REPUBLIC OF SERBIA
CENTER FOR INVESTIGATION OF ACCIDENTS IN TRANSPORT
SECTOR FOR INVESTIGATION OF ACCIDENTS IN WATERBORNE TRAFFIC
Nemanjina 11, 11000 Belgrade

No.: 342-00-5/2025-03-9

Date: 29.12.2025

ANNUAL REPORT FOR 2024

C O N T E N T:

The Center for Investigation of Accidents in Transport (hereinafter referred to as: the Center) is a special organization, which includes the Sector for Investigation of Accidents in Waterborne Traffic, that carries out professional activites related to the investigation of accidents in waterborne traffic, referring to the investigation of very serious maritime accidents, serious maritime accidents, maritime accidents, serious inland navigation incidents and inland navigation incidents in waterborne traffic.

Pursuant to the Article 7 of the Law on Investigation of Accidents in Air, Railway and Waterborne Traffic ("Official Gazette of RS" No. 66/15 and 83/18), the Sector for Investigation of Accidents in Waterborne Traffic issues **this Annual Report for 2024.**

1. Center

The Center has been formed pursuant to the Law on Investigation of Accidents in Air, Railway and Waterborne Traffic ("Official Gazette of RS" No. 66/15 and 83/18).

Within Center, the following basic internal units are established: Sector for Investigation of Accidents in Air Traffic, Sector for Investigation of Accidents in Railway Traffic, Sector for Investigation of Accidents in Waterborne Traffic and General Affairs Department. (the structure of the Center is shown in Fig. 1.1.).

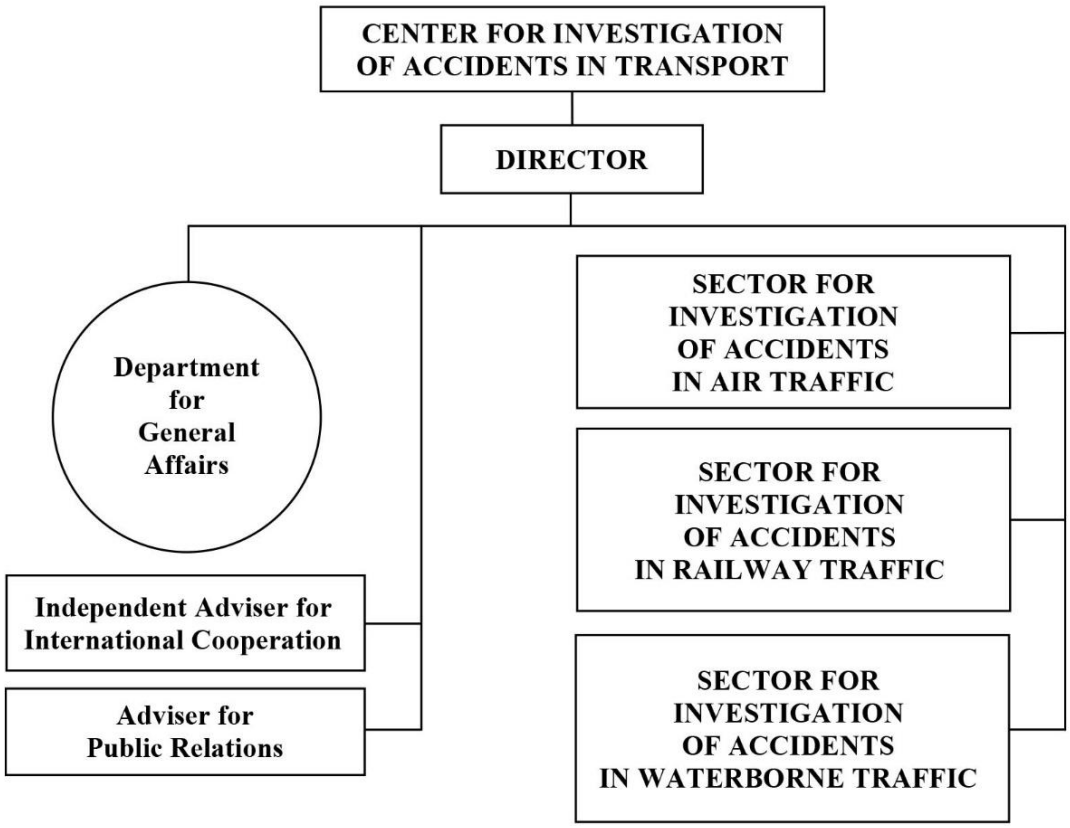


Figure 1.1. The structure of the Center

Sector for Investigation of Accidents in Waterborne Traffic became operational on June 1st, 2017 and it has a Main Investigator for Waterborne Traffic, Senior Adviser for Accident Coordination and Analysis in Waterborne Traffic and Independent Adviser for Accident Coordination and Analysis in Waterborne Traffic.

The Center, Sector for Investigation of Accidents in Waterborne Traffic, is independent in its functioning and independent from all other bodies and organizations competenet for waterborne traffic , as well as all the legal and physical entities whose interest may be in conflict with the tasks and authorities of the Center.

Professional work related to investigation is independent of criminal investigations or other parallel investigations that determine responsibility or the degree of guilt.

The investigation and determining the causes of accidents does not aim to establish criminal, economic, misdemeanour, disciplinary, civil or other liability.

Basic tasks of the Center, Sector for Investigation of Accidents in Waterborne Traffic, are:

- Investigation of very serious maritime accidents, serious maritime accidents, maritime accidents, serious inland navigation incidents and inland navigation incidents,
- Drafting and Publishing of Final reports on conducted specific investigations that may contain safety recommendations aiming to improve safety of waterborne traffic.

The Center performs other tasks stipulated by the Law on Investigation of Accidents in Air, Railway and Waterborne Traffic ("Official Gazette of RS" No. 66/15 and 83/18).

2. Investigative procedure in the field of waterborne traffic

2.1. Types of maritime and inland navigation accidents and incidents

Pursuant to the Law on Investigation of Accidents in Air, Railway and Waterborne Traffic ("Official Gazette of RS" No. 66/15 and 83/18), the accidents and incident in waterborne traffic can be:

1. **Very serious maritime accident** is an accident which has, as a consequence, a total ship loss, fatality or serious pollution of the marine environment caused by the functioning of the vessel.
2. **Serious maritime accident** is a maritime accident which involves a fire, an explosion, a collision, stranding, damage to the hull or freeboard or a defect on them caused by severe weather conditions, ice, fracture of a hull or presumed fault at production which has, as a consequence, the inability to operate the main propulsion devices, major damage to the superstructure or severe structural damage (rupture of the submerged part of the hull) which in turn incapacitates the vessel and pollutes marine environment (serious leakage: when over 50 tons of oil and oil derivatives or similar hazardous substances are released into the sea) or a fault which requires the vessel to be tugged or provided with assistance from the coast;
3. **Maritime accident is** an event or series of events occured as a direct consequence of the vessel management or operation of the vessel, resulting in any of the foillowin consequences: fatality or serious injury of a person, loss or presumed loss or abandonment of the vessel, major damage to the vessel, stranding or incapacitation of the vessel or its participation in a collision, major damage to marine infrastructure which can endanger the vessel, the other vessels or a person, major damage to marine environment caused by damage to a vessel or to vessels.
4. **Maritime incident is** an event or series of events, differentiating from a maritime accident, that have occurred as a direct consequence of the vessel operation which is endangered or which can endanger the vessel safety, persons on the vessel or maritime environment.
5. **Serious inland navigation incident** is an unexpected accident in the inland waterborne traffic or usage of a vessel, waterway or facilities along it which leads to a total loss of the vessel, fatalities or injuries to persons aboard or major damage to the environment caused by leakage of over 50 tons of oil and oil derivatives and other hazardous substances;
6. **Inland navigation incident** is an emergency in internal waters which occurred during navigation or exploitation of an internal navigation vessel, waterway or facilities along it which leads to material damage, pollution of environment fatalities or injuries to persons aboard.

2.2. Registration/ Obligation to notify

Authorities and organizations, shipowners, maritime companies, the master of the vessel or the person who replaces him, other members of the vessel's crew, persons who participated in a very serious maritime accident, serious maritime accident, maritime accident, maritime incident, serious inland navigation incident and inland navigation incident, as and all other legal and natural persons who have information about the occurrence, must inform the Center without delay.

2.3. Obligation to investigate

After a very serious maritime accident and a maritime accident, a safety investigation must be conducted if maritime vessels flying the flag of the Republic of Serbia were involved or if the state has an important interest regardless of the location of the very serious maritime accident and maritime accident.

In the case of serious maritime accidents, before making a decision to initiate a safety investigation, the Center performs a preliminary assessment of the need to undertake a safety investigation. If it decides that there is no need to conduct a safety investigation, it must record the reasons for such a decision and submit it to the European Commission. In the case of maritime accidents, the Center makes a decision on the need to undertake a safety investigation.

After every serious inland navigation accident in inland navigation, a safety investigation must be conducted, if it occurs on the waterway of the Republic of Serbia, regardless of the flag of the vessel flying.

In the case of navigation incidents, the Center, before making a decision to initiate a safety investigation, assesses the need to undertake a safety investigation, taking into account the severity of the inland navigation accident, the type of vessel and its cargo, as well as the possibility that the results of the safety investigation may affect the prevention of inland navigation incidents.

