PKBWM

PAŃSTWOWA KOMISJA BADANIA WYPADKÓW MORSKICH

SIMPLIFIED REPORT

050/20

serious marine accident

Tugboat "Uran"

Tugboat's bow hitting the XXX-lecia Quay in Gdynia on 19 July 2020

July 2021

The investigation of a serious marine accident of the tugboat "**Uran**" was conducted under the Act of 31 August 2012 on the State Marine Accident Investigation Commission (Journal of Laws of 2019, item 1374) as well as norms, standards and recommended procedures agreed within the International Maritime Organisation (IMO) and binding on the Republic of Poland.

In accordance with the provisions of the above-mentioned Act, the objective of the investigation of a marine accident or incident is to ascertain its causes and circumstances in order to prevent future accidents and incidents and improve the state of marine safety.

The State Marine Accident Investigation Commission does not determine liability nor apportion blame to persons involved in the marine accident or incident.

The following report shall be inadmissible in any judicial or other proceedings whose purpose is to attribute blame or liability for the accident referred to in the report (Article 40(2) of the Act on the SMAIC).

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1. Facts

On the night of 19 July 2020, the tugboat Uran sailed from the Bułgarskie Quay in Gdynia, where it performed a towing service while mooring the ship Christopher, to the berth at the Polskie Quay. At 02:45 a.m.[1] while sailing at a speed of approx. 9.0 knots, it struck its bow at the XXX-lecia Quay at a distance of around 15 m from its corner with the Włoskie Quay which caused damage to the bow of the tugboat and significant damage to the quay made of reinforced concrete. After the accident, the tugboat continued without stopping to the berth at the Polskie Quay.

2. General information

2.1. Ship particulars

Photo 1. – Tugboat URAN (source: MarineTraffic.com)

[1] Local time is given throughout the report (GMT + 2h).

