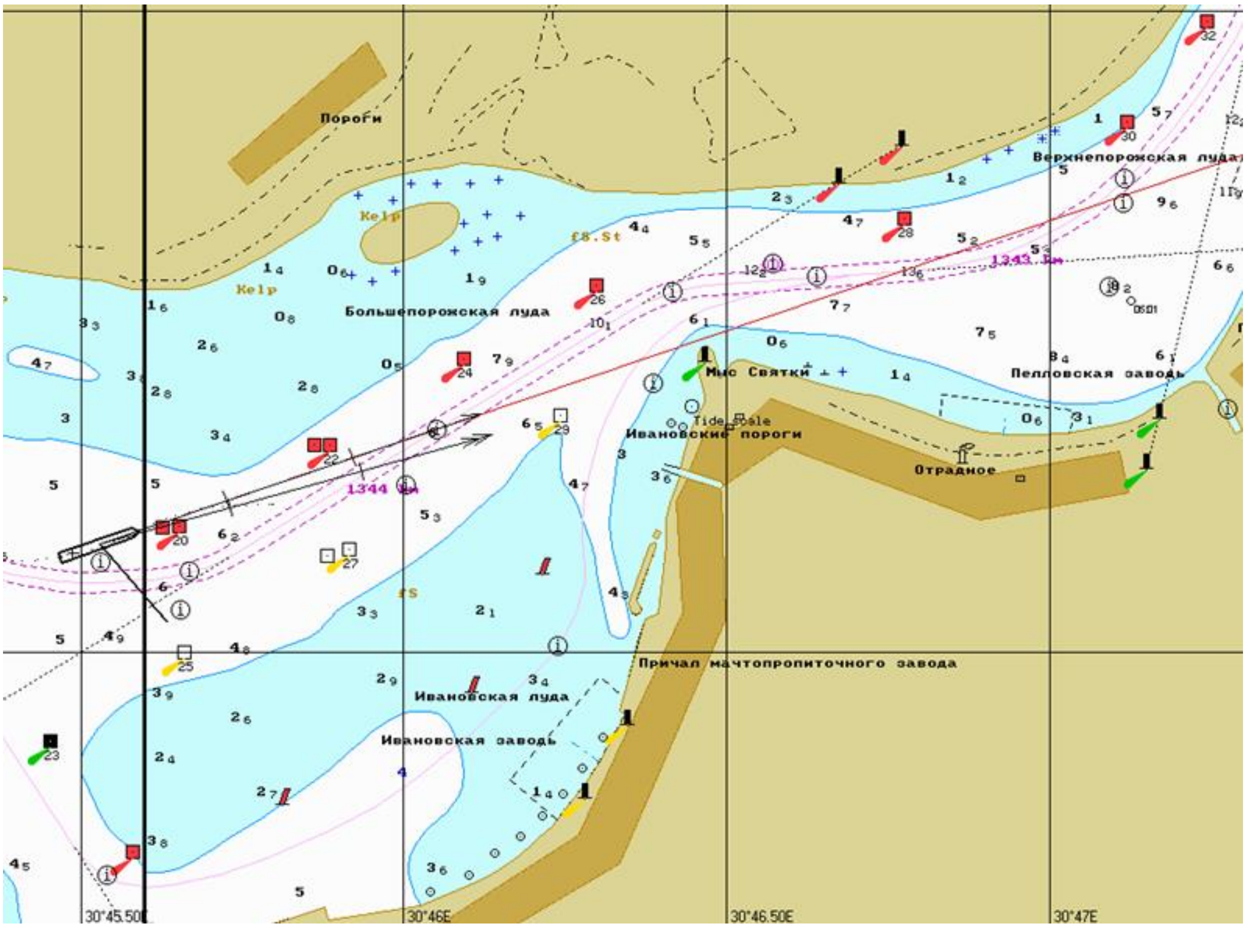


Figure 6.30. Display on the ECDIS window of the vessel speed vector during nonlinear motion when turning to the stern Verhneporozhsky range line

When moving upstream, one of the most unfavorable places where it is difficult to determine the starting point of the turn will be the transition from the Tosnensky range line to the Verkhneporozhsky range line. In particular, in conditions of unfavorable winds in the southern and southeastern directions, because the turning moment they create will prevent the vessel from turning on a new course. In such circumstances, the vessel turning ability will be insufficient and even a slight delay in turning will not allow to change course in time. Under the influence of a favorable current, the vessel will receive an unacceptable deviation from the fairway axis and will go beyond its edge.

Western winds will be more unfavorable, however, allow for wind, i.e. it is dangerous to keep the vessel to the right of the fairway axis. This can be explained by considering the consequences of a possible accident when the vessel is yawing. If there is significant yaw and the vessel is unable to turn away, it could hit the ground or run aground, which are much more serious than lean on a buoy. The vessel can only be prevented from exceeding the limits of the fairway by a sharp change in the course to the left and then to the right, but in this case it is unavoidable to pile on the marks of floating navigation equipment and, in addition, there is reason to believe that as a result of the wind influence the vessel will leave the right edge of the fairway. In such circumstances, it may be advisable to steer the vessel with special care and care and follow the range lines as closely as possible.

Figure 6.31. Display of the visual situation around the vessel, piloting of which was carried out only using the radar, obtained during record playback

The northwest wind will be the most unfavorable. This is primarily due to the presence of a strong cross current, as well as to the peculiarities of the vessel control when moving upstream.

By commenting on this case, we can emphasize again:

When moving upstream, the rudder angle required to compensate for the turning moment from the wind is reduced;

Passing upstream the degree of current influence on the vessel increases; in such conditions the vessel turning ability in existing circumstances has a great importance; to confirm this to pay attention to the dependence of the rudder displacement and angular speed, despite the rudder amount and its duration the angular speed will increase slowly; this leads to the fact that the vessel cannot change course in time and under the drift influence move outside the fairway edge.

Figure 6.32. Display of the visual situation around the vessel, piloting of which was carried out only using the radar, obtained during the record playback

With the combined action of wind and current, the worst case will be when the current and the wind act from different sides; this is due to an increase in the relative speed of the vessel, which causes an increase in the hydrodynamic force, respectively, the moment created by this force also increases.

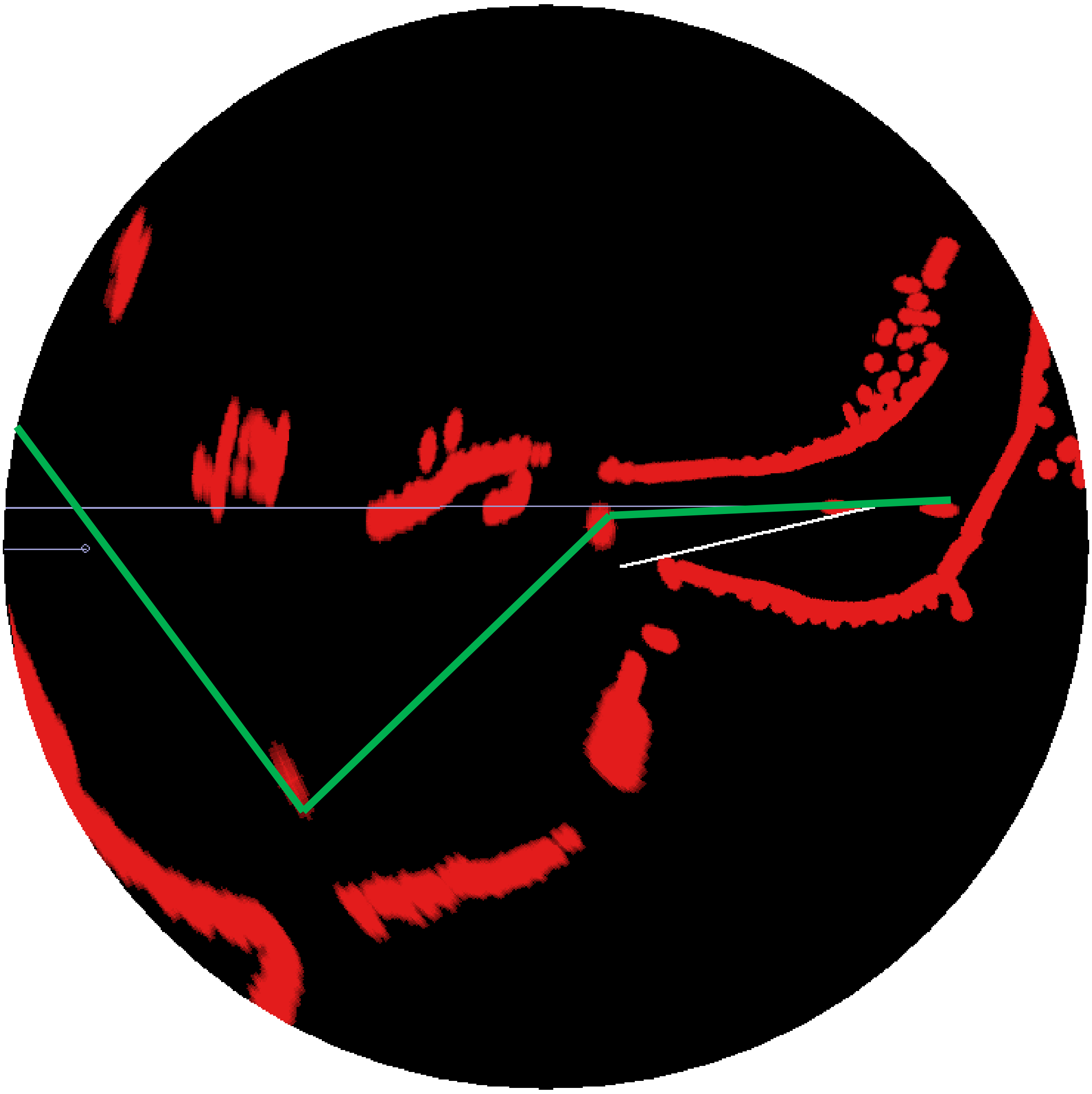


Figure 6.33. Displaying echo signals from buoys on the radar PPI, which are necessary to improve the accuracy of orientation when navigating the vessel along the sections of the Verkhny Pellovsky, Verkhneporozhsky, Tosnensky range lines

It should be mentioned that in this section it will not be possible to keep the vessel with a margin for the current, i.e. to the left of the fairway axis. This is due to the fact that the cross current acts as soon as the vessel enters the fairway axis, and when turning, it is preferable to keep the vessel closer to the convex edge rather than to the concave one.