2.4. Safety investigation

The safety investigation in waterborne traffic is carried out with the aim of increasing the safety of navigation, preventing pollution of the marine environment, waterways from the vessel and reducing the risk of a very serious maritime accident, serious maritime accident, maritime accident, maritime incident, serious inland navigation accident and inland navigation incident.

The Rulebook on the method of conducting the investigation of accidents and incidents in maritime navigation ("Official Gazette of RS" No. 50/16) prescribes the method of conducting the investigation of very serious maritime accidents, serious maritime accidents, maritime accidents and maritime incidents in maritime navigation, as well as way of monitoring the implementation of safety recommendations. The provisions of the aforementioned Rulebook are also applied to the investigation of serious inland navigation incidents and inland navigation incidents in inland navigation, except for the provisions related to notification and data entry into the European Information Platform for Maritime Accidents (ECIP).

For the purpose of investigating every accident and incident in maritime navigation, every serious inland navigation incident and inland navigation incident in inland navigation, the Director of the Center establishes a Working group, led by the Main Investigator in waterborne traffic. The

members of the Working group are other employees of the Center or the Sector for the Investigation of Accidents in Waterborne Traffic who participate in the investigation of accidents and incidents, as well as experts from outside the Center.

2.5. Investigation Report

The Rulebook on the content of the safety investigation report, the content of the notification, the content and the way of keeping the database on the safety investigation of accidents and incidents in waterborne transport ("Official Gazette of RS" No. 26/16) prescribes the content of the safety investigation report in more detail.

After the safety investigation in waterborne traffic, the Center prepares and publishes a report on the investigation, which in particular contains data on the vessel, data on navigation, data on maritime accidents and incidents, data on navigation incidents in inland navigation, the involvement of coastal services and emergency actions in maritime navigation, event description, analysis, conclusions and safety recommendations and appendices. The report does not contain personal data. The investigation report can be: simplified report, final report and interim report.

2.6. Safety recommendations

The Center issues safety recommendations based on data analysis and the overall results of the conducted investigation in waterborne transport.

Safety recommendations are sent to the parties to which they are issued, to competent authorities and organizations in the Republic of Serbia, as well as to competent authorities and organizations of interested countries and international organizations.

Bodies and organizations to which safety recommendations have been sent, except for competent bodies and organizations of other interested states, are obliged to take appropriate measures in order to implement them, and to submit a report to the Center at least once a year on the measures taken or planned to be taken.

Adopting safety recommendations aims at prevention and improvement of all technical and operational elements in the function of navigation safety.

3. Safety investigations initiated in 2024

In 2024, 1 (one) investigation has been opened. Basic data on investigations initiated is given in Table 3.1.

Table 3.1. Review of the opened safety investigations

S. No.	Type	Date	Description	Location	Fatally injured	Seriously injured
1.	Inland navigation incident of the veseel "ZRENJANIN"	05.07. 2024	collision	The Sava River at around 5 km + 550 m	2	0

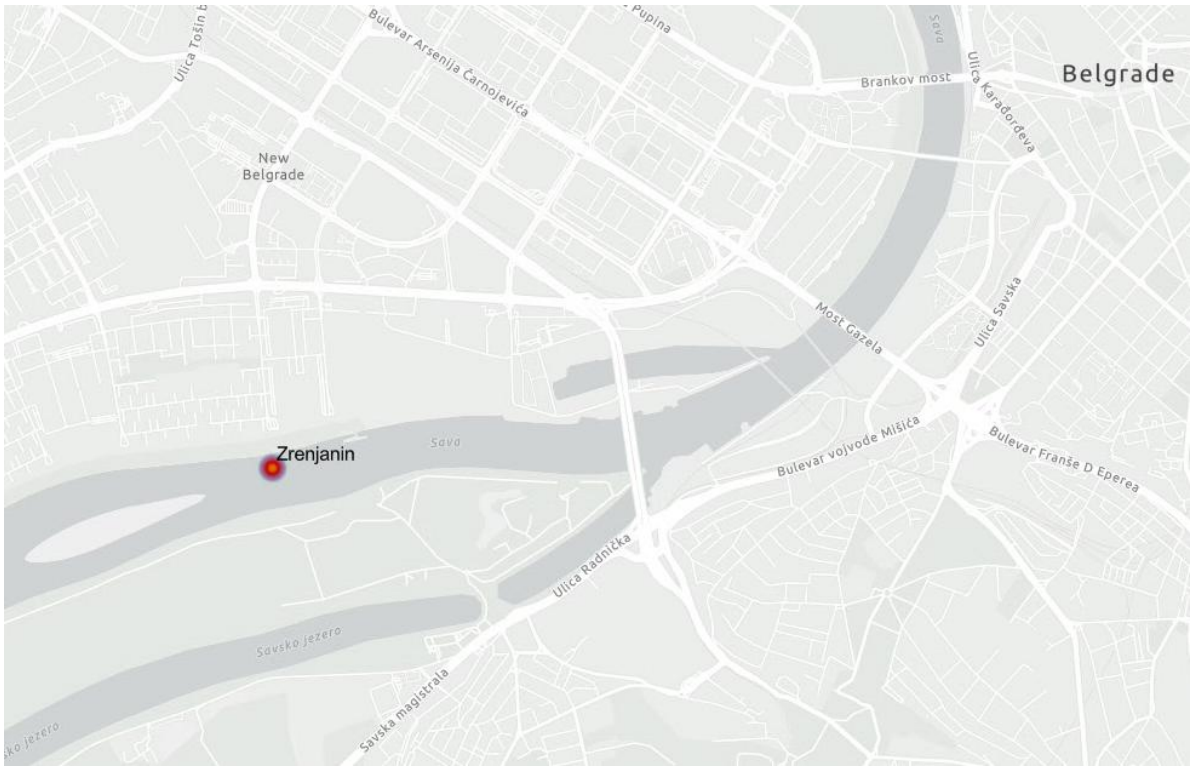
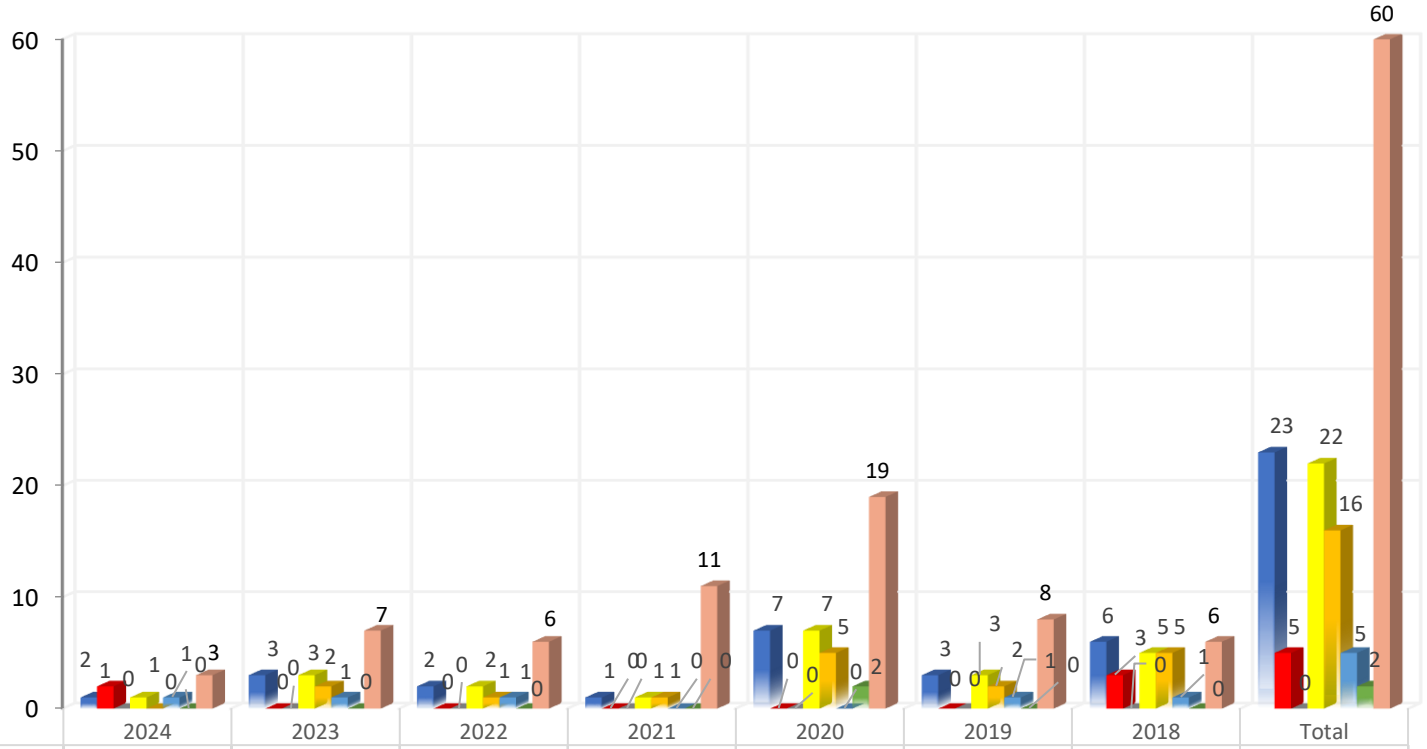


Figure 3.1. Location of the inland navigation incident

On graph 3.1. a comparative overview of the initiated safety investigations by year on the Danube, Sava and Tisza rivers with the total number of fatally injured, injured, material damage and issued safety recommendations is given.