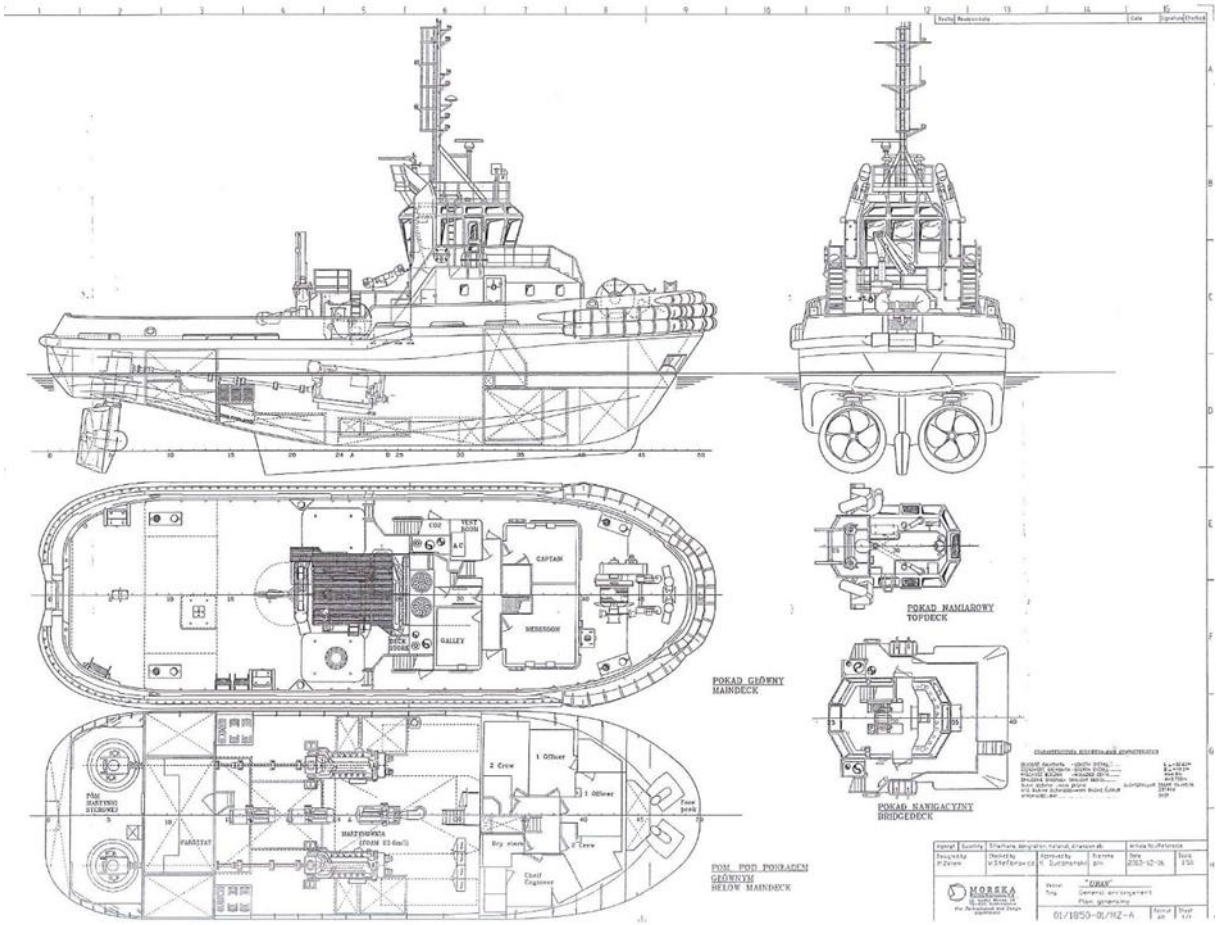


Figure 1. – General plan of the tugboat URAN

Name of the ship:	Uran
Flag:	Poland
Shipowner:	Fairplay Polska Sp.z.o.o. & Co.Sp.k., Szczecin
Operator:	see above
Classification society:	Polish Register of Shipping (PRS)
Vessel type:	tugboat
Call sign:	SPS2396
IMO number:	9190482
Gross tonnage (GT):	313
Build:	2001
Power:	3374 kW
Length overall:	30.82 m

Width:	9.40 m
Hull construction material:	steel
Minimum crew:	3 men
Type of the VDR (S-VDR):	none

2.2. Marine accident or incident information

Kind:	serious marine accident
Date and time of event:	19 July 2020, 02:45 LT (CEST)
Geographical position of the event:	φ=54°32.3'N λ=018°31.3'E
Geographical area of the accident:	Port of Gdynia – XXX-lecia Quay
Nature of the water region:	internal waters
Weather during the accident:	good visibility, variable wind 1°B
Operating state of the vessel during the event:	returning to the berth at the Polskie Quay in the Port of Gdynia
Place of the accident on the vessel:	bow
Accident effects on people:	no effect on people
Accident effects on the vessel:	damage to the bow part of the boat (perforation of the hull plating above the water line) and signs of scratch against the quay along the starboard
Accident effects on infrastructure:	damaged reinforced concrete structure of the quay on the lower landing and on the main quay (cracked edges on approx. 2.5 m and approx. 4 m, respectively); rubber fender damaged and torn off (approx. 4 m) on the lower landing, and low railing on the quay pulled out on one side and bent (approx. 5 m).

2.3. Information on shore services involved and rescue operation

There was no rescue operation and no shore services were involved. The captain did not call for any help, and only notified the dispatcher of the towing company about the accident when the tugboat reached the berth.

3. Circumstances of the accident

On 19 July 2020 at approx. 02:40 a.m., after providing the towing service while mooring the container ship "Christopher" to the Bułgarskie Quay in the Port of Gdynia, the tugboat "Uran" started returning to its permanent berth at the Polskie Quay. The captain of the tugboat reported this fact on VHF channel 12 to the towing company dispatcher. The crew of the tugboat "Uran" consisted of three people: a captain, an engineer, and a senior sailor. The tugboat was steered by the captain with two joysticks for two independent Schottel thrusters (details of this type of propulsion are provided in 4.1 Mechanical factors). In addition to the captain, two other crew members were present on the bridge. Initially, the tugboat followed the course of approx. 110° along the route near the quays from its starboard, going past Bułgarskie, Bramowe and Dokowe Quays, increasing the speed to 9.0 knots. Passing the Bramowe Quay, the captain turned to the course of approx. 125°, at which the tugboat's route continued to run close to the Dokowe Quay at a distance of about 35-40 m. The course of 125° directed the tugboat directly at the corner of the XXX-lecia Quay and Włoskie Quay. At a distance of approx. 12 m from the XXX-lecia Quay, the tugboat's course slightly changed to approx. 113° and at this course, at about 02:45 a.m., the tugboat hit the quay with its bow at a constant speed of approx. 9.0 knots. Due to the last manoeuvre of turning left, the tugboat's bow deviated to the left from the line perpendicular to the quay by approx. 33°.