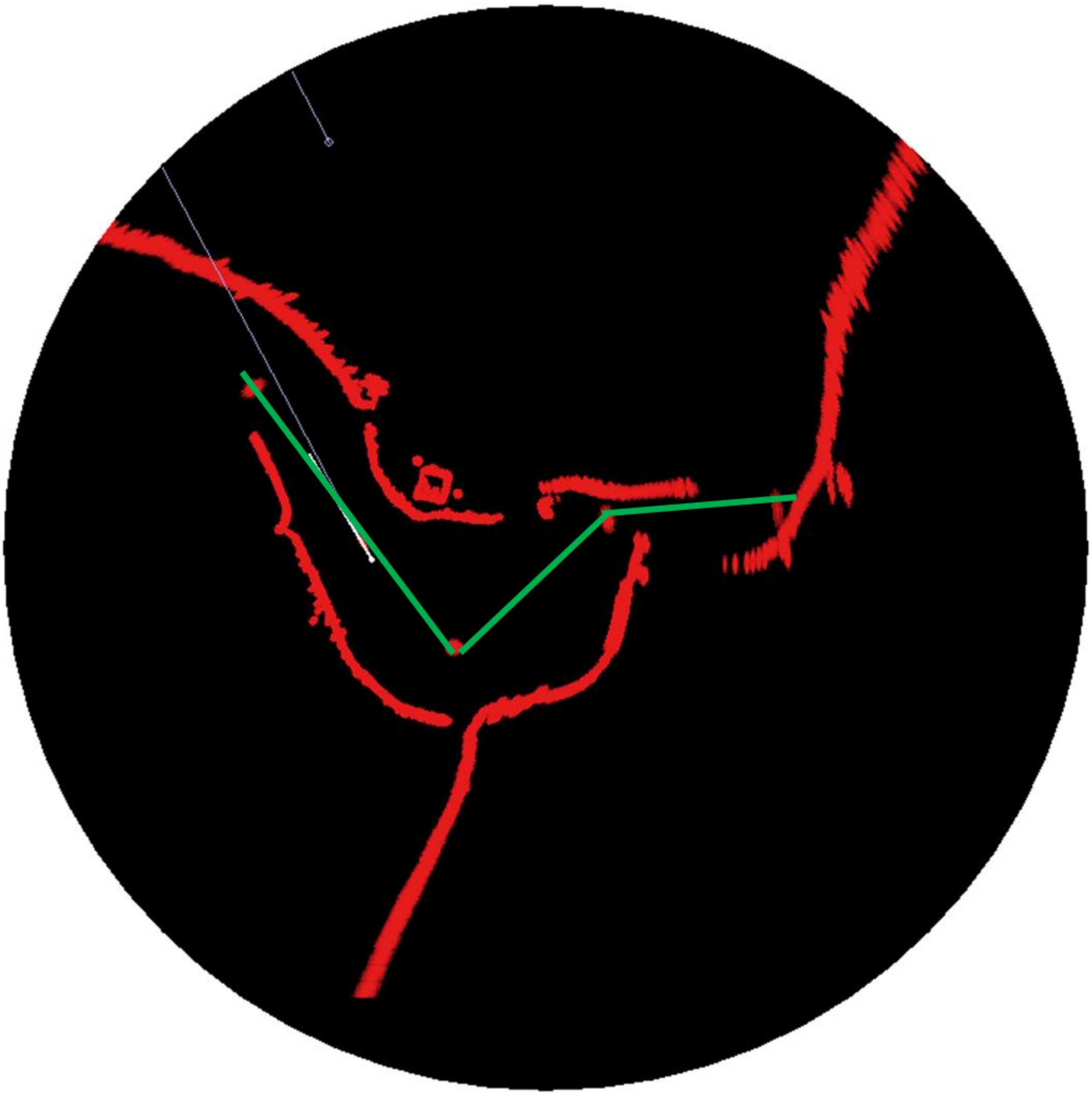


Figure 6.34. Displaying echo signals from buoys on the radar PPI, which are necessary to improve the accuracy of orientation when navigating the vessel along the sections of the Verkhny Pellovsky, Verkhneporozhsky, Tosnensky range lines

Based on the results of the estimated vessel runs along the Ivanovskiye Porogy rapids section, which is difficult for navigation, and the route elaboration with the analysis of the influence of external factors on the vessel, it was decided to install minimum number of navigation floating signs at four points:

- to indicate the intersection point of the Verkhny Pellovsky and Nizhny Pellovsky range lines;

- to prevent the vessel from yawing in the direction of Bolsheporozhskaya Luda when rounding Cape Svyatki;

- to assess the starting point of the turn around the Bolsheporozhskaya Luda;

- for orientation when turning around Novoderevenskaya Luda.

These buoys are indicated in Figures 6.33 through 6.34 and are connected by a line. The visual construction of the lines connecting the echo signals from the indicated buoys, during radar observation, makes it possible to determine the position of the fairway axis to assess the lateral deviation, as well as to determine the moment of the beginning of the turn when measuring the distance with an electronic range cursor.

For further mathematical modeling, the indicated layout of navigation floating signs was used, which has shown its effectiveness.

When the vessel was piloting to the orientation base according to the indicated scheme, an increase in the accuracy of assessing the lateral deviation of the vessel from the path, decrease in the frequency of rudder shifts, smooth increase and decrease in the angular vessel speed were noted.

Using the radar simulator when conducting estimated vessel runs

Below there is the data on the pilotage of the estimated vessel using only radar for the downstream case.

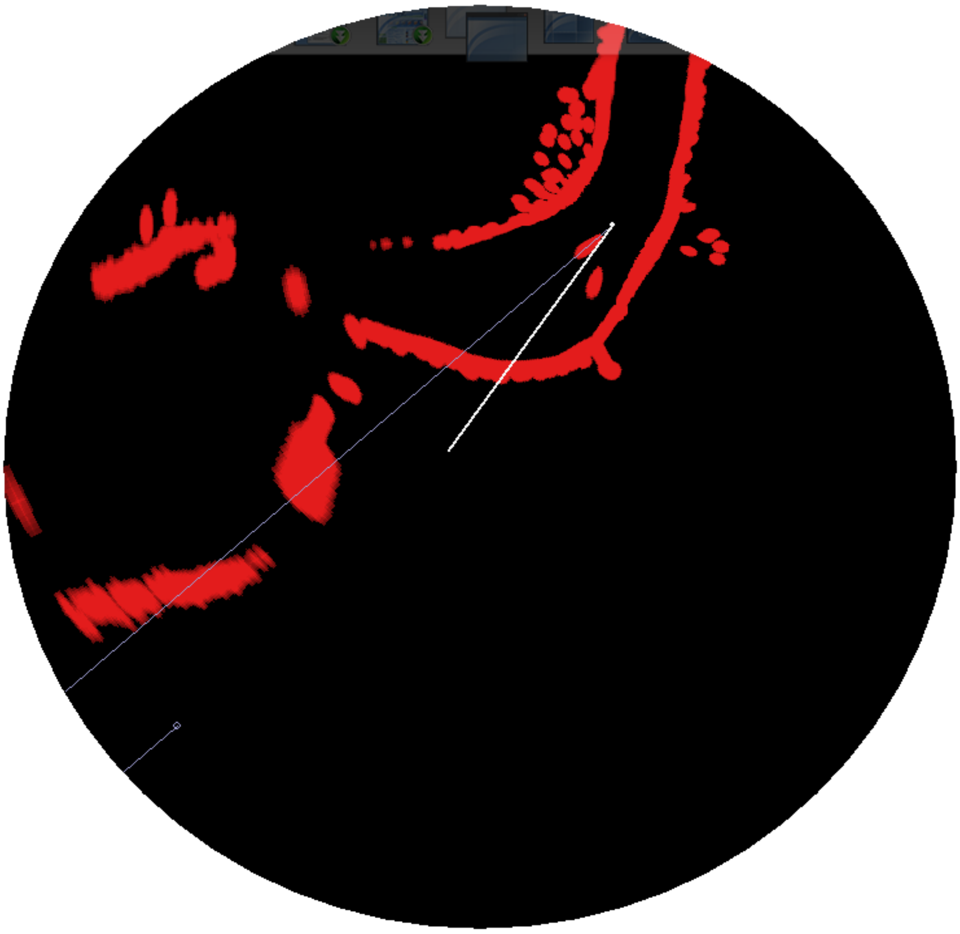


Figure 6.35. Display on the radar PPI of the entire navigation situation around the vessel, observed at the time of the beginning of the turn from the Nizhny Pellovsky range line to the Verkhniy Pellovsky range line

Mathematical modeling of the controlled movement of the vessel began from ZAO Spetsdorstroy berth located at the left bank of 1,336.8th km. Further, the vessel, under the control of experienced navigators, made a smooth turn and entered a rectilinear section, along which the bow Petrushinsky and the opposite aft Kuzminsky range line lead.

This section has sufficient dimensions. Before the start of the turn to the next straight section, the fairway is constrained by Ostrovskaya Luda, which is a navigational hazard. Based on the results of the simulator pilotage of the vessel, the ability to navigate by radar display of the right bank in this place is shown. The right bank in this section is steep, which allows the vessel to be steered closer to the right bank, without excessive approach to the dangerous isobath.

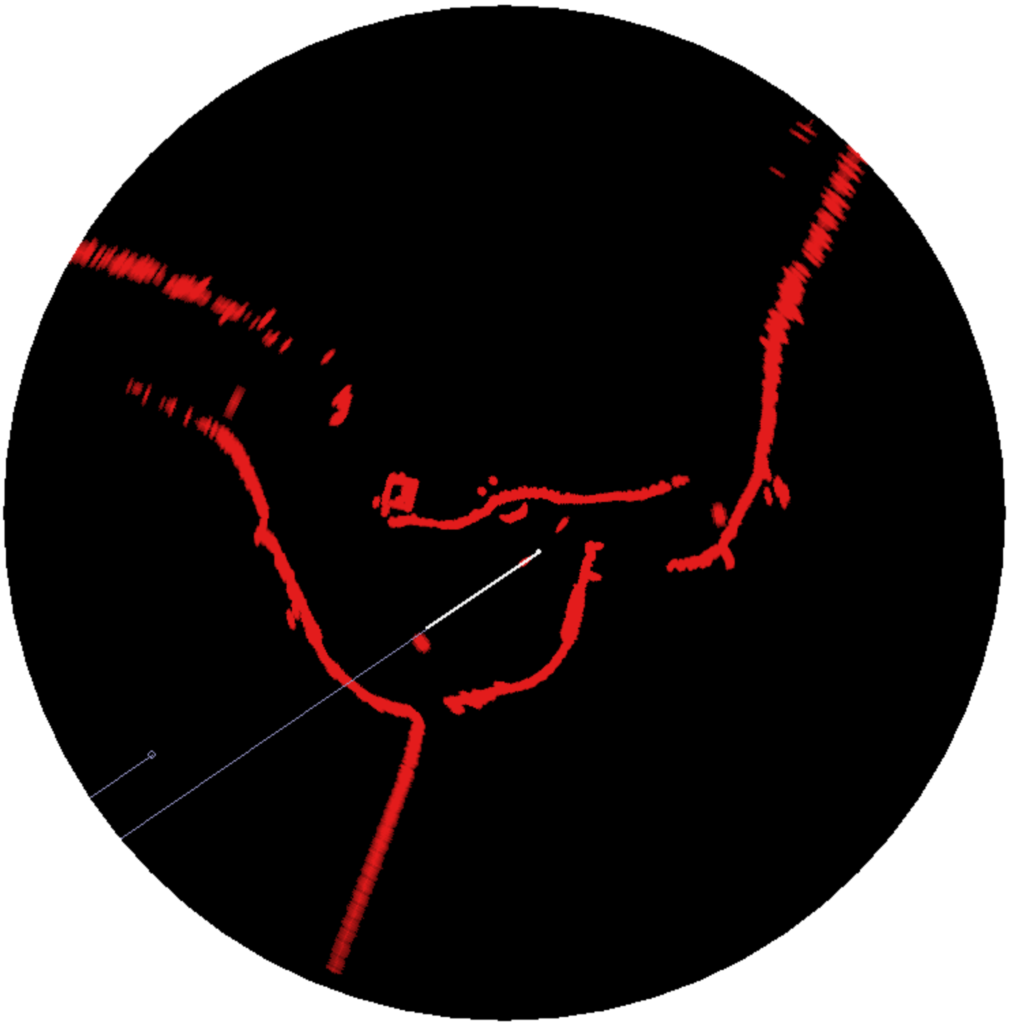


Figure 6.36. Display on the radar PPI of the entire navigation situation observed in the area that causes difficulties when piloting

Further, during piloting when entering the Nizhniy Oranzhereysky range line, following this range it is possible to perform a confident orientation, including determining the vessel position not only relative to the right and left edges of the fairway, but also relative to the distance to the exit to the point where the turn starts on the next straight line section, using the ducts separating Glavryba Island as radar reference points.