Graph 3.1. A comparative overview of the initiated safety investigations for the time interval from 2018 to 2024



	2024	2023	2022	2021	2020	2019	2018	Total
Safety investigation	1	3	2	1	7	3	6	23
Fatally injured	2	0	0	0	0	0	3	5
Injured	0	0	0	0	0	0	0	0
Material damage	1	3	2	1	7	3	5	22
Danube River	0	2	1	1	5	2	5	16
Sava River	1	1	1	0	0	1	1	5
Tisza River	0	0	0	0	2	0	0	2
Safety recommendations	3	7	6	11	19	8	6	60

3.1. Inland navigation incident of the vessel "ZRENJANIN"

On 05 July 2024, at around 21:40, at approximately river kilometer 5 + 500 m on the Sava River, an inland navigation incident occurred—a collision between the motor cargo vessel "ZRENJANIN", flying the flag of the Republic of Serbia, and the motorboat with registration No. "BG-193 B", which is entered in the Register of Boats of the Belgrade Port Authority. On that occasion, two persons from the said motorboat drowned.

The motor cargo vessel "ZRENJANIN" was navigating upstream and, in a side formation, was carrying along its port (left) side a technical floating structure—the elevator "ZLATICA."

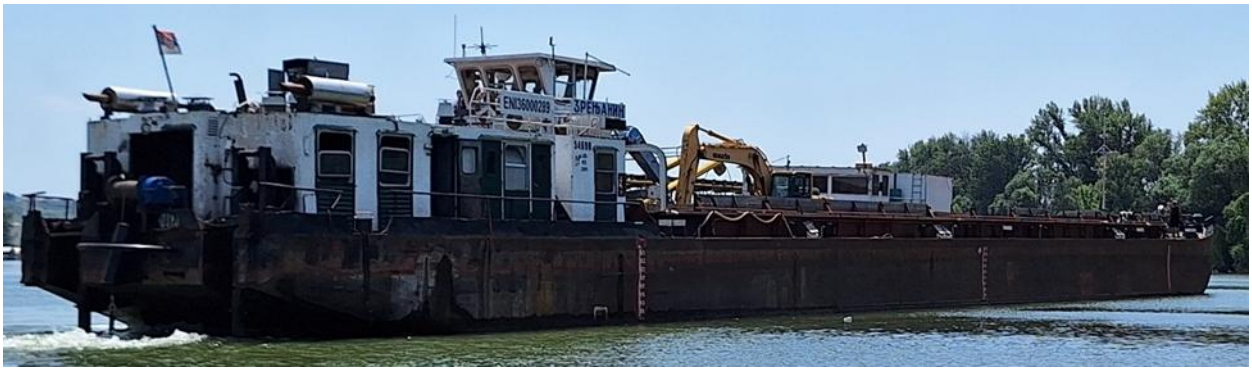


Figure 3.1.1. The motor cargo vessel "ZRENJANIN"

There is no material damage to the motor cargo vessel "ZRENJANIN" **or to the technical floating structure—the elevator** "ZLATICA"**—in the side formation. The material damage to the motorboat** "BG-193 B" will be determined after the boat is salvaged.
There was no spillage of hazardous substances into the waterway. The Center for Investigation of Accidents in Transport of the Republic of Serbia was notified of the inland navigation incident at 23:43 on 05 July 2024 by the Head of the Serbian Harbour Master's Offices. The investigative team of the Center for Investigation of Accidents in Transport of the Republic of Serbia arrived at the scene immediately after receiving notification of the said inland navigation incident.

4. Safety investigations closed in 2024

4.1. Inland navigation incident of the vessel “BEO“

4.1.1. Short description

The Interim Report presents the results of the investigation of an inland navigation accident—the ingress of water into the cargo barge with registration No**.** “71771”**,** which was part of the upstream composition of the motor cargo vessel “BEO**”**, as determined by the Center. The inland navigational incident occurred **on** 06 April 2023 at approximately 12:30**,** at river kilometer 1051 + 300 m of the Danube River.

After a maneuver to beach the barge on the right bank of the Danube River in order to prevent sinking, the operational maneuver did not yield a positive result, and the barge with registration No. “71771” sank on 08 April 2023 at approximately 05:30**.**

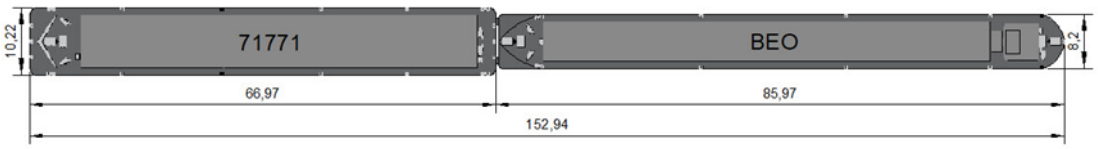


Figure 4.1.1.1. Model of the pushed composition of the vessel “BEO“

In describing the factual situation, records and documentation collected by the following were used: the Main Investigator for Waterborne Traffic, the Authority for Determining Vessel Seaworthiness, the Waterways Directorate (“Plovput”), the Navigation Safety Inspection, the Republic Hydrometeorological Service of Serbia (hereinafter: RHMS), and the shipowner’s documentation.

According to the data from the Report and the Supplement to the Report of the shipmaste of the vessel “BEO,” in its upstream composition it was pushing the loaded barge with registration mark “71771.” The composition proceeded upstream from the Romanian port of Turnu Severin, where coal had been loaded for the Port of Smederevo. On 06 April 2023, at around 12:30, at position 1051 km of the navigation channel, according to the master’s statement, a sudden jolt of the composition was felt at one moment, similar to a situation when the securing ropes give way. The master immediately sent a sailor to carry out a visual inspection of the vessel and the barge. According to the master’s Report, during the inspection of the ship’s ropes, the sailor noticed that they had slackened, and then, by waving his hand, indicated to the master to steer the composition toward the right bank, while at the same time noticing water ingress into the cargo barge. After receiving information about the water ingress into the barge, according to the Report, the shipmaster, after passing the dredger (a technical floating object, bucket-type) “BUKOVAC,” steered the composition across the steel cable that carries the dredger’s main anchor. In order to prevent a possible sinking of the barge, the master grounded the bow of barge “71771” on the right bank and dropped the bow anchor at 1051 km + 300 m (Figures 4.1.1.2 and 4.1.1.3).

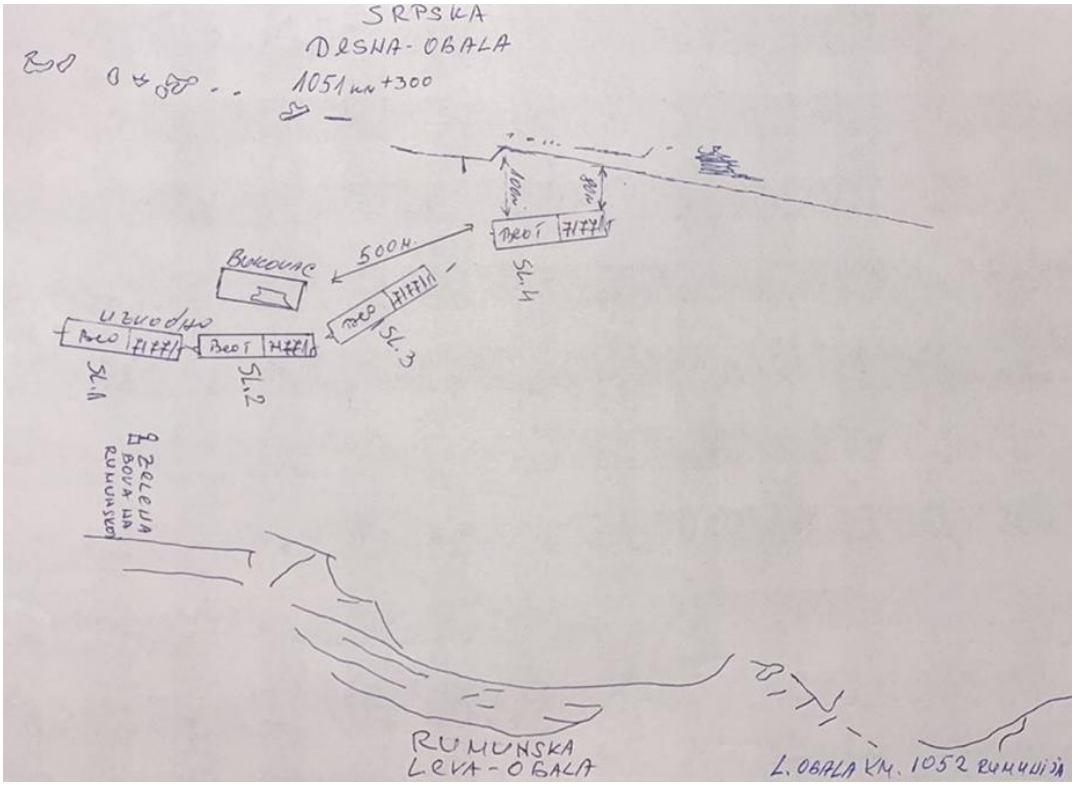


Figure 4.1.1.2.