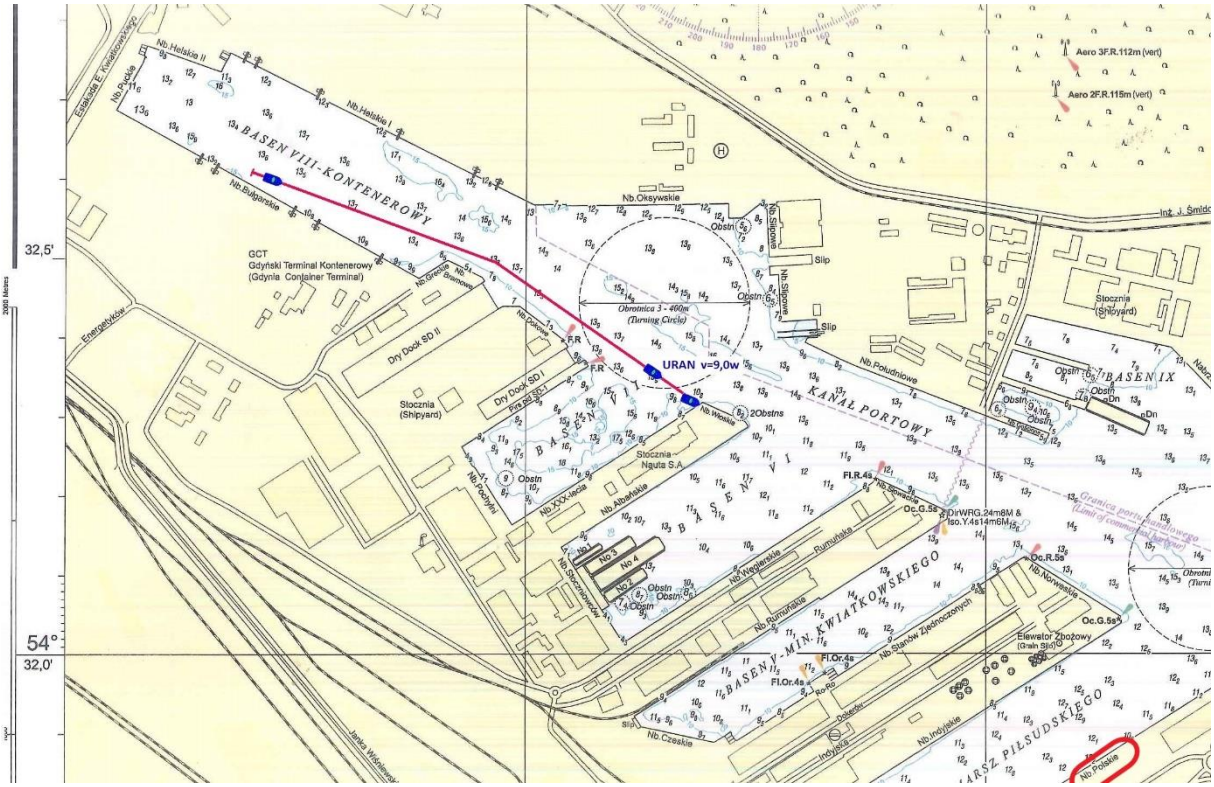


Figure 2. – The route of the tugboat Uran from the Bułgarskie Quay to the accident site (part of the BA 2636 map)

After the collision with the quay approx. 15 m from the quay corner, the tugboat turned starboard parallel to the quay and, with its engines still running, moved forward at low speed, rubbing its starboard against the quay until it passed the quay corner, and then along the Port Channel at a safe distance from the Słowackie and Norweskie Quays, it reached the Polskie Quay where it moored. Immediately after the accident, the captain ordered the senior sailor to check the bow rooms and the deck, and the engineer to check the engines' efficiency. No water inside the hull was found, and the engineer did not find any failure of the propulsion and steering system. Shortly after the accident, in the main port channel and while navigating to the Polskie Quay, the captain tested the operation of the steering and control system by making full turns on both joysticks, observing the indicators and the tugboat's behaviour. This test did not reveal any disruptions in the operation of the devices and the captain continued sailing to the Polskie Quay. After mooring to the Polskie Quay, the captain and the crew inspected the damage to the hull and checked the technical condition of the engine room, then at approx. 03:45 a.m. he notify the towing company dispatcher of the event, informing him that due to a crack in the hull plating in the bow part, the vessel is out of service. After

receiving this information, the dispatcher notified the Port Authority in Gdynia of the accident. The damage to the tugboat's bow and the XXX-lecia Quay is shown in photos 2 and 3.