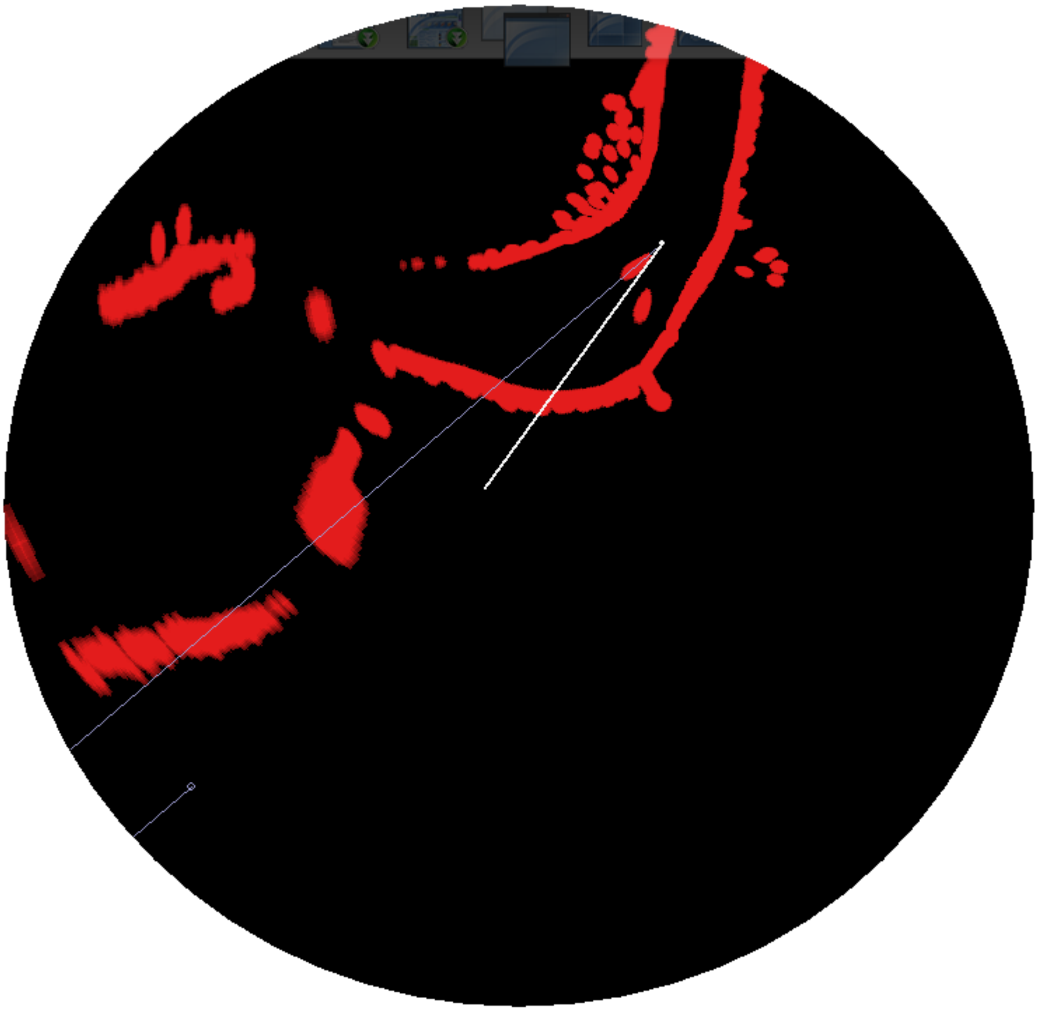


Figure 6.37. Display on the radar PPI of the entire navigation situation around the vessel, observed at the time of the beginning of the turn from the Nizhny Pellovsky range line to the Verkhniy Pellovsky range line

The use of the right bank as the main reference point allows, when approaching the turn at Tikhmenovskaya Luda, to start the turn in advance and, thus, take into account the vessel drift under the cross current influence to the right bank. When entering the Nizhniy Pellovsky and the opposite Maslovsky range line and decreasing the speed to ensure good controllability and power reserve when passing through the rapids, the vessel yaw rate increased, which made it difficult to control its position, movement, and resulting in movement correction.

In view of this, it was decided not to reduce the vessel speed since only in this way it was possible to overcome the excessive vessel yawing and focus on conducting radar surveillance.

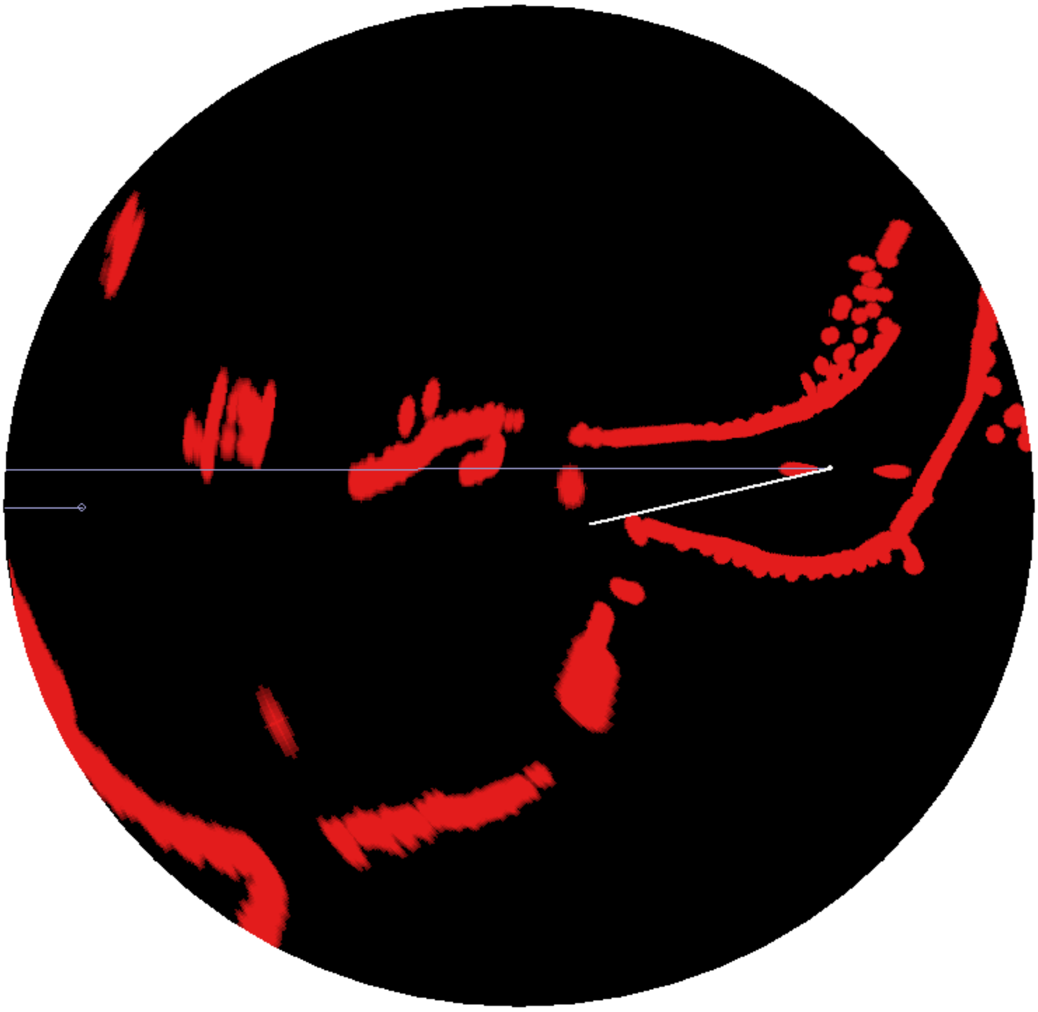


Figure 6.38. Display on the radar PPI of the entire navigation situation around the vessel, observed when approaching the Verkhny Pellovsky range line

Entry to the Nizhny Pellovsky and opposite Maslovsky range line did not cause any difficulties, since the radar image clearly shows the coast bend in the area of Maslovskaya Luda.

When approaching the point of the beginning of a sharp and prolonged turn at Verkhneporozhskaya Luda, when passing from Nizhny Pellovsky to the stern Verkhny Pellovsky range, it is necessary to try to keep the vessel without significant angular velocities and avoid significant drift. With an early start of the turn, one can get too close to the right bank and, thus, lose radar control over the distance to the right bank, since the fairway axis is already at a close distance.

Figure 6.39. Display on the radar PPI of the entire navigation situation around the vessel, observed at the time of the change in the direction of the vessel speed vector when moving along the Verkhny Pellovsky range line

Thus, in this area it is necessary to determine as accurately as possible the moment of the turn beginning to avoid large rudder shifts to the right, during which the stern can roll to the left under the cross current influence.

When approaching the Verkhny Pellovsky range line to the Cape Svyatki gradually turn to the left on the Verkhny Novoderevensky range line and the opposite Verhneporozhsky range line. Having entering the specified range lines increase the speed. From the Verkhny Novoderevensky it is necessary to go to the stern Tosnensky range line leading to the rapids exit.

Figure 6.40. Display on the radar PPI of the entire navigation situation around the vessel, observed when moving along the Tosnensky range line

When port-to-port passing with meeting vessels the following shall be done:

-passing the Nizhny Pellovsky range, move to the fairway right edge (to the right along the course) and keep closer to the red buoys, making sure that the vessel stern does not cross the Verkhny Pellovsky range line;

-passing the Verkhny Novoderevensky range, having going to this range line and passing Cape Svyatki, keep the vessel bow closer to the range line and prevent the vessel drift to the upper part of the Bolsheporozhskaya luda. Then keep to the fairway right edge making sure that the vessel or convoy stern does not cross the Verkhny Novoderevensky range line;

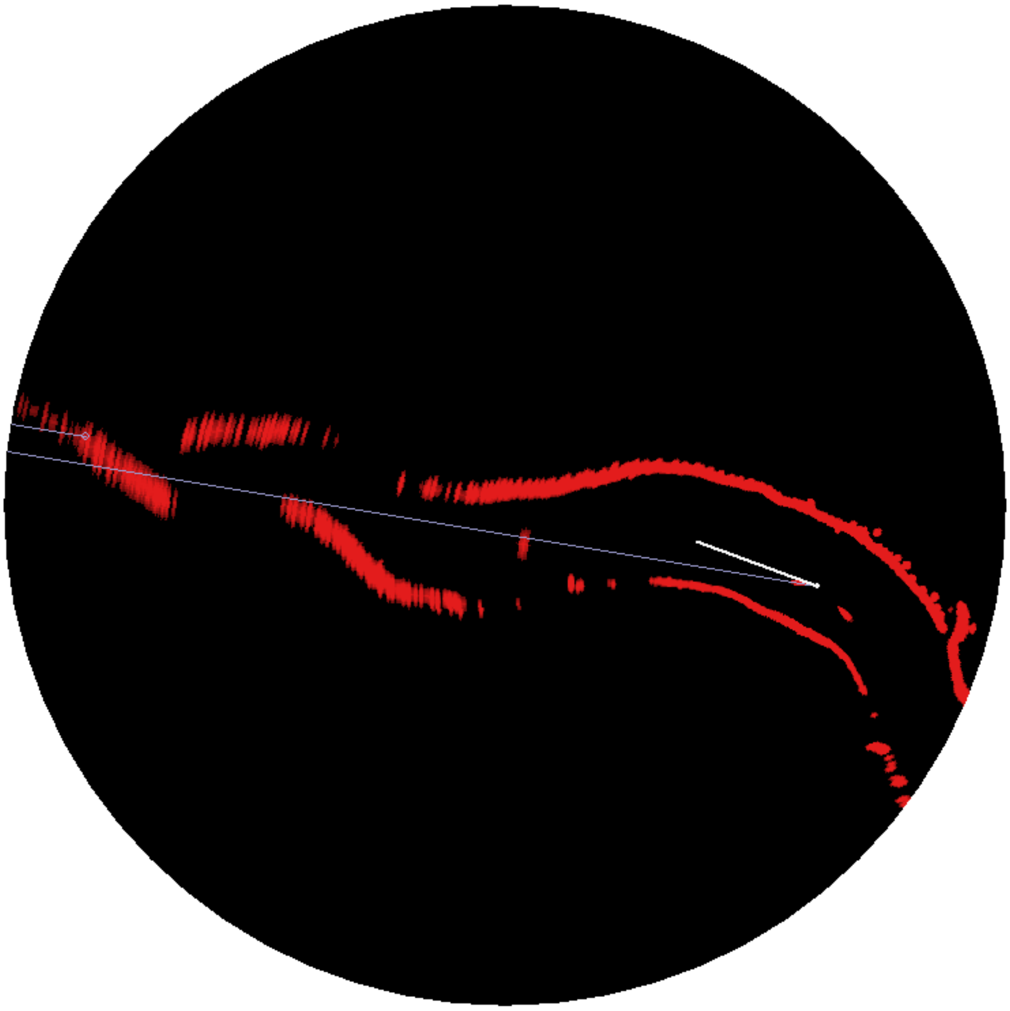


Figure 6.41. Display on the radar PPI of the entire navigation situation around the vessel, observed when approaching the Chernorechensky range line

-passing the Tosnensky range line from the red buoy No. 22 turn right smoothly and avoid a high drift of the vessel or convoy to the meeting vessels.

When approaching the turn from the Tosnensky section to the bow Saperny and the opposite aft Chernorechensky range line, it is necessary to keep in mind that the section of the fairway axis runs close to the left bank. Moreover, this section is located after the buoys indicating the left edge.