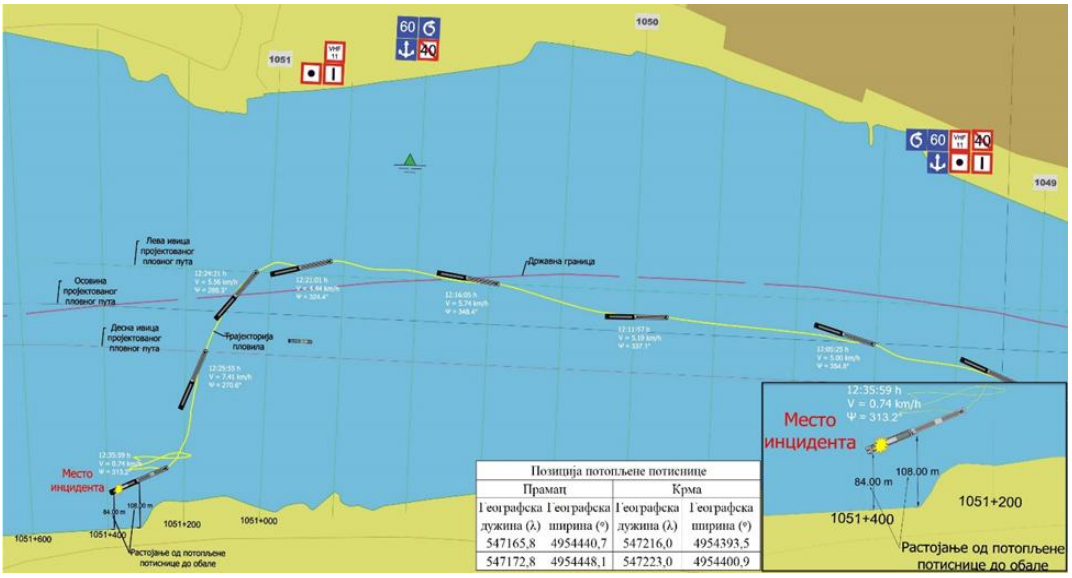


Figure 4.1.1.3.

The maneuver-operational action of controlled grounding of the pusher was completed at approximately 13:30. The commander informed the Port Authority of Veliko Gradište and the Navigation Safety Inspector about the maritime incident. For the purpose of providing assistance, the motor tugboat “DEOS” arrived at the scene. Due to the loss of buoyant force, the pusher submerged with its stern below the water surface, which caused a reduction in the freeboard height (Fr). For this reason, and due to the disproportion in height between the two vessels, the vessel “DEOS” was unable to secure it and additionally ground it onto the shore. According to the commander’s report, he moored the vessel “BEO” alongside (port side) next to the pusher, which

was continuously taking on water and had developed a transverse list to the starboard side (Figure 4.1.1.4).

Figure 4.1.1.4.

Due to the ingress of water into the internal compartments, the pusher initially developed a stern trim and a loss of reserve buoyancy in that part of the hull. This was followed by deck flooding and the overflow of external water over the coaming into the cargo space. Based on the commander's report, it can be observed that the pusher was continuously taking on water inside the hull, which during the given time period resulted in the flooding of both cargo compartments and its sinking on 08 April 2023 at approximately 05:30 (Figure 4.1.1.5).

Figure 4.1.1.5.

Upon review of the crew list book, the motor cargo vessel "BEO" had an embarked crew which, in terms of number, composition, and ranks, in accordance with the Rulebook on the Minimum Number of Crew Members for Safe Navigation (Official Gazette of the Republic of Serbia Nos. 28/2015, 99/2015, 3/2017, and 8/2019), ensured safe navigation.

There were no fatalities or injured crew members.

At the site of the sinking of the pusher “71771,” there was no discharge of hazardous substances into the Danube River.

In order to determine all causes that led to the inland navigation incident in question, it is necessary to raise the sunken pusher from the riverbed to the water surface and haul it into a dry dock or slipway for a detailed inspection of the vessel’s hull. To conduct a professional and comprehensive analysis based on established facts, it is necessary to carry out a visual inspection of the internal spaces of the vessel complex, the structure and plating of the hull, as well as any potential damage affecting watertight integrity in accordance with technical shipbuilding regulations. There is a possibility that, prior to the maritime incident, the pusher’s hull, including structural strength elements and hull plating, had been compromised during the previous period of operation due to sustained anomalies.

Based on the table provided in the annex showing the projected position of the sunken pusher “71771” (Figure 4.1.1.3, page 12), the coordinates of geographic longitude (φ) and latitude (λ) are given, as well as a distance of 108 m from the right bank. In this sector of the waterway, the navigation corridor gravitates toward the right bank, and it should be noted that exploitation areas for natural gravel extraction extend across this part of the water area. Particular attention should be paid to technical vessels—dredgers—which move within the exploitation field during natural gravel extraction operations. In the dredger working zone, vessels and vessel composition perform technical and handling operations, including anchoring, positioning of floating units for loading, formation of convoys, and similar activities. As an additional risk factor for navigation safety, hydrometeorological conditions for navigation should also be taken into account. Considering all of the above and the position of the sunken pusher, it can be concluded that the sunken object constitutes a hazard and an obstruction to navigation.

Based on all of the above, the Center has prepared a Preliminary Report until the pusher “71771” is raised and hauled into a dry dock or slipway, in order to determine the factual condition of the vessel complex and the cause of the sinking, all in accordance with Article 46, paragraph 4 of the Law on the Investigation of Accidents in Air, Rail, and Waterborne Traffic (Official Gazette of the Republic of Serbia Nos. 66/2015 and 83/2018).

4.1.2. Issued safety recommendations

The shipowner/owner
BEOBROD LTD

SR_01/24 It is recommended that the shipowner/operator of the pusher bearing registration mark "71771" submit an application to the competent Port Authority of Veliko Gradište for the issuance of a Permit for the salvage (raising) of the sunken pusher, in accordance with Article 76, paragraphs 1, 2, 3, and 6, and Article 79, paragraph 2 of the Law on Navigation and Ports on Inland Waters (Official Gazette of the Republic of Serbia Nos. 73/10, 121/12, 18/15, 96/15, 92/16, 104/16, 113/17, 41/18, 95/18, 37/19, 9/20, and 52/21).

To the Ministry of Construction, Transport and Infrastructure, Sector for Water Transport

SR_02/24 It is recommended that the competent Port Authority of Veliko Gradište issue a Decision requiring the owner/shipowner, within an appropriate time limit, to remove the sunken object—in this case, the pusher bearing registration mark "71771"—in accordance with Article 78, paragraphs 1, 2, and 3, and Article 79, paragraph 2 of the Law on Navigation and Ports on Inland Waters (Official Gazette of the Republic of Serbia Nos. 73/10, 121/12, 18/15, 96/15, 92/16, 104/16, 113/17, 41/18, 95/18, 37/19, 9/20, and 52/21).

4.2. Inland navigation incident of the vessel ”PODUNAVLJE“

4.2.1. Short description

On October 30, 2023, at approximately 05:00, at river kilometer 1106 + 200 m along the right bank of the Danube River, a navigation incident occurred involving the partial sinking of the anchored motor cargo vessel "PODUNAVLJE" (see Figure 3.3.1). The vessel flies the flag of the Republic of Serbia and is registered in the Ship Register of the Smederevo Port Authority.

Figure 4.2.1.1. Motor cargo vessel “PODUNAVLJE“ at km 1106 + 200 m of the Danube river

The motor cargo vessel "PODUNAVLJE" was navigating upstream, loaded with 738 tons of natural gravel (according to the accompanying cargo document – bill of lading). The loading was carried out on October 29, 2023, at km 1065 of the Danube River under the dredger "BUKOVAC

There were no fatally injurted or injured among the crew members. There was no discharge of hazardous substances into the watercourse.

Based on the Report of the shipmaster m/t “PODUNAVLJE” and the Statement of the trainee helmsman, on 29 October 2023, during the time period between 11:00 and 13:30, it was not observed that the vessel was taking in river water inside the hull; the technical cargo loading operation was carried out in the regular operational handling procedure. After the technical loading operation, according to the Master’s Report, the vessel proceeded upstream at 13:30, and during navigation no change in draft was noticed; according to the information from the accompanying document, the vessel was loaded to a mean draft of 205 cm. According to the Report of the Master of the vessel m/t “PODUNAVLJE,” the upstream navigation was interrupted at around 21:00, when the vessel was anchored closer to the right bank, according to the sketch, about 30 m from the shore at river kilometer 1106 (Figure 4.2.1.2).

Based on the Report of the Master of the **vessel m/t “PODUNAVLJE” and the Statement** of the trainee helmsman, on 29 October 2023, during the time interval between 11:00 and 13:30, it was not observed that the vessel was taking in river water inside the hull; the technical cargo loading operation was carried out in the regular operational handling procedure. After the technical loading operation, according to the Master’s Report, the vessel proceeded upstream at 13:30, and during navigation no change in draft was noticed; according to the information from the accompanying document, the vessel was loaded to a mean draft of 205 cm. According to the Report of the Master of the vessel m/t “PODUNAVLJE,” the upstream navigation was interrupted

at around 21:00, when the vessel was anchored closer to the right bank, according to the sketch, about 30 m from the shore at river kilometer 1106 (Figure 4.2.1.2).