Photo 2. – Tugboat URAN, damage to the bow

Photo 3. – Damage to the XXX-lecia Quay at the Port of Gdynia

4. Analysis and comments about factors causing the marine accident or incident with regard to examination results and expert opinions

The analysis of the recording of signals from the on-board GNSS receiver showed[2] that the tugboat, until the impact with the quay, was sailing at an average speed of 9.0 knots and a constant course of 125° on the last examined section of the route before the accident. There was a slight change of the course to the left to 113° without any reduction in speed only at a distance of 12 m before the quay. The analysis of the operation of the thrusters before and after the accident did not reveal any deficiencies in the operation of both propellers and main engines.

The conducted examination of records of devices recording the parameters of the vessel's movement and operation of propulsion devices exclude the possibility of uncontrolled operation of the propulsion.

4.1. Mechanical factors

Construction of the tugboat "Uran" was completed and handed over to the operator in January 2001. It is a serial construction made at the Damen Shipyards Den Helder in the Netherlands, designated as project 3110. The tugboat "Uran" is a Schottel ASD type vessel, which means that it is equipped with a propulsion system consisting of two independent engines with two independent shaft lines which drive two Schottel azimuth thrusters – rotating columns with screw propellers in the Kort nozzle, mounted under the hull. The angle of the nozzle rotation and the screw rotation are set by a lever (joystick) on the bridge for each driving unit separately. The boat is steered by appropriate rotation of the nozzles, and the speed is changed by increasing/decreasing the rotation of the screw propellers. Power (4,589 HP) is provided to the thrusters by two Caterpillar CAT 3304 engines which enable the tugboat to reach a speed of 13.2 knots.

Tests of the thrusters carried out by the captain shortly after the accident showed no malfunctions in their operation, and the engineer did not find any symptoms of malfunctioning in the operation of the engines.

The event took place when an attempt was made to adjust the vessel's course to one that would allow it to go pass the XXX-lecia Quay at a safe distance and to move further. To this end, the captain made such a manoeuvre with the joystick to correct the course by turning left.

[2] Calculations included in the excerpt from the expert opinion are presented in Appendix 1 to the report.

Shortly before the accident, the captain's actions about 30-40 m before the quay (length of the tugboat is approx. 31 m), i.e. reduction of the engine speed, turning the thrusters (backwards) and increasing the speed again, were late and ineffective, and the tugboat hit the quay. The possibility of a temporary failure of the driving system thrusters, consisting in an uncontrolled increase in propeller speed, which was suspected by the captain, just as the tugboat was sailing at a speed of 9 knots straight at the quay corner, was examined after the accident by an authorised MG-CAT service and ruled out.

During the accident, the captain ordered the engineer to go to the engine room to check for any breakdowns. The examination did not reveal any irregularities. After the accident (while sailing to the berth), the drive was tested. This test showed the proper operation of the engines and thrusters, and that before and during the collision there was no alarm on the panel of alarms for engine operation on the bridge.