Therefore, it is necessary to steer the vessel so that, while conducting radar surveillance, continuously monitor the distance to the left bank.

Passing this hazard place, it is necessary to keep the vessel to a straight section, along which the aft Nizhny Novoderevensky range line leads. Therefore, when moving this straight section, it is necessary to determine the fairway leading between the Sverdlovskaya Luda and the shallows located near the left bank.

According to the results of the estimated vessel piloting along the difficult for navigation Ivanovskiye Porogy rapids section, when moving downstream using only radar, it can be noted that the proposed arrangement of floating navigation signs allows to improve the navigation quality, which manifests itself in less yaw both from an uneven current and hydrodynamic interaction when the vessel approaches the fairway edges.

According to the results of the simulator pilotage of the vessel, the correctness of the choice of the course by the navigators was noted when moving from narrow straight sections to wide ones and vice versa, without fear of excessive approaching with the dangerous isobath.

Below there is the data on the estimated vessel pilotage using only radar for the upstream case.

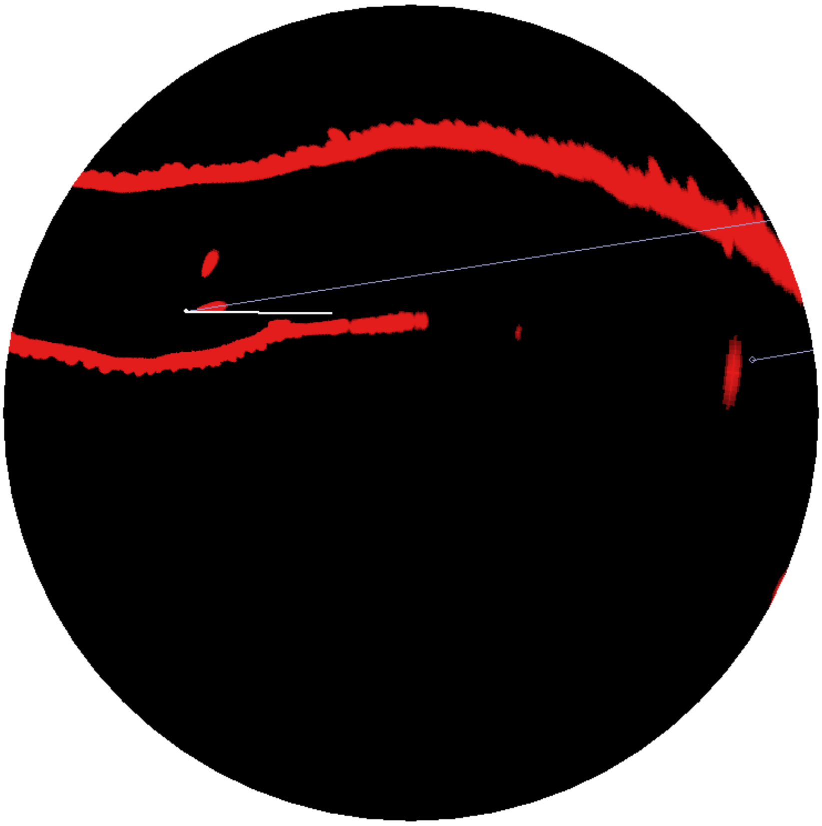


Figure 6.42. Display on the radar PPI of the entire navigation situation around the vessel, observed when approaching the Chernorechensky range line

The approach to the Ivanovskiye Rapids section, difficult for navigation, when moving upstream, starts from the Pirogovo pier. Passing this hazard place, it is necessary to keep the vessel to a straight section, along which the Nizhny Novoderevensky range line leads. Therefore, when moving this straight section, it is necessary to determine the fairway leading between the Sverdlovskaya Luda and the shallows located near the left bank.

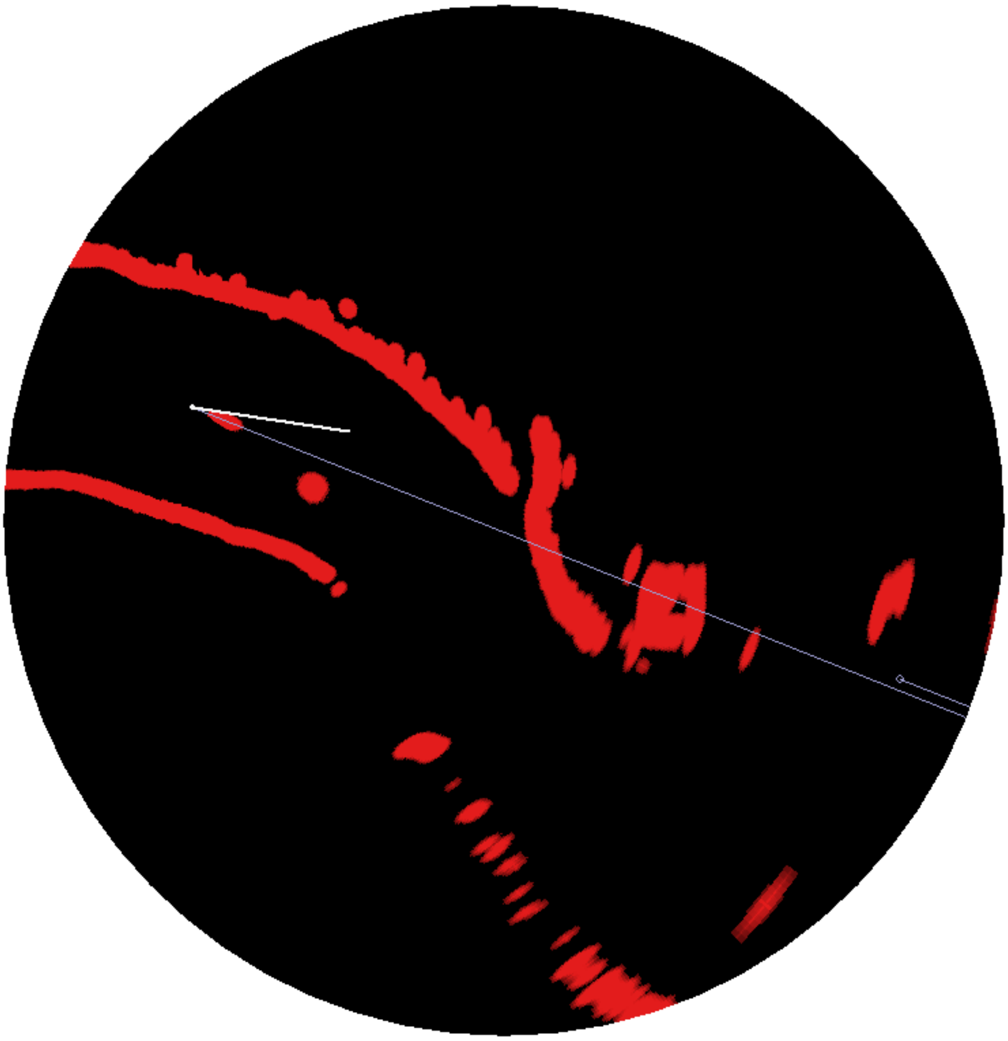


Figure 6.43. Display on the radar PPI of the entire navigation situation around the vessel, observed when approaching the Tosnensky range line

When approaching the Sverdlovskaya Luda, make a smooth turn to the Chernorechensky and the opposite Saperny range lines. It should be borne in mind that the Chernorechensky range line is more sensitive.

Moreover, this section is located after the buoys indicating the left edge.

Therefore, it is necessary to steer the vessel so that, while conducting radar surveillance, continuously monitor the distance to the left bank.

Figure 6.44. Display on the radar PPI of the entire navigation situation around the vessel, observed when moving along the Tosnensky range line

By passing the Novoderevenskaya luda steer to the Tosnensky range line. At the point of transition from Chernorechensky to Tosnensky range line passing and overtaking vessels are not recommended.

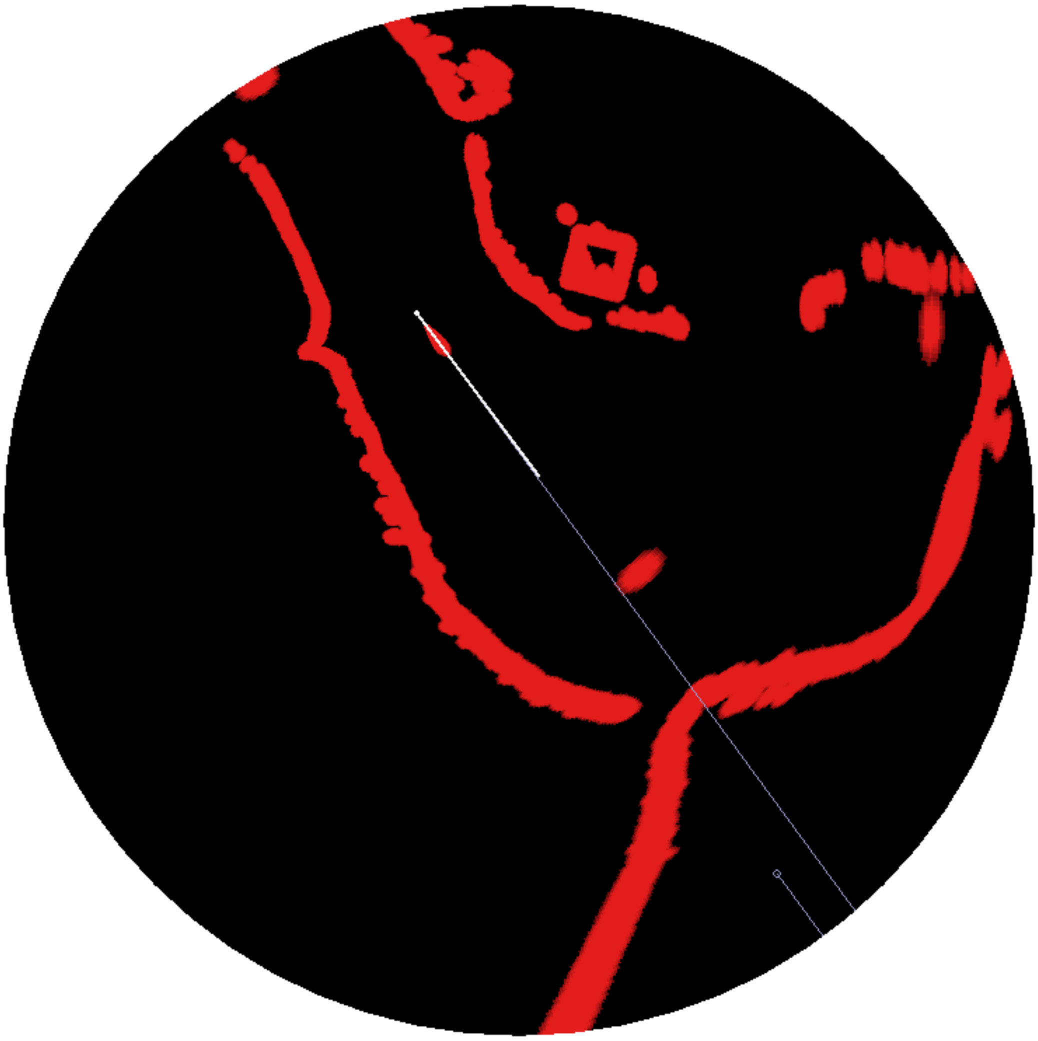


Figure 6.45. Display on the radar PPI of the entire navigation situation around the vessel, observed when moving along the Tosnensky range line

When moving up the Tosnensky range line, if necessary, a vessel moving upstream may pass up a meeting vessel or a convoy on its starboard side. To do this, keep to the fairway right edge and stop the movement downstream the red buoy No. 18 against the pier at the Hill of Glory. In the absence of meeting vessels and convoys move smoothly from the Tosnensky range line to the Verkhneporozhsky range line the opposite Verkhny Novoderevensky range line.

Figure 6.46. Display on the radar PPI of the entire navigation situation around the vessel, observed when approaching the Verkhneporozhsky range line

When port-to-port passing with meeting vessels and convoys the following shall be done:

-passing the Tosnensky range to deviate from this range line to the fairway left edge (to the right along the course), taking into account a drift of the vessel or convoy moving downstream;

-passing the Verkhneporozhsky range line, deviate from the line to the fairway left edge (to the right along the course) and go along this edge without approaching white buoys to a distance of less than 20 m; in this case, it is necessary to take into account the effect of the cross current directed towards the Ivanovskaya luda;

-passing the Verkhny Pellovsky range line, go around Cape Svyatki keeping at a distance of 30-40 m from the left bank; then go to the right of the range line, taking into account the drift of the vessel passing downstream and the effect of the cross current directed to the Pellovskaya Zavod creek.