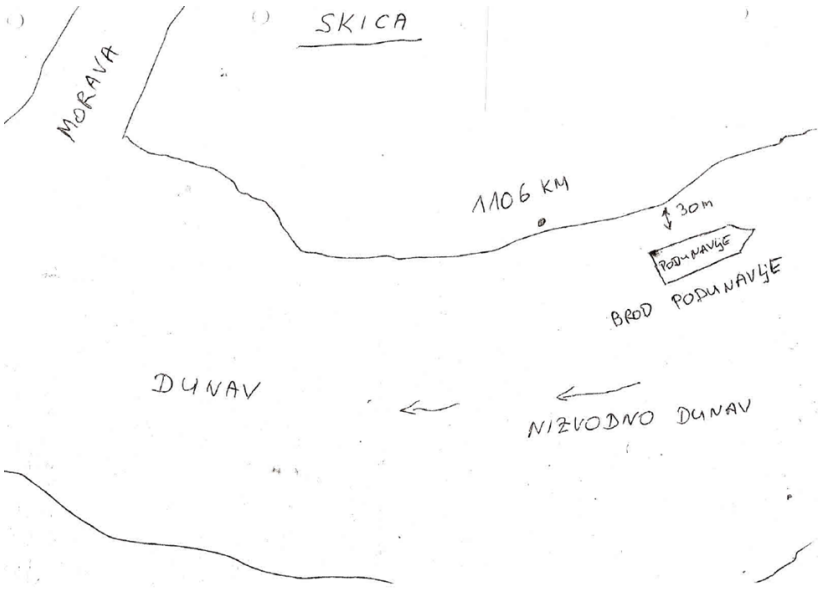


Figure 4.2.1.2.

After the vessel had anchored, an inspection of the draft marks showed, according to the shipmaster's Statement, that the draft was unchanged at 205 cm. During the morning of 29 October 2023, at 05:00, the Master observed an increased draft of the vessel, i.e. that water had flooded the main deck on the port side toward the stern, meaning that the freeboard was Fr = 0 cm.The Master immediately started the main propulsion engine in order to intentionally ground the vessel as close as possible to the right bank (shallow water area) and dropped the bow anchor. In an effort to save the vessel, the crew engaged two electric pumps and two engine-driven pumps to remove water from the cargo hold and side compartments. The Port Authority of Smederevo was informed of the emergency situation and the vessel's position. Through the subsequent engagement of salvage pumps and the arrival of unloading equipment (a technical floating facility – elevator) "RAVANGRAD", as well as by lightening the vessel's cargo space, the loss of conditional seaworthiness and the sinking of the vessel were prevented (Figure 4.2.1.3).

Figure 4.2.1.3.

The task of analyzing the stability and the causes of the inland navigation incident involving the flooded vessel "PODUNAVLJE" is to: assume all missing data and assess their validity; determine the time frames during which the reported outcome could have occurred; and reconstruct the events during the navigational accident that are related to the vessel's stability in the flooded condition.

The data on the vessel "PODUNAVLJE" used for this analysis were taken from the following documents: the lines plan (drawing No. 4059); the hydrostatic curves diagram (diagram sheet, drawing No. 4060); the general arrangement plan of the vessel "PANONIJA" – a vessel from the same series (drawing No. 4638); the drainage, fire-fighting and lifesaving system diagram of the vessel "PANONIJA" – a vessel from the same series (drawing No. 4445); and the midship section (drawing No. 4419).

Based on the available data, a hull model was created in hydrostatic software, as shown in Figure 4.2.1.4.

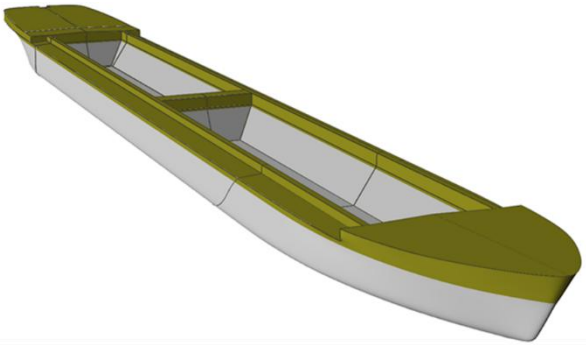


Figure 4.2.1.4. The appearance of the 3D model of the vessel "PODUNAVLJE"

Only elements that can affect the vessel's stability were modeled. For this reason, full railings and superstructures that are not watertight are not shown in the model. A comparative presentation of the Lines Plan from the design documentation of the vessel "PODUNAVLJE" and the Lines Plan obtained based on the vessel model is shown in Figures 4.2.1.5 and 4.2.1.6.

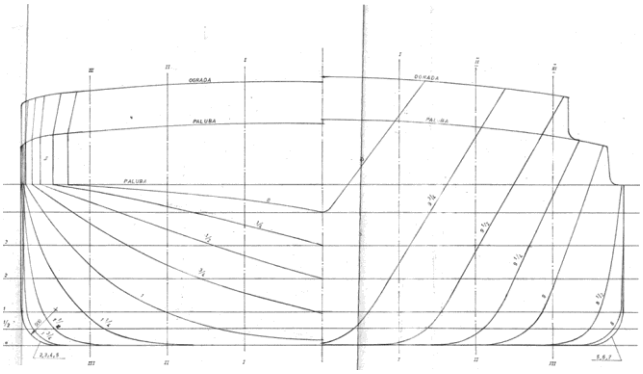


Figure 4.2.1.5. Lines plan from the vessel "PODUNAVLJE" documentation

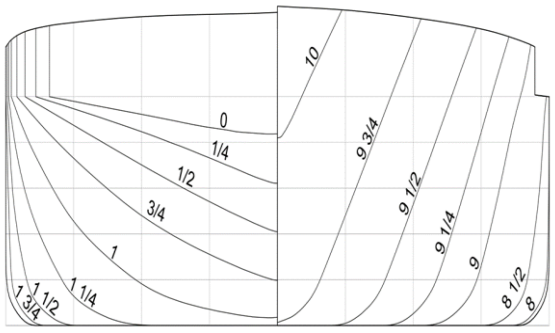


Figure 4.2.1.6. Lines plan based on the model of the vessel "PODUNAVLJE" documentation

The flooding most likely occurred through the bilge wells in the compartment – watertight space (WT3), via open valves, and further through the piping system to the settling tanks in the compartments – watertight spaces (WT4 and WT7). A simplified schematic of this section of the piping system is shown in Figure 4.2.1.7. The figure shows four positions that will be used in the following analysis: bilge well A, branch B, settling tank C, and settling tank D.

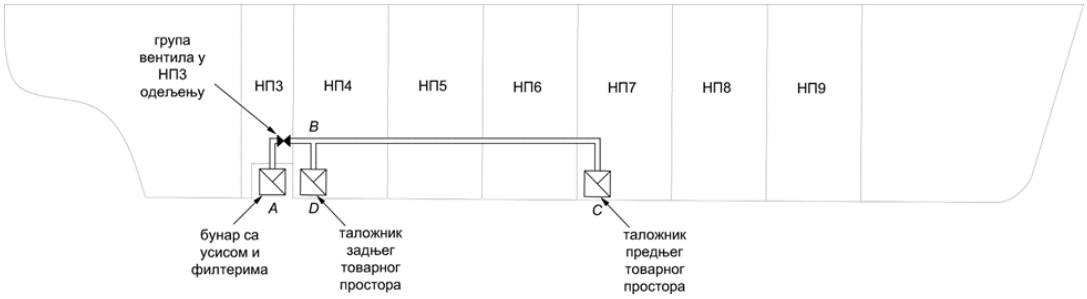


Figure 4.2.1.7. Schematic of the piping system through which the vessel flooding occurred

In the following, the possibility of such flooding will be examined in accordance with the chronology of statements provided by the crew members.

The calculation will be performed in a simplified manner using Bernoulli's equation. This calculation method introduces certain assumptions and can therefore be considered approximate. However, the equation is capable of providing engineering-practical results, and these are expected to be qualitatively useful.

The following form of Bernoulli's equation will be used:

$$p + \rho g h + \frac{1}{2}\rho v^2 = \text{const}(1)$$

where p is the pressure, h is the height of the water column relative to a reference position, and v is the flow velocity of the water. Since a complex piping system is involved, it is necessary to identify appropriate sections; therefore, the following sections are defined: section **AB**, from bilge well A to branch B; section **BC**, from branch B to settling tank C; and section **BD**, from branch B to settling tank D.

where ζ represents local losses in the piping system (losses due to friction, suction, valves, branches, and bends). Since the intake of water occurs by gravity flow, pump head does not appear in the equation. By solvi

$$\sum \zeta_{AB} \cdot \frac{v_{AB}^2}{2} + \sum \zeta_{BD} \cdot \frac{v_{BD}^2}{2} + g(h_2 - h_1) = 0 \quad (3)$$

$$\sum \zeta_{AB} \cdot \frac{v_{AB}^2}{2} + \sum \zeta_{BC} \cdot \frac{v_{BC}^2}{2} + g(h_3 - h_1) = 0 \quad (4)$$

ng the system of equations (2), (3), and (4), it is possible to determine the flow velocities in each section, from which the change in water flow rate over time can be determined by applying the continuity equation for each section:

where ζ are local losses in pipelines (losses due to friction, intake, valves, branches, and bends). Since the water loading is by gravity flow, the pump head does not appear in the equation. By solving the system of equations (2), (3), and (4), it is possible to determine the flow velocities in each section, and from that the change in water flow over time can be determined by applying the continuity equation for each section.

$$dt = \frac{1}{v \cdot r^2 \pi} dm \quad (5)$$

where r is the radius of the pipe. However, it is first necessary to express the height of the water column in equations (3) and (4) as a function of the loaded mass m. By applying hydrostatics, and subsequently using mathematical software, the corresponding relationship was determined.