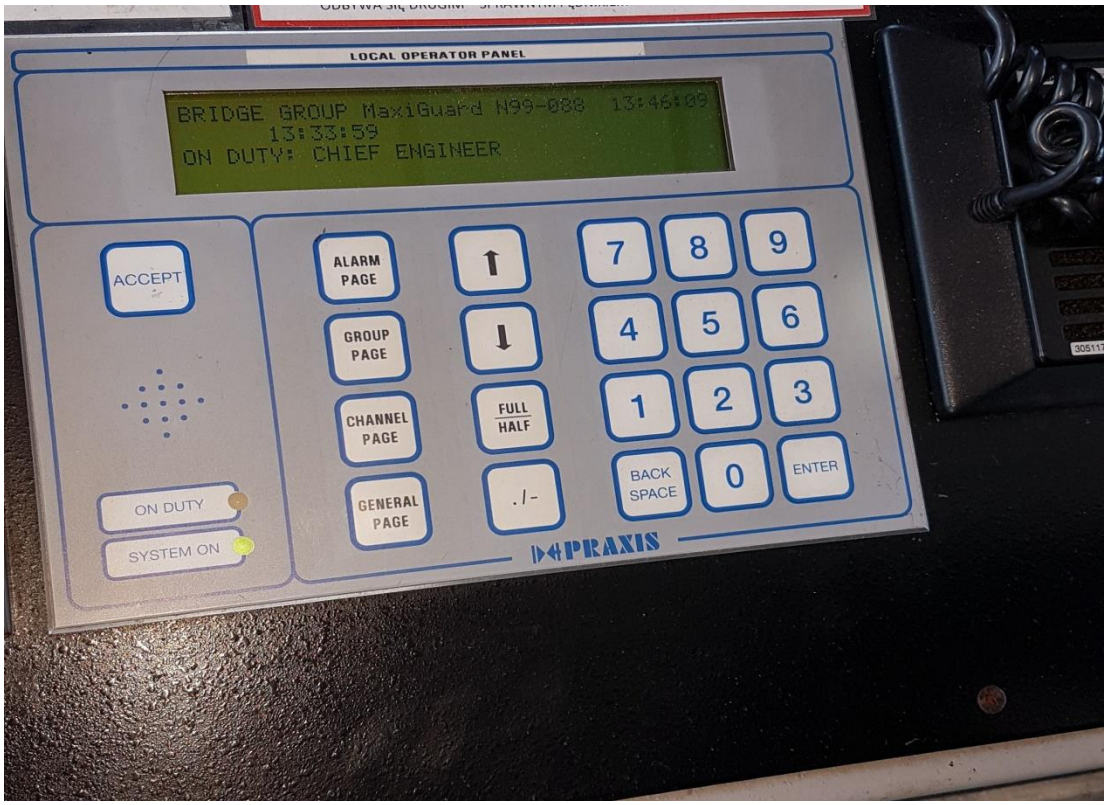


Photo 4. – Panel of alarms on the bridge

Emergency stopping of the drive is possible by using a button on the bridge which disconnects the main engine from the thrusters through a pneumatic clutch in the shaft line.

The engine room has an alarm and parameter control system from the Dutch company Praxis. An alarm recorder is not installed.

Photo 5. – Panel of alarms in the engine room

Main engine Caterpillar type 3516B, s/n 4BW00369 (left), 4BW00371 (right), 1600 rpm, operating hours 35367 (left) and 35385 (right).

Photo 6. – Main engine PS

CAT series 35 engines are the most popular engines fitted on ships, known for their high reliability. After the accident, at the request of the Operator, an engineer from the MG-CAT service authorised by the manufacturer inspected the engines and made a printout from the memory of computers on both engines. To ensure high reliability and constant control of parameters, the engines are equipped with backup computers.

According to the report of the MG engineer, “there are no indications/alarms regarding the moment of collision in the history stored in the computers (main and backup) of the engines.”

All repairs, inspections and service works were carried out in accordance with the technical and operational documentation of the engines.

It is unlikely that a CAT 35 engine, reliable according to popular opinion, in a good technical condition, regularly serviced and not causing technical problems, would suddenly increase its speed just ahead of the quay. Each mechanical failure of the fuel dose control link and, consequently, an increase in the engine speed would require a necessary intervention of the staff to control the situation. After the collision, the operation of all devices was checked and no damage to the mechanisms was found.

4.2. Human factors (fault and neglect)

There were 3 crew members on the tugboat Uran, which met the requirements set out by the administration and included in the Safety Charter. The crew had documents compliant with the requirements of the flag state. On 19 July 2020, the captain was on watch on the bridge of the tugboat Uran both during towing services in the port and while sailing from the berth and back.

The captain and other crew members worked in the 12/12 hour system (after 12 hours of work, 12 hours of rest). The captain started work at 07:00 p.m. on the previous day and did not have any orders for the tugboat at the berth at the Polskie Quay until 01:00 a.m. With this work system and a long standstill waiting for the first towing service, the fatigue factor could not play a significant role in the accident. The captain's knowledge of the port in Gdynia was very good.