Figure 6.47. Display on the radar PPI of the entire navigation situation around the vessel, observed when approaching the Verkhneporozhsky range line

Passing the Verkhneporozhsky range line, it is necessary to take into account the effect of the cross current directed towards the Ivanovskaya luda. The buoys placed in this section form a straight line, the direction of which slightly differs from the direction of the axis of the fairway, indicated by the Verkhneporozhsky and the opposite Verkhny Novoderevensky range lines. This allows the master to choose the right course both in the event that when entering the straight-line section there is a delay in pullout and the vessel will yaw in the direction of the

Verkhneporozhskaya Luda, and in the case when the vessel completes the turn without entering a new course.

Figure 6.48. Display on the radar PPI of the entire navigation situation around the vessel, observed when approaching turning place to the Verkhny Pellovsky range line

Figure 48 shows entire navigation situation around the vessel observed on the radar PPI, and a vessel speed vector and course line when approaching the turning point to round Cape Svyatki, drift angle indicates velocity value of the cross current directed to Ivanovskaya Luda. Thus, the positioned buoy, the echo signal of which is clearly visible in Figure 6.48, assists the master to start the turn in time and maintain the difficult trajectory.

Figure 6.49. Display on the radar PPI of the entire navigation situation around the vessel, observed when turning to the Verkhny Pellovsky range line

Against Cape Svyatki go from the Verhneporozhsky range line to the Verkhny Pellovsky range line. According to Figure 6.49, where navigational situation observed by the navigator presented on the radar PPI is displayed, it can be concluded that the installed additional buoy is significant, being guided by which the navigator can determine the starting point of the turn to the Verkhny Pellovsky range and, when beginning the turn, keep the vessel without significant angular velocities and avoid significant drift.

Figure 6.50. Display on the radar PPI of the entire navigation situation around the vessel, observed when approaching the Verkhny Pellovsky range line

At the end of the turn to the Verkhny Pellovsky range line, the echo signal from the additional buoy placed at Cape Svyatki enters the shadow sector of the vessel radar station, however, the navigator can correctly determine the new course, based on visual observation of the vessel movement parameters and being guided by the echo signal from the additional buoy near Pellovskaya Zavod creek, clearly visible in Figure 6.50, which provides an overview of all navigational conditions observed around the vessel.

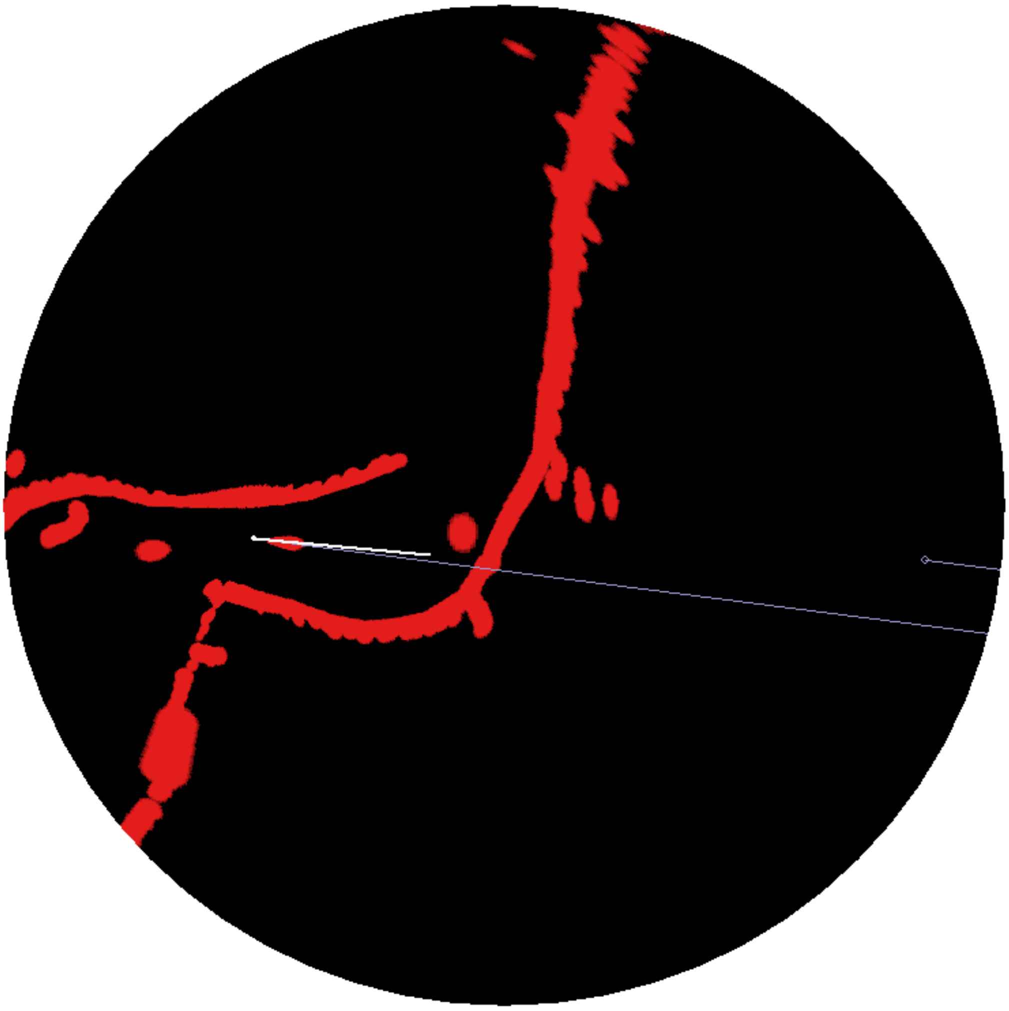


Figure 6.51. Display on the radar PPI of the entire navigation situation around the vessel, observed when moving along the Verkhny Pellovsky range line

When port-to-port passing with meeting vessels and convoys by passing the Verkhny Pellovsky range line, go around Cape Svyatki by keeping at a distance of 30-40 m from the left bank; then go to the right of the range line, taking into account the drift of the vessel passing downstream and the effect of the cross current directed to the Pellovskaya Zavod creek.

Figure 6.51 shows the entire navigational situation around the vessel observed on the radar PPI. Between two echoes from the navigation floating signs, which are also clearly observed on the radar PPI, it is possible to visually draw a straight line, which indicates the fairway axis, which enables each of the vessels to follow its own side of the fairway.

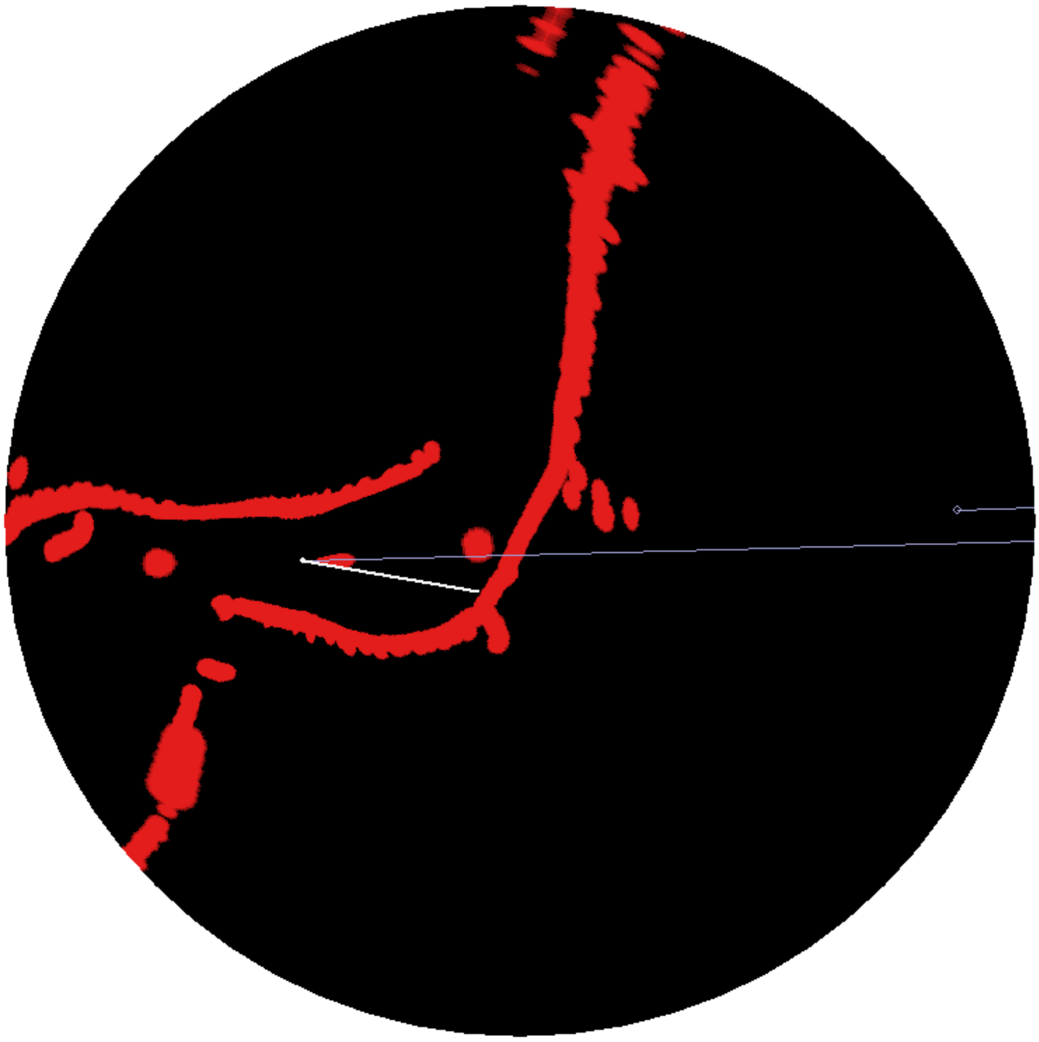


Figure 6.52. Display on the radar PPI of the entire navigation situation around the vessel, observed at the beginning of the curvilinear movement when leaving the Verkhny Pellovsky range line

When approaching the point of the beginning of a sharp and prolonged turn at Pellovskaya Zavod, when passing from Verkhny Pellovsky to the stern Nizhny Pellovsky range, it is necessary to keep the vessel without significant angular velocities and avoid significant drift, which will compensate for the effect of the cross current directed to the left edge of the fairway to the Pellovskaya Zavod creek. Figure 6.52 shows entire navigation situation around the vessel observed on radar PPI and vessel speed vector and course line at the start of the curvilinear motion when moving from the Verkhny Pellovsky range line, even visually one can assess the cross current force.