In order to verify stability in the flooded condition, it is necessary to know the initial conditions. A more detailed analysis established possible, realistic parameters of the vessel at the moment just before flooding: mean draft of the vessel, T = 2.05 m; trim, t = 0.2 m (stern trim); heel, φ = 0.1° (heel to port side); vertical center of gravity, GK = 1.45 m.

These parameters were selected through systematic variation and verification of results, with the aim of obtaining a floating condition as close as possible to that on the day of the inland navigation incident on 30 October at 05:00, as reported by the crew. It will be shown that these parameters represent that condition well.

An additional assumption is that the loaded water was not retained only in the cargo spaces, but also occupied the spaces in the wing tanks and the double bottom surrounding the cargo holds. Accordingly, the water could pass through the observed inadequately executed penetrations of pipes and power cables through watertight bulkheads, or through the observed cracks that appeared as a result of corrosion.

Due to the relatively small diameter of the pipelines, as well as significant local losses, a longer flooding time required for the deck to become submerged was expected. Figure 4.2.1.8 shows the change in the loaded mass of water as a function of time. Indeed, using the presented calculation procedure and comparing it with the hydrostatic calculation, the required time for the deck passage to submerge is found to be approximately 20 hours, measured from the moment the valve is opened. At that moment, approximately 137 t of external water has been loaded into the vessel.

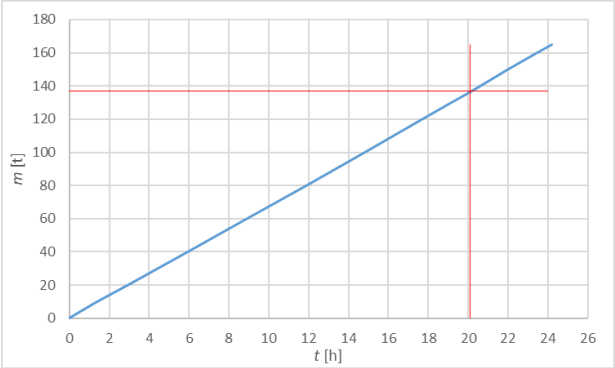


Figure 4.2.1.8. Dependence of the loaded water mass on the time

The changes in draft, heel angle, and trim over time are shown respectively in Figures 4.2.1.9, 4.2.1.10, and 4.2.1.11. The moment at which the crew noticed the flooding corresponds to the 20th hour from the start of calculation.

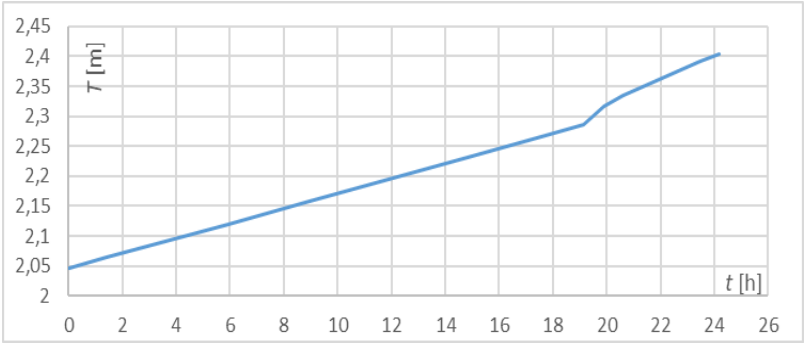


Figure 4.2.1.9. Change of the trim of the vessel as the function of time

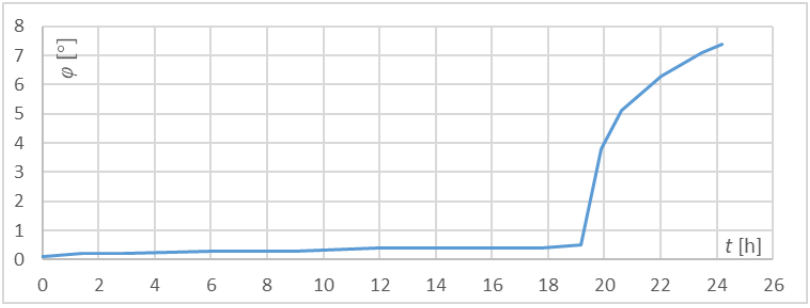


Figure 4.2.1.10. Change of the heel of the vessel as the function of time

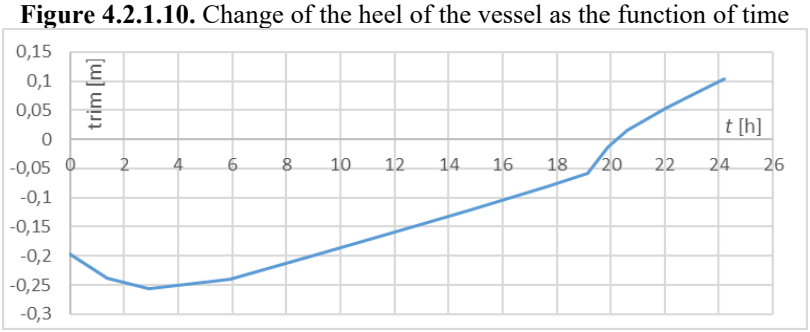


Figure 4.2.1.11. Change of the trim of the vessel as the function of time

It is interesting that at this very moment a sudden change in the floating condition occurs—there is an accelerated change in draft and trim, and the change in the heel angle is particularly pronounced. From the diagrams, the following values of the floating condition at the moment when the crew noticed the flooding can be read: mean draft of the vessel, T = 2.317 m; trim, t = −0.014 m (stern trim); heel, φ = 4.1° (heel to port side).

The reason for this sudden change is that the deck becomes submerged at that moment, which results in a reduction of the metacentric height and a deterioration of the vessel's stability. The change of the initial metacentric height as a function of time is shown in Figure 4.2.1.12.

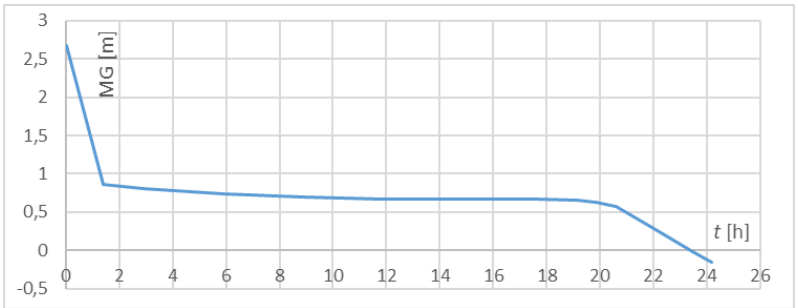


Figure 4.2.1.12. Change of the initial metacentric height as a function of time

Based on the input assumptions, at the moment the valve was opened the initial metacentric height was approximately MG = 2.7 m. During the first hour of flooding, the water wets the bottom of the flooded compartments and a free-surface effect is created, which has a noticeable influence on the initial metacentric height. Subsequently, over a longer period of time, there are no significant changes with regard to stability. However, at the moment the deck becomes submerged, the initial metacentric height decreases, and from that point onward the stability changes drastically. Had the crew delayed their response and not taken measures to save the vessel, a complete loss of stability would have occurred due to negative metacentric height and flooding of the cargo hold bilge slightly more than 24 hours after the moment the valve was opened.

Visual representation of the floating condition during flooding:

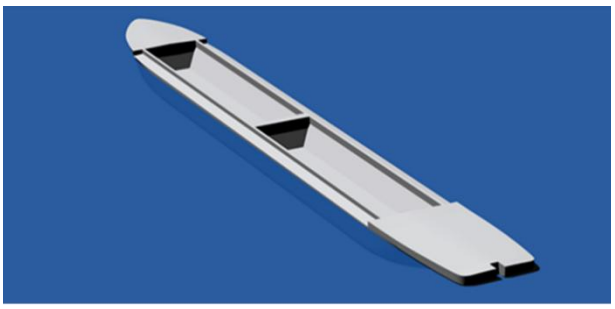


Figure 4.2.1.13. Flooding illustration: t = 0 h 0 min; m = 0 t (start of the flooding)

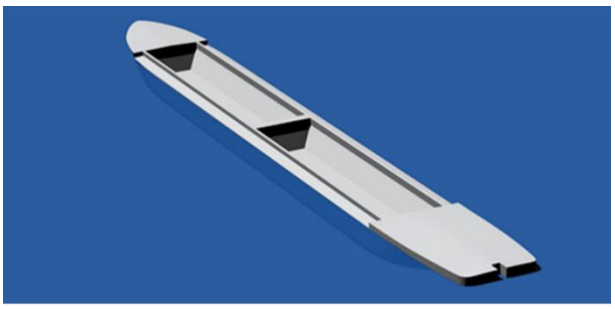


Figure 4.2.1.14. Flooding illustration: t = 11 h 50 min; m = 80 t (21.00, the crew did not notice the problem)

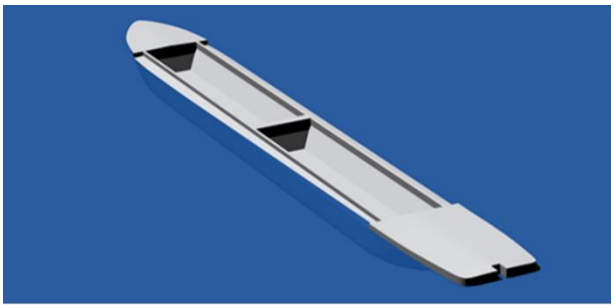


Figure 4.2.1.15. Flooding illustration: t = 19 h 10 min; m = 130 t (the deck begins to submerge)