4.3. Organisational factors

The choice of the return route from the Bułgarskie Quay to the Polskie Quay near the starboard quay, with the course of approx. 125° chosen after the turn, straight to the corner of the XXX-lecia Quay and Włoskie Quay, was not justified, especially that there were no other vessels moving at that time in the port channel and adjacent port basins. Failure to start the manoeuvre to turn left early enough in order to safely avoid the corner of the XXX-lecia Quay leads to the assumption that there was no reliable look-out (with good visibility and operational radar switched on). From the seat from which the captain was steering the tugboat, there was a good view of the area in front of the bow, as well as the radar screen and the electronic map screen. Maintaining too high a speed of around 9.0 knots had no justification and exceeded the permissible speed of ships in the port of Gdynia, which is 6.0 knots.[3]

[3] (Ordinance No. 9 of the Director of the City Hall in Gdynia of 16 July 2018 – Port regulations, Chapter 2.
2. Additional regulations for the Port of Gdynia, § 121)
1. Ships shall move at a safe speed, in accordance with the COLREGs, but not greater than:
1) 10 knots in the roadstead;
2) 6 knots in port.
2. The Harbour Master may consent to ships exceeding the speed specified in paragraph 1 when it is necessary for proper maneuvering or when it is necessary due to the special maneuvering characteristics of the ships.
3. The speed limits set out in paragraph 1 shall not apply to state service ships during the performance of statutory tasks.