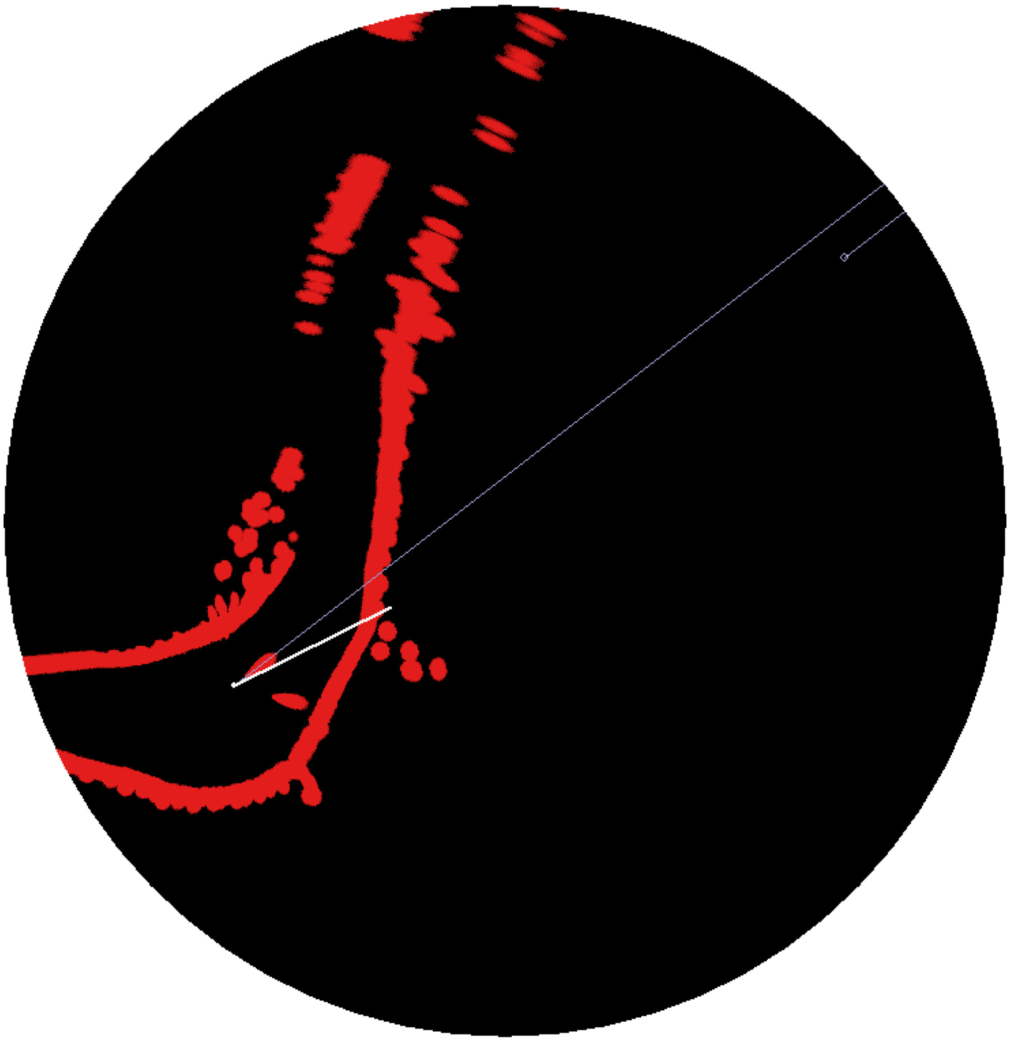


Figure 6.53. Display on the radar PPI of the entire navigation situation around the vessel, observed during curvilinear movement when leaving the Verkhny Pellovsky range line

With an early start of the turn, one can get too close to the right bank and, thus, lose radar control over the distance to the right bank, since the fairway axis is already at a close distance.

Thus, in this area it is necessary to determine as accurately as possible the moment of the turn beginning to avoid large rudder shifts to the right, during which the stern can roll to the left under the cross current influence.

Figure 6.54. Display on the radar PPI of the entire navigation situation around the vessel, observed during curvilinear movement when approaching the Verkhny Pellovsky range line

When moving the Maslovsky range line, the vessel yaw is observed, however, the river banks in this section are steep and are good radar reference points. The yaw rate in this section is caused by an uneven current, therefore, to overcome yawing, the vessel speed shall not be reduced. In such a situation, it is more important for the master to concentrate on conducting radar surveillance and in time to determine the moment of transition to the next straight section along which the Verkhny Oranzhereyskiy range line leads. The turn shall be started in such a way as to avoid the yawing in the direction of Maslovskaya Luda, which may occur if the vessel approaches at a short distance.

Figure 6.55. Display on the radar PPI of the entire navigation situation around the vessel, observed during curvilinear movement when approaching the Nizhny Pellovsky range line

Further, during piloting when entering the Verkhny Oranzhereysky range line, by following this range it is possible to perform a confident orientation, including determining the vessel position not only relative to the right and left edges of the fairway, but also relative to the distance to the exit to the point where the turn starts on the next straight line section, using the ducts separating Glavryba Island as radar reference points.

Figure 6.55 shows the entire navigation situation on the radar PPI, as well as the vessel speed vector, during curvilinear movement when entering the Nizhny Oranzhereyskiy range.

Further, the vessel made a smooth turn and entered a rectilinear section, along which the bow Petrushinsky and the opposite aft Kuzminsky range line lead.

This section has sufficient dimensions. Before the start of the turn to the next straight section, the fairway is constrained by Ostrovskaya Luda, which is a navigational hazard. Based on the results of the simulator pilotage of the vessel, the ability to navigate by radar display of the right bank in this place is shown. The right bank in this section is steep, which allows the vessel to be steered closer to the right bank, without excessive approach to the dangerous isobath.

6.7. Carrying out simulated runs of the estimated vessel using ECDIS only

Using ECDIS when conducting estimated vessel runs

The navigation simulators use ECDIS Navi-Sailor 3000 manufactured by Transas, which is one of the most widespread electronic cartographic systems in the world. ECDIS Transas has type approval certificates of the Russian Maritime Register of Shipping, the Ministry of Transport of the Russian Federation, the Russian River Register of Shipping, BSH, DNV. The real electronic-cartographic system, which is part of the simulator, allows to study all the nuances of working with electronic maps, including the creation and elaboration of routes, updating of electronic maps, as well as the principles of displaying various information.

The Navi-Sailor 4000 ECDIS MFD system is a multifunctional and adaptable solution that provides the navigator with all the necessary information to assess the navigation situation and make decisions.

User-friendly interface allowing a single watch officer to work on the bridge, reducing workload and stress;

Self-intuitive interface for convenient work with the system;

Improved functional integration of navigation data;

Redundant system: all ECDIS, radar and conning display functions are available on any vessel multifunction display;

Graphic palette synchronization in all applications;

Sensor redundancy and dual network ensure data integrity and reliability in network configuration;

Rational and efficient alarm processing;

Simultaneous monitoring of the loaded route in ECDIS, on the radar and on the conning display;

Switching the status of the main ECDIS station to any station in the network;

Distribution of radar images in network from all available radars;

Synchronization of the route, user database, collection of maps and updates to it on all workstations and in all applications;

Benefits

Safe navigation and ease of use

All necessary information is presented through a convenient, intuitive interface.

Information system and decision support

A continuous flow of information to display the most important and necessary navigation data and objects.

Possibility of choice and adaptation to specific requirements

New options such as multi-mode operation with seven different card formats make it possible to optimize the system according to customer needs.

Sensor integration

Integration of all available navigation sensors and systems, such as two positioning systems, gyrocompass, log, two ARPA systems, AIS, echo sounder, autopilot, Navtex and others.

Even in the minimal configuration, it is possible to exchange information with radar/ARPA and display AIS information. The simulator fully complies with the requirements of IMO, STCW.

When carrying out mathematical modeling to assess the position and movement of the vessel along the fairway, the visual observation of the position of the symbol of the vessel displayed in scale and the vector of the vessel speed was evaluated.

The reference trajectory was the fairway axis indicated on the electronic chart.

The vessel position in the fairway can be described by the following parameters: distanced from the center of mass of the vessel from the fairway axis, its linear dimensions and drift angle (leeway). As is well known, the position of center of mass relative to the centre of the fairway can be subsumed under the parameter characterizing the quality of the vessel control by the entire control system (the bridge command itself and the regional vessel traffic control system), and the drift parameter will characterize the effect of wind and current in the navigation area. Taking into account the current state of the navigation equipment system in the navigation areas, the vessel position (center of mass) can be measured very accurately (errors range from 1 to 3 meters with a probability of 0.997).

In addition, modern ship navigation aids and systems allow to determine and evaluate a whole vector of navigation parameters, including the drift angle.

Own vessel symbol can be displayed in ECDIS on a map scale, which is important for assessing the accuracy of the vessel movement, in particular for estimating the starting point of the turn, for using predictive tools for the vessel movement, for evaluating the lateral deviation of the vessel from the trajectory or from the dangerous isobath.

The *standard load* is the minimum set of data to ensure safety during route plotting and planning. Standard load includes baseline one as well as drying-up lines, stationary and floating navigation aids, fairway boundaries, channels, prominent visual and radar objects, prohibited and restricted areas, and some other information.

The *full load* consists of standard and all other information. All other information includes: depth values, submarine cables and pipelines, ferry routes, details of all individual hazards, features of navigational aids, warning content to mariners, date of issue of electronic map, horizontal geodetic datum, zero depths, magnetic declination, geographical names, etc.

To improve the safety of navigation and to ensure the possibility of quick adoption of correct and well-grounded decisions, the master shall be provided with information characterizing all aspects of the navigation process in a visual and easily interpretable form. The basis of such integrated information is an electronic map.

For ease of use, electronic map shall be displayed both in the *original scale*, which corresponds to its data, and in other scales. The scale at which the map is presented on the display screen is called the *image scale*. The map imaging on the display at a larger scale than the original one, called the *rescaling* (overscale). It should be borne in mind that when rescaling the map may turn out to be underloaded, i.e. not detailed enough, so the system should inform the operator about cases of rescaling.

Presentation on screen display maps at a scale smaller than the original called *downscaling* (underscale). Unless special measures are taken, in case of underscaling the map may become overloaded with information.

With the change in the map scale the concepts of the largest and smallest image scales are associated. The *largest (smallest) map scale* is the value of the largest (smallest) scale at which a particular map can be displayed in the system.

Own ship's safety contour - the contour line corresponding to the least safe depth — in master's opinion — for the vessel at a given draft. The value of this depth is entered into the system by the navigator, and serves to distinguish hazardous waters from safe waters on the display and is used to generate a signal about the hazard of grounding.

In some systems, the *own ship's symbol* can be selected in the form of its outline expressed in scale or as a symbol. The ship image is scale-adjusted as per the maximum length and breadth of the *hull contour* is produced on a large scale map and is used to evaluate on the display the free space when navigating in narrows and in fairways, and the distance to hazards. Own ship's symbol is a symbol, not necessarily in the form of a "boat", intended to indicate and easily distinguish the own ship position on a map.

An important advantage of ECDIS is the *cartographic information discrimination function*. It allows to set the map load level — usually one of three levels of information density is used: Basic, Standard, and Full; selective display or highlighting of certain types of data: navigation aids, lighthouses, wrecked ships, isobaths and a number of other cartographic objects.

In ECDIS, the map is presented in true or relative motion mode. In the true motion mode during the execution plotting, the automatic shift of the map is provided when the ship approaches the screen edge, so that the ship is always in the display field. In relative motion mode, the ship is in the center of the screen, and the map "floats" relative to it.

Tracking and tracing

ECDIS continuously monitors the vessel passing along the route. It provides the navigator with the route name and the data of its passage: strip coordinates: distance (DTG), bearing and estimated time (TTG) of movement to the nearest waypoint; the expected time of arrival at this point (ETA), bearing to this point (WTG), and the current heading offset to reach that point (difference between HOG and WTG). The current heading of the planned route (CUR) and the following heading (NXT), as well as the lateral offset from the route (XTE) are also displayed.

For visual control of the ship movement along the planned route, ECDIS allows to show on the map the *permissible limits of the route* (Clearing lines). ECDIS warns of deviations from the route outside the specified limit, as well as the approach to the turning point, so that the master can prepare for maneuvering in advance.

There is a *function for operational route modification* without using the "preliminary plotting" section.

Navigational safety control

ECDIS monitors the navigation safety in an automatic mode according to parameters that can be set by the master, for a certain period, in relation to specific navigation circumstances and conditions. Also in ECDIS, due to the specified mathematical algorithms, a security circuit (safety online) is formed, which can be displayed or not. The function of automatic warning signal when a dangerous object enters the safety figure, regardless of whether it is shown on the screen or not, is implemented. Several types of warnings are generated. Each type has its own field on the display panel and is accompanied by a special sound signal, also with the possibility of duplicating a voice message.

ECDIS has a *function for setting the traffic lane width* when navigating along a given route. During the passage, when the ship leaves this line, an alarm is triggered.

In ECDIS *highlighting safe depth and contour* is possible. The navigator can use this feature to identify areas of hazardous depths on the map (i.e. areas with a depth less than or equal to the ship's safety depth). When the ship enters the area of hazardous depths, according to the map, ECDIS will give an audible warning accompanied by a visual indication. An echo sounder is also connected to the ECDIS to warn the master of hazardous depths. ECDIS interfacing with an echo sounder allows to display depth information on the screen in the form of a bottom relief curve, the echo sounder information is saved by the system and can be played back when the navigation situation is played back in the recording.

In order to draw the master attention and the possibility of taking timely precautions, ECDIS provides automatic warnings about the entry of a ship into areas with special navigation conditions.