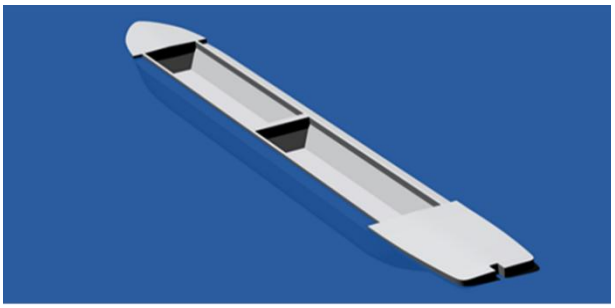


Figure 4.2.1.16. Flooding illustration: t = 20 h 10 min; m = 137 t (the crew notices the problem)

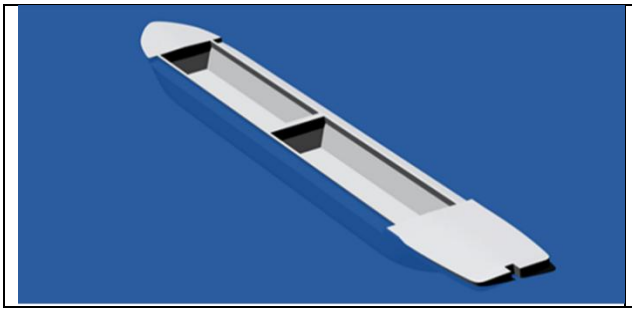


Figure 4.2.1.17. Flooding illustration: t = 22 h 0 min; m = 150 t submerged- progressive flooding would have followed)

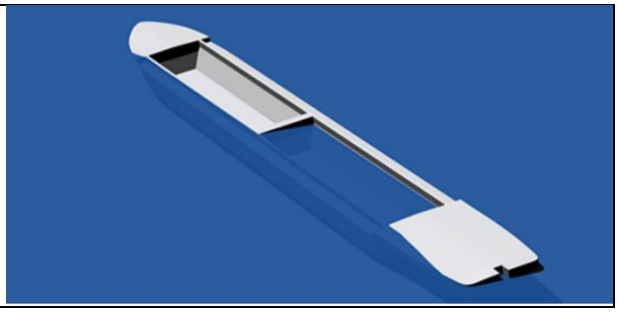


Figure 4.2.1.18. Flooding illustration: t = 24 h 10 min; m = 165 t (the bilge would have (condition in the case the crew did not react)

Observed deficiencies on the vessel m/t "PODUNAVLJE":

1. Technical documentation: Complete technical documentation related to the vessel "PODUNAVLJE" does not exist; there are no schematics of the ship's pipelines displayed in visible locations in the accommodation areas, including: the ship's flooding prevention system, the fire protection system, and the cargo hold drainage system.

2. Ship and machinery systems: There is no stable fire protection system on the vessel (fire pump, complete fire cabinet with equipment). There are only two fire hoses in the engine room; the drainage system for pumping out the forward cargo hold into the watertight space NP12 is not operational; the pump for the drainage system of the aft cargo hold into the watertight space NP3 is not installed in accordance with shipbuilding regulations – its foundation on the tank top (hull bottom) between frames R26 and R27 is not correct.

In the event of water ingress in the area below the pump, it is not possible to respond properly; the portable submersible pump Jastrebac is not operational, and its power supply cable is cut; the brake of the starboard anchor winch is not functional; deck railings are not secured and are deformed; the vessel's flooding prevention system on the port side is not installed; remote closure of the drainage valves in the stern and bow peak tanks is not functional; the dry space amidships, watertight compartment NP12, has no means to prevent water ingress; the valve on the aft watertight bulkhead cannot be operated and has no extended pipeline; the gas installation in the accommodation space is installed contrary to technical regulations; the hot water heating system is non-functional. Unnecessary installations should be removed from the vessel. According to the Rules for the Construction of Inland Navigation Vessels, Part 7, Article 2, point 2.1.2, self-propelled vessels with a main engine power of less than 220 kW must have at least two bilge pumps, one of which can be a stationary mechanically driven pump. Visual inspection shows that not a single pump is present. There are concerns regarding handling of gasoline for supplying the auxiliary generator in the engine room—specifically, where and how fuel cans for portable pumps are stored. The day fuel tank uses a plastic tube as a level indicator, which is not permitted by the rules; connections with a valve for pouring fuel from the tank into a can are not allowed; the tray under the tank lacks a drain for spilled fuel. The main fuel tanks have discharge valves positioned too low, just above the tank top (hull bottom). Sludged dirty fuel should be transferred to the dirty fuel tank, but according to the current technical setup, this is not possible.The installation of a rapid shut-off device and a control box for steel bulkheads, size 3, according to SB 3456, for centralized remote fuel shut-off to all consumers at one location in the box, is missing. An international fuel filling connection according to SB 8159 on the deck, with spill protection, is not installed. The dirty oil tank lacks manipulation valves; the potable water tank has no international filling connection; the fuel transfer pump setup is technically entirely inappropriate. Equipment in the well—pipe loop, spindle, mushroom, suction bell, grating on the casing, and coarse filter in the well—is not cleaned, raising questions about operational usability. The installed water tap on the well casing should be removed and the opening closed. There are no tanks for dirty wastewater and sewage; there is no pump for discharging the contents, nor is there a connection for unloading wastewater and sewage (according to SB8459); a bilge water separator is not present.

3. Ship structure: During operation, the ship's structure, due to the action of stress forces on structural elements (longitudinal and transverse framework) and the hull plating, has caused permanent plastic deformations (according to the technical supervision report, a hull bend was observed). The cargo hold in the interframe sections, with transverse stiffening, is plastically deformed (Figure 4.2.1.19), and the condition of the outer plating is no better.

In the cargo hold, at the junctions of sloped parts, visible leakage is present (Figure 4.2.1.20). The double bottom shows localized porosity in the plating. Structural deformation is observed in watertight compartment NP2 on the starboard side, extending from the end of the accommodation space toward the side. Arbitrarily executed, averaged, and unsealed passages exist through bulkheads for electrical conductors. Cutting of frames for pipeline passages, as well as watertight bulkheads, is evident. Pipe passages through bulkheads are made without using watertight penetrations. Deck hatches leading to the wing tanks are not watertight. In the first port-side wing tank, on the tank top, from the bilge toward the middle, there is a grease ball repaired with a box.

Figure 4.2.1.19.

Figure 4.2.1.20.

Electrical installation: On the vessel, there are routes of electrical conductors hanging outside of their conduits; use of extension cords with multiple sockets in the engine room; arbitrary drilling of watertight bulkheads for the passage of power cables (Figure 4.2.1.21) without the use of proper high-temperature-resistant sealing compounds; a cut electrical conductor intended for power supply in watertight compartment NP12; anchor windlass electrical starting is performed via an extension cable along the deck route; electrical connection of the generator to the GRT. The condition of the electrical installation is extremely concerning.

Figure 4.2.1.21.

Upon review of the ship's books and documents, the following was found: the ship's Seaworthiness Certificate No. 44-0499 was issued on 26.04.2018 by the Administration for Determining the Seaworthiness of Ships, and its validity expired on 26.04.2022. The ship must have a ship's Seaworthiness Certificate, which certifies that the ship complies with the requirements of the Technical Rules. The validity period is determined in each specific case in accordance with the

Technical Rules. The validity period is entered in the Certificate of the ship's seaworthiness, Article 106, paragraphs 1, 2, 4 and 5 of the Law on Navigation and Ports on Inland Waters ("Official Gazette of the Republic of Serbia" No. 73/10, 121/12, 18/15, 96/15, 92/16, 104/16, 113/17, 41/18 and 37/19 - other laws 9/2020 and 52/2021), hereinafter referred to as the ZPLUV; Ship Certificate No. 04/21 was issued on 30.11.2021 by the Port Authority of Smederevo, the validity of the certificate expired on 26.04.2022. The ship must have a Ship's Certificate. The Ship's Certificate proves the Serbian nationality of the vessel, the right and obligation to fly the flag of the merchant navy of the Republic of Serbia, the type and purpose of the ship, the navigation zone in which it is authorized to sail, the number of passengers and the mass of cargo that the ship is allowed to transport, as well as the status of a Rhine vessel.

The Ship's Certificate is issued by the Port Authority, it is issued on the basis of the Certificate of Seaworthiness of the ship issued by the Administration, Article 105, paragraphs 1, 3, 4 and 5 of the ZPLUV; Ship's Logbook No. 342-7-21/21 was issued by the Port Authority of Smederevo on 06.12.2021, it has been kept since 22.09.2023, ending on 29.10.2023. and has not been verified by the Port Authority, Article 118, paragraph 4, and in connection with Article 31, paragraph 2 of the Regulations on Ship's Documents and Books ("Official Gazette of the Republic of Serbia" No. 60/2015, 20/2019, 145/2028 and 139/2022); the crew list book is not kept (there is no crew on board the ship), No. 342-7-22/21 issued on 06.12.2021 by the Port Authority of Smederevo.