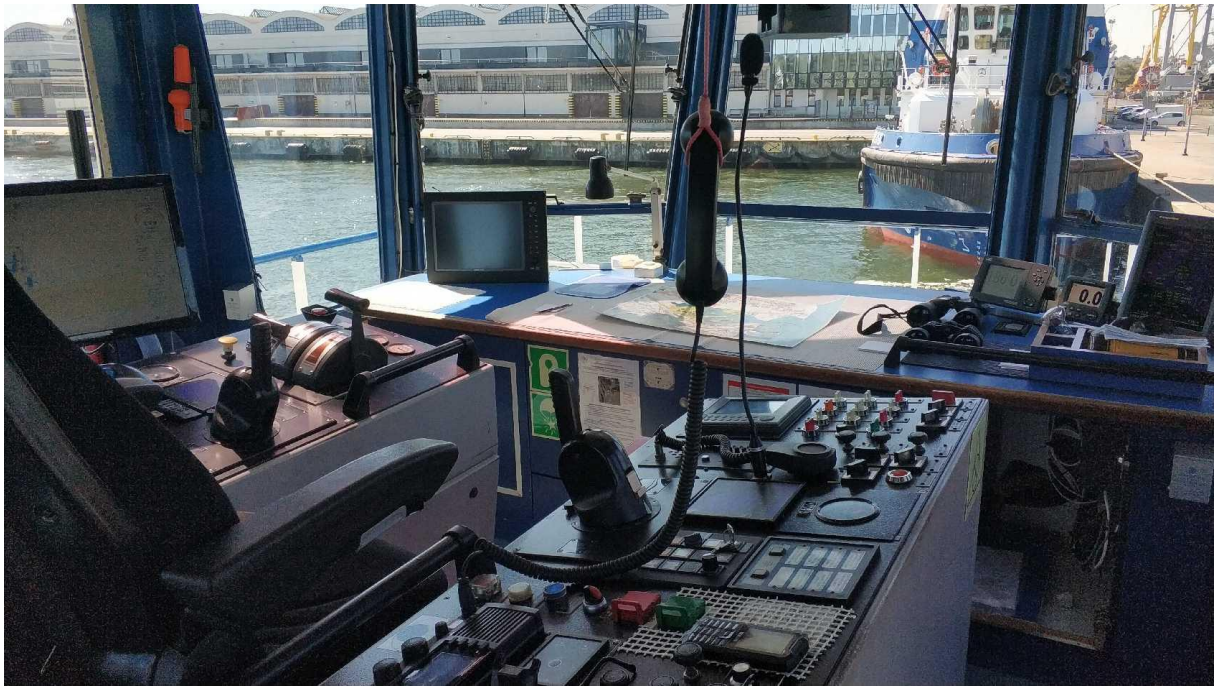


Photo 7. – Tugboat control place

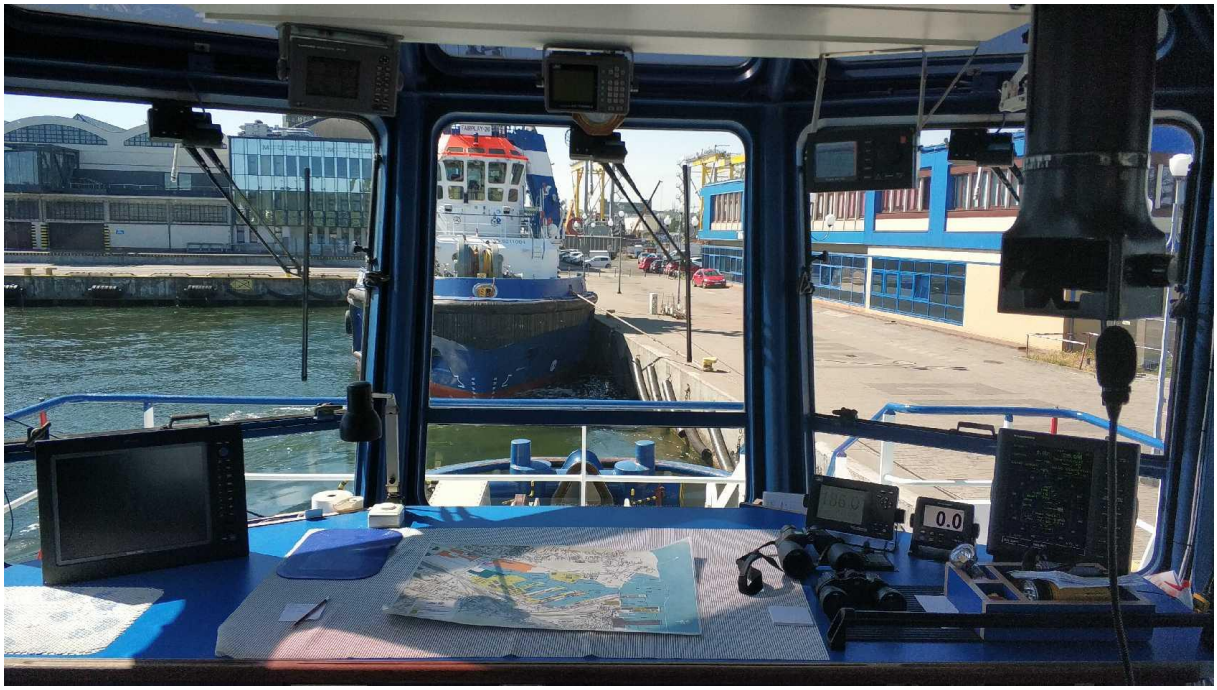


Photo 8. – Field of vision in front of the tugboat's bow from the steering position

4.4. The influence of external factors, including the marine-related ones, on the accident

The weather conditions had no influence on the accident. The passage of the tugboat from the Bułgarskie Quay to the Polskie Quay took place at night which – with good visibility, lighting of the quay and navigation lights on the quay edge and an efficient, operating radar – was not a significant obstacle for the navigator of the vessel.

5. Description of examination findings including the identification of safety issues and conclusions

The Commission found that the decisive factor in the collision of the tugboat Uran with the quay was improper look-out by the captain as well as his delayed actions in order to safely go past the corner of the quay.

The results of tests and calculations included in the expert opinions exclude faulty operation of the tugboat's engines and thrusters before and during the accident. The analysis of the image of the tugboat's movement in the pre-accident phase, showing the invariable speed and course almost to the last moment before the accident, allows for the conclusion that the cause of the boat hitting the quay was:

1. Lack of look-out required by rule 5 of the COLREG 72[4] by the tugboat crew.
2. Taking the route too close to the quays on the starboard side of the tugboat, despite the lack of movement of other vessels in the port channel and adjacent basins.
3. Maintaining too high a speed when returning to the berth.
4. Maintaining the course of approx. 125° leading the tugboat directly to the corner of the XXX-lecia Quay, without early attempts to correct it to safely go past the corner, as well as too late attempt to reduce the speed 30-40 m before the quay.

6. List of photographs

[4] International Regulations for Preventing Collisions at Sea (COLREGs).

7. List of figures

8. Sources of information

Notification about the accident.

Documents of the tugboat Uran.

Documents received from the Port Authority in Gdynia.

Photos taken by representatives of the SMAIC.

Engines' service report, prepared by MG – Przedsiębiorstwo Techniczno-Handlowe.

Hearings of the SMAIC.

Expert opinions prepared by Jacek Pietraszkiewicz and Bogusław Harańczyk.

9. Composition of the Accident Investigative Team

Team Leader – Grzegorz Suszczewicz – Vice Chairman of the SMAIC

Team Member – Marek Szymankiewicz – Secretary of the SMAIC

10. Appendix