To control the ship movements according to the moments when it reaches a certain position relative to one or another characteristic point on the terrain (landmark, hazard, element of the coast, etc.), event markers can be set. A point selected on the map is indicated by a special mark (marking). The navigator can choose the following conditions for the relative position of the ship and the marker:

reaching a given bearing, approaching a given distance, moving away at a certain distance, reaching a traverse. After the described event has occurred, ECDIS will give an audible and visual warning.

The *control of navigation accuracy provides* for the pre-calculation of observation errors for various positional systems (EPE - expected position error) with displaying its boundaries on the screen, comparison of data from several positional means, identification of coarse acquisitions based on comparing the observation with a pre-calculated reckoning position and with observations for another independent positional system. The quality control of information from various sensors is carried out.

The *functions of working with custom layers of information* allow the master to put additional lines, symbols, sectors, text on top of any map to raise the map, which helps to increase the safety of passing difficult sections of the route.

ECDIS provides *receiving and display on the screen of messages from the receiver* (navigation, meteorological and ice warnings, information on search and rescue operations, meteorological forecasts, etc.), which is important when navigating in the estuaries of large rivers where sea vessels can passage.

ECDIS *monitors the operation of navigation devices connected to it and reports a malfunction of any of them* to the master.

In ECDIS, it is necessary to have the following signaling and warning indications, where an alarm means a message by acoustic or acoustic and visual means about conditions and situations requiring the operator's attention; and indication - a visual presentation to the operator of certain information about events, and functioning of the system or equipment. According to the mandatory requirements of the Russian River Register of Shipping, the ECDIS shall ensure *alarm* about going beyond the boundaries of the established traffic lane, crossing the safe contour, exceeding a specified deviation from the route, approaching a critical point (for example, to a turning point), various geodetic systems for determining a place and a map.

Signaling or indication of rescaling, passage through areas with special conditions, malfunctioning of the ECDIS.

Indication that there is a map of a larger scale, that SENC and additional information (for example, from radar) in different coordinate systems, about planning a route through a safe contour, planning a route through a special area, positioning system failure, errors during the system testing.

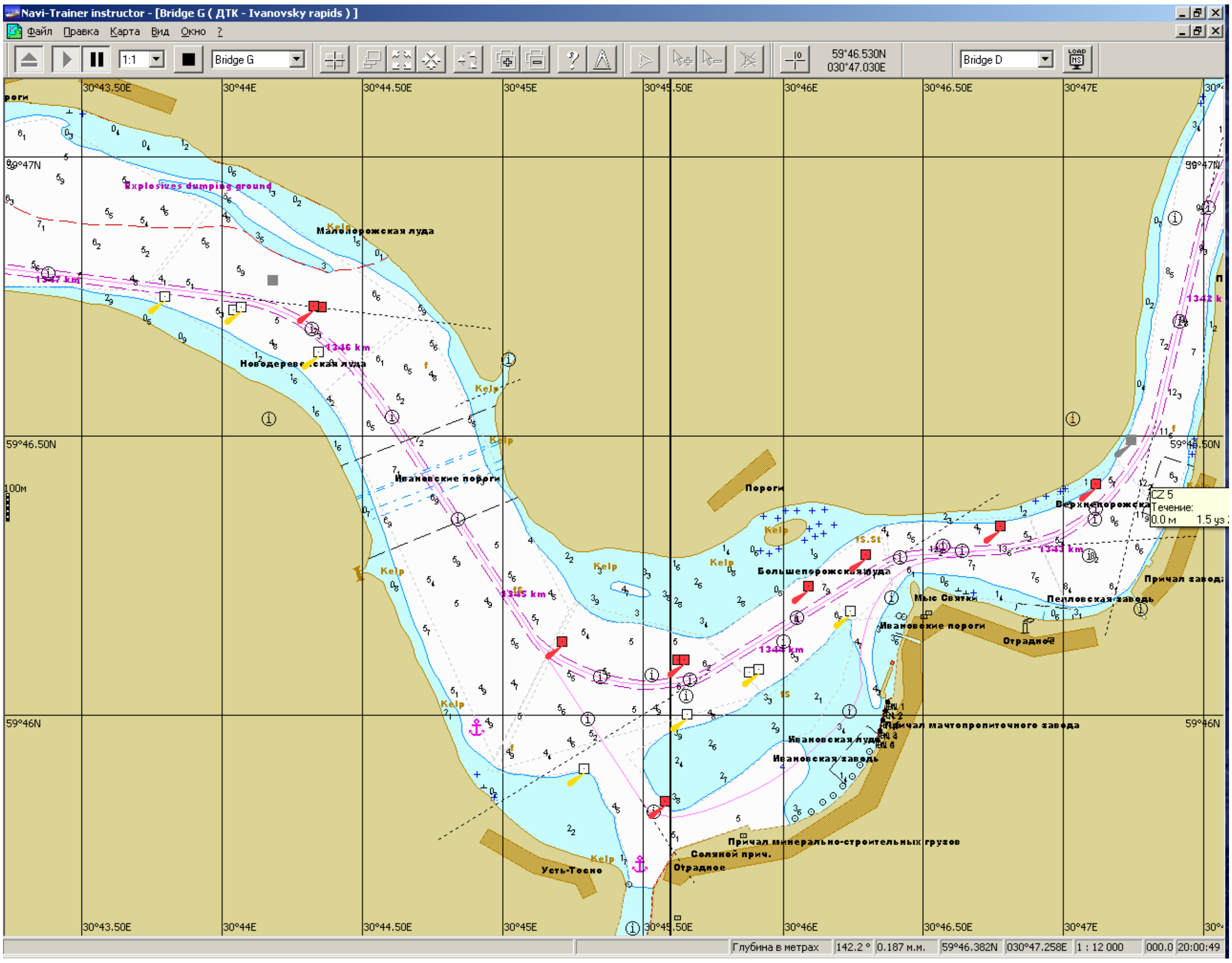


Figure 6.56. Fragment of an electronic navigation map of the most hazard area of the Ivanovskiye Porogy rapids section imaging floating navigation signs

The use of only ECDIS when passing the Ivanovskiye Porogy rapids section, which is difficult for navigation, can significantly increase the navigational safety due to both abrupt changes in the directions of straight sections of the fairway, alternation of narrow and wide sections, the action of cross currents, significant current velocities, variability of currents depending on the water level and places.

Despite the complexity and variability of navigation conditions, control over the location and kinematic parameters of the ship movement, performed using ECDIS, showed an increase in the quantitative account of the effect of wind and current on ship.

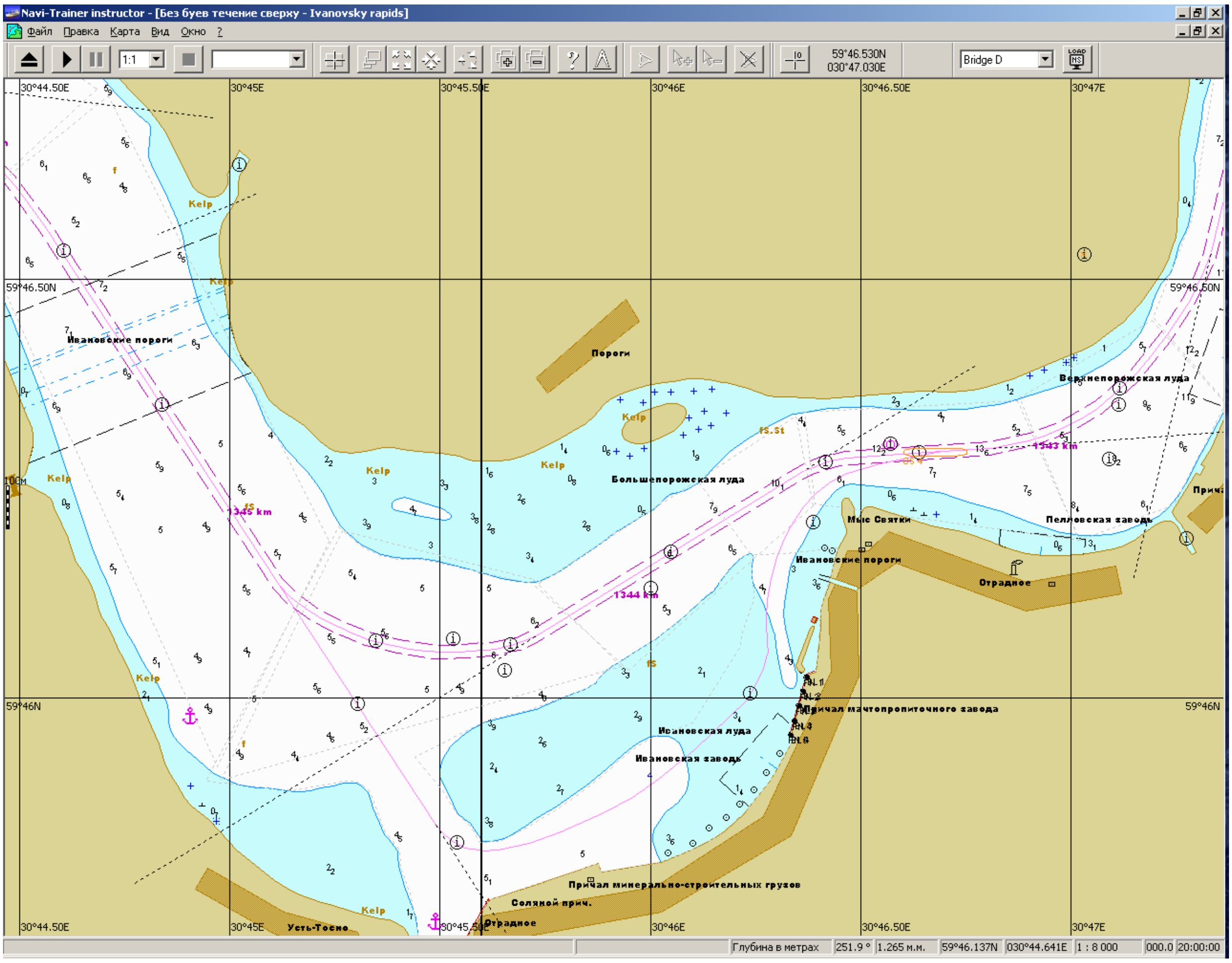


Figure 6.57. Fragment of an electronic navigation map of the most hazard area of the Ivanovskiye Porogy rapids section non-imaging floating navigation signs

Displaying the own ship’s symbol in the form of a contour in a map scale in combination with kinematic parameters allows to take into account the hydrodynamic interaction between the ship hull and the fairway edges when moving the fairway axis passing near the fairway edges, despite the effect of hydrodynamic forces and moments on ships both in nature and in intensity, depending on the position of the ships relative to each other and the shore.

The ECDIS reduces the master workload when keeping the ship on a constant course near the shore, since it accelerates the assessment of forces from the PSU action, and the forces acting on the ship bow and stern. To keep the vessel on a straight course when moving close to one side of the fairway, it is necessary to shift the rudder towards the shore. And the closer to the shore, the more you need to shift the rudder to compensate for the shore effect. Since the efficiency of the rudder is higher at small shift angles, the greater the angle we shift the rudder, the less its efficiency increases, and the remaining shift margin decreases.

In modern river-sea vessels, strong attraction force can be expected when moving in narrow fairways, or when approaching the fairway edges, for reasons of limiting ship dimensions: wide width causes additional yaw; the more vessel length, the more arm of the attraction force moment increases.

In conditions of a significant water space on one side and a constrained cross-section of the fairway on a vessel experiencing the influence of the shore effect, the stern will be yawed, which will come even closer to the shore and as a result the attraction force will become stronger. In addition, there is less space in this case to prevent yawing. Selecting the map scale in ECDIS allows to detail this effect.

At lower speeds, the master has more time to control the weaker shore forces and, in addition, it is possible to increase the propeller speed to improve controllability.

In the general case, when moving along the range line of the considered section, one should not always strictly follow the fairway axis, since its axis approaches either the right or left edge of the fairway. With north winds, keep to the range lines, and the transition from one straight section to another shall be started in advance. The use of ECDIS allows to refine the heading angles of the apparent wind and correct the ship movements depending on the wind directions, which can both facilitate the turn of the ship and prevent it. Therefore, when making a turn with winds of some directions, it is possible to follow the range lines, and in other cases to keep the margin for wind drift, the transition from one range line to another shall be carried out considering the actual position and course of the ship relative to the fairway axis and direction.