On board the m/t "PODUNAVLJE" during the inspection, two crew members were found, according to written statements, in the capacity of commander and helmsman trainee, the person does not have a title acquired in the merchant navy of inland navigation. The listed persons were not entered in the Crew List Book, Article 130 and Article 131 of the ZPLUV, the ship m/t "PODUNAVLJE" according to the Regulations on the minimum number of crew members for safe navigation that ships and other vessels of the merchant navy must have ("Official Gazette of the Republic of Serbia", No. 28/15, 99/15 and 3/17), hereinafter referred to as the Regulations, did not have the crew on board in the number and ranks required for safe navigation.

The vessel does not comply with the technical requirements of ES-TRIN, in accordance with Article 31.02 (Standard S1) and Article 31.03 (Standard S2), page 8, item 47 of the Ship Certificate.Pursuant to Article 18, paragraphs 1 and 2 of the Rulebook, for vessels that do not have equipment for Standard S1, the prescribed minimum number of crew members is increased by one crew member with the prescribed qualification, for navigation model A1 and A2. By inspecting the Ship’s logbook and reviewing the entered data, the previous status of the vessel cannot be determined, namely whether the vessel was laid up (long-term or short-term lay-up). The owner, or operator, of a vessel that does not have a valid certificate of seaworthiness is obliged to submit an application for the determination of lay-up by the competent Port Authority, pursuant to Article 56, paragraph 2 of the Law on Inland Navigation.

Based on the analysis of the inland navigation incident in question, the flooding of the cargo vessel “PODUNAVLJE” was, according to all indications, caused by the opening of valves connecting the external water intake from the sea chest in the watertight compartment NP3 with the bilge wells of the cargo spaces in the watertight compartments NP4 and NP7. From that moment, water flowed by gravity (free flow, without the operation of pumps) toward the bilge wells in the forward and aft cargo holds, thereby flooding the vessel.

In the early morning hours, the ship’s crew reported that the main deck had submerged (stern section, port side). However, for such a floating condition to occur, prior to the flooding the vessel must have had a stern trim (up to 0.2 m), as well as a slight heel to port (on the order of 0.1°). Furthermore, the assumed vertical position of the center of gravity, with GK = 1.45 m, represents

a realistic expected value for this type of vessel and also the required value for the vessel to have assumed the reported floating condition on 30 October 2023 at 05:00.

With such a center of gravity, and as a result of the deck being submerged, the vessel had a noticeably reduced stability, which led to an increase in the initial heel from 0.1° to more than 4°. It is possible that this list represented the first indication to the crew that something was wrong with the vessel. The presented results show that approximately 20 hours were required for the vessel to reach the reported floating condition (submerged deck on the port side, stern section of the vessel). This implies that, under these assumptions, the onset of flooding began at 09:00 on 29 October 2023. However, it should be noted that the results may vary by several hours depending on the assumptions used regarding local hydraulic losses; for example, if a valve was partially closed, the flooding time would increase, whereas if the local losses were smaller, the flooding time could be shorter. Therefore, it can be expected that the actual time of the onset of flooding was between the early morning hours (which may correspond to the beginning of the day shift) and the afternoon hours (which correspond to cargo loading operations that took place on that day).

Based on the written statements of the crew, it is evident that they woke up at 05:00 on 30 October 2023, at which time they noticed that the main deck had been flooded. According to this information, it is apparent that the vessel was not under watch during the night. The crew's reaction to the observed floating condition of the vessel was justified, but nevertheless untimely. The analysis shows that, had no measures been taken, the vessel would have suffered a complete loss of stability, i.e. would have lost its conditional seaworthiness within the next four hours.

In accordance with Article 50 of the Law on Inland Navigation, a vessel with a crew that is stationary must maintain a continuous watch. The composition of the ship's watch must at all times be sufficient and appropriate to the specific circumstances and conditions under which the watch is performed. During the watch, a crew member must not leave the watch position and the space in which the watch is being carried out without the approval of the Ship Master. During the period while anchored, the cargo vessel "PODUNAVLJE" was not under continuous and direct watch, which is contrary to Article 123, paragraph 5 of the Regulation on Conditions for Navigation and Rules of Navigation on Inland Waters ("Official Gazette of the Republic of Serbia", Nos. 96/14 and 111/20), hereinafter referred to as the Regulation.

The Ship Master is appointed and dismissed by the operator. Pursuant to Article 144, paragraphs 1, 2 and 4, the Ship Master is obliged to take care of the vessel's provisioning, shipboard documentation, and maintenance, as well as to ensure that the hull, machinery, systems and equipment are kept in proper working condition, to ensure the safety of the vessel's installations, and to perform all duties related to the work process and safety on board.

Ultimately, when considering the maneuvering of the vessel "PODUNAVLJE" and the extraordinary event that occurred during it, the Ship Master, as the person responsible, made the decision to put the vessel into navigation contrary to the precautionary measures required by the general obligation of due dilligence, navigational practice, and legal provisions, in accordance with Article 48 of the ZPLUV.

4.2.2. Issued safety recommendations

Owner

DST HIDROSISTEM DOO

SR_01/24 It is recommended that the owner/operator address the following identified deficiencies:

1. The Ship's Logbook of the vessel "PODUNAVLJE", No. 342-7-21/21, issued by the Smederevo Port Authority on 06 December 2021, has been kept from 22 September 2023 until 29 October 2023 and has not been certified by the Port Authority, which is contrary to Article 118, paragraph 4, in relation to Article 31, paragraph 2 of the Regulation on Ship Certificates and Logbooks ("Official Gazette of the Republic of Serbia" Nos. 60/2015, 20/2019, 145/2018, and 139/2022).
2. A review of the Logbook shows that it was not maintained for the period from 06 December 2021 to 22 September 2023. By examining the entered data, the status of the vessel cannot be determined, i.e., whether the vessel was laid up (long-term or short-term lay-up).
3. The Certificate of Seaworthiness of the vessel, No. 44-0499, was issued on 26 April 2018 by the Administration for the Determination of the Seaworthiness of Vessels and expired on 26 April 2022. The vessel must possess a valid Certificate of Seaworthiness, which confirms that the vessel complies with the requirements of the Technical Rules. The validity period is determined in each specific case in accordance with the Technical Rules and is recorded in the Certificate of Seaworthiness of the vessel (Article 106, paragraphs 1, 2, 4, and 5 of the Law on Inland Navigation).
4. The owner or operator of a vessel that does not have a valid Certificate of Seaworthiness is obliged to submit an application for the determination of lay-up by the competent Port Authority (Article 56a, paragraph 2 of the Law on Inland Navigation).
5. During any reconstruction of a vessel, the Administration for the Determination of the Seaworthiness of Vessels must be notified. The appropriate technical documentation of the as-built condition must be submitted, which will be approved by the Administration, based on which the installation will be supervised. During the installation supervision, the authorized personnel of the Administration must be provided with the corresponding certificates for materials and equipment with the components being installed. Technical supervision of the superstructure, modification, or reconstruction of the vessel, as well as supervision over the production of individual components to be installed on the vessel, is carried out at the request of the operator, shipyard, manufacturer, or their authorized representatives, in accordance with Articles 90b and 90c of the ZPLUV.

SR_02/24 Recommendation for the master of the vessel "PODUNAVLJE" The Ship Master is obliged, before departure, to carry out the following actions within his/her authority:

1. Verify the validity of the operator's certificates and ensure that the Ship Master and the crew members are entered in the operators' certificates and recorded in the crew register. Subsequently, have them certified by the Port Authority. A review of the relevant documents revealed that the Ship master and the crew members are not recorded therein.
2. Verify whether the vessel has a sufficient number of crew members with the prescribed qualifications. A review of the Ship's Certificate shows that, according to the Regulation on the Minimum Number of Crew Members Required for Safe Navigation of Vessels and

Other Merchant Marine Vessels ("Official Gazette of the Republic of Serbia" Nos. 28/15, 99/15, and 3/17), the vessel does not have the crew embarked in accordance with the required numbers and qualifications for safe navigation. The vessel does not comply with Article 31.02 (Standard S1) and Article 31.03 (Standard S2), page 8, item 47 of the Ship's Certificate.

3. Verify whether the Ship's Certificate is valid. A review of Ship's Certificate No. 04/21, issued on 30 November 2021 by the Smederevo Port Authority, shows that its validity expired on 26 April 2022 (page 2, item 11 of the Ship's Certificate.
4. Review the Ship's Logbook and verify whether it has been certified by the Port Authority within the prescribed period. In column 20, "Important Notes," all data on significant events and observed deficiencies must be entered, as prescribed by the Regulation on Ship Certificates and Logbooks ("Official Gazette of the Republic of Serbia" Nos. 60/2015, 20/2019, 145/2020, and 139/2022). Ship's logbook No. 342-7-21/21, issued by the Smederevo Port Authority on 06 December 2021, has been kept from 22 September 2023 until 29 October 2023, has not been certified by the Port Authority, and contains no entries regarding the vessel's status during the previous period, nor information on the handover of the vessel, Article 118, paragraph 4 of the Regulation on Ship Certificates and Logbooks ("Official Gazette of the Republic of Serbia" Nos. 60/2015, 20/2019, 145/2020, and 139/2022). Based on the observed irregularities, the Ship Master acted contrary to Article 103, paragraph 1, and Article 144, paragraphs 1, 2, and 4 of ZPLUV.

Based on the above, the Ship Master acted contrary to the legal provisions within his authority. **It is recommended that** the master of the vessel, in the interest of due care for navigational safety and good seamanship, and taking into account the position in which he is embarked, strictly comply with the legal provisions in accordance with Article 48 and Article 144, paragraphs 1, 2, and 4 of the ZPLUV.