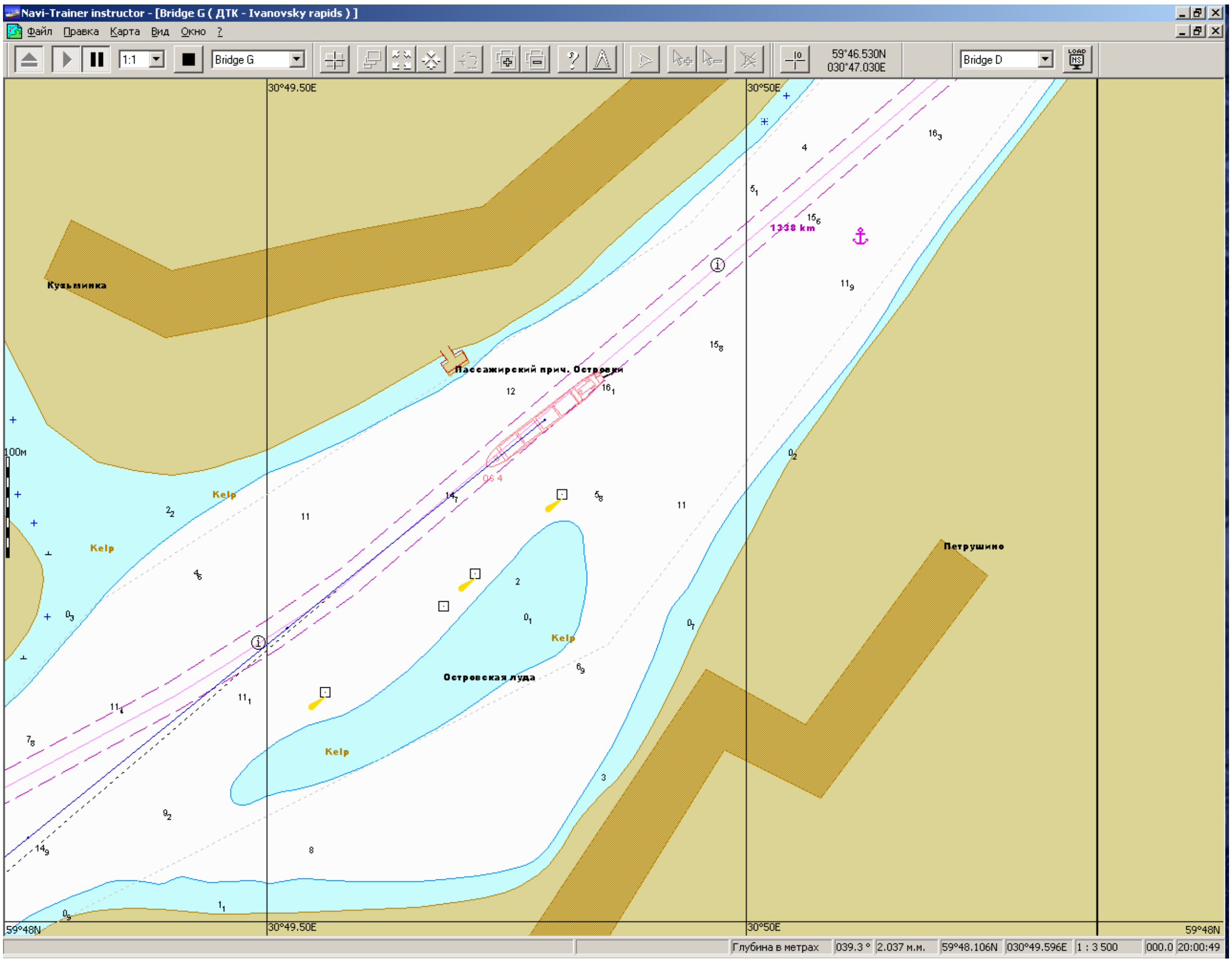


Figure 6.58. Fragment of an electronic navigation map of a straight-line section near Ostrovskaya Luda, imaging floating navigation signs

Attraction force depends on the vessel speed relative to the water, and it rises more slowly when the rudder is turned on board. When the vessel, under the action of the rudder shifted on board, and the increased engine speed, comes to a course, it is necessary to reduce the speed to the initial one and only then begin to gradually ease the rudder, since while the vessel is near the shore, it is exposed to the shore effect. If the vessel yaws across the fairway, the hydrodynamic pressure in the vessel bow, the action of which could prevent subsidence on the opposite shore, is not created because there is no rise of water level between the bow and the shore, as the vessel approaches the other shore at an angle.

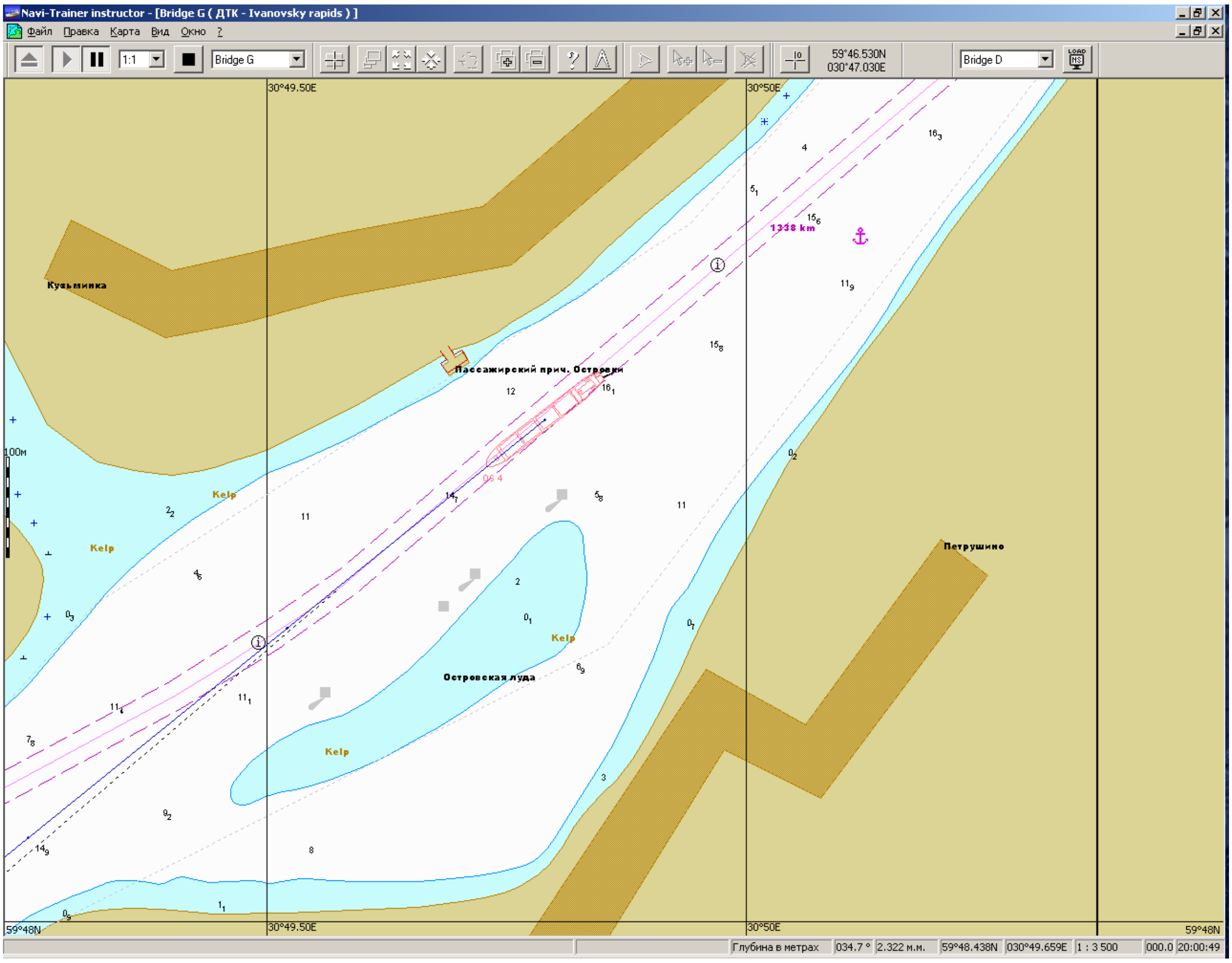


Figure 6.59. Fragment of an electronic navigation map of a straight-line section near Ostrovskaya Luda, non-imaging floating navigation signs

The vessel that has received information about the occupation of an IWW section shall ensure a safe crossing/passing, and if the IWW section does not allow the movement of ships in both directions, simultaneously stop and wait in a place safe for the passage of an oncoming ship.

In case of simultaneous approach of ships passing upstream and downstream to the IWW section, which does not allow the simultaneous movement of ships in both directions, the ship moving upstream shall stop in a safe place and let the vessel passing downstream.

In the event that, for any reason, the crossing at the IWW section is difficult, the ship heading upstream, from the moment the ship heading downstream is detected, shall maneuver so that the crossing occurs in the most convenient place.

CONCLUSIONS

As part of the work the classification list of organizational and technical measures aimed at improving the safety of navigation during the navigation extension period was prepared. Each of the activities was considered in detail.

As part of the analysis of the possibility of ice navigation on the Neva River, data on ice conditions on the Neva River over a long period were collected and systematized. As a result of the analysis, it was found that the conditions vary significantly from year to year, but in the last decade there has been a tendency towards a decrease in the ice cover thickness and even its absence in winter. The results of the analysis indicate a favorable forecast for the navigation during the navigation extension period.

In winter, even in the absence of ice cover, most floating navigation signs are removed from their original positions, but positions of all coastal navigation signs are remained unchanged; ice buoys there are in the most difficult navigation areas. The number and distribution of such signs on the Neva River were analyzed.

Recommendations on information and navigation support for navigators during the navigation extension period were formulated and considered in detail. To ensure the safety during the extension navigation period, it is necessary to develop a special service for prompt provision of the entire range of data to navigators via the Internet. To solve the problem the River Information Service (RIS) or, at the first stage, its elements shall be developed and created. It is also a prerequisite to provide navigators with up-to-date navigation charts. Provided that the ENC is used, the updated files for them shall be promptly delivered to the ships. In the case of using paper navigation charts, this problem can be solved using the "print on demand" technology.

A preliminary navigation, hydrographic and hydrometeorological study of the route and the estimated vessel movement along the selected section of the route was carried out.

The characteristic features of the influence of external factors on the ship are systematized, considering the special pilotage of the section, which allows to develop a unified manner of ship control, and thus increase the synchronization of control actions depending on the kinematic parameters of the ship's movement.

Runs of the estimated vessel were carried out on a navigation simulator for cases of downstream and upstream movement in the complete absence of visibility and the absence of floating navigation signs, including ice buoys-cigars, with navigation only using the radar PPI.

In the process of carrying out the runs, the most suitable radar simulator by functionally for the ship control was chosen.

On the basis of the estimated vessel runs along the considered section, sections were identified during the passage of which control over the vessel movement in the absence of visibility is significantly difficult, which was confirmed by the vessel behavior during control:

These features include:

Poor entry of the vessel in turning;

Unstable movement with significant course changes during the transition from one straight section to another;

Poor possibility to pullout in time with wind and curved currents;

Yawness when moving straight sections.

The analysis of a possible layout of the minimum number of floating navigation signs was carried out.

A scheme for the placement of floating navigation signs was selected and approved, including the minimum number of signs to ensure the ability to control the ship's exit to the point of the turn beginning, curvilinear movement and exit to a new straight section.

The estimated vessel runs were carried out on a navigation simulator for cases of downstream and upstream movement in poor visibility and the presence of a minimum number of floating navigation signs, with navigation only using radar PPI.

The number of runs was assessed as sufficient for subsequent statistical analysis.

Mathematical modeling of the estimated vessel movement along the selected IWW section was carried out in the complete absence of a floating navigation signs and poor visibility.

The areas where the difficulty in the radar orientation in combination with hydrometeorological factors leads to the ship moving out of the fairway or grounding are determined.

The optimal scheme for setting the minimum amount of floating navigation signs was chosen for the navigation extension period.

The simulation of the estimated vessel movement along the section equipped in accordance with the approved scheme was carried out.

The number of runs was determined by the expert group as sufficient according to the amount of recorded data on the vessel movement.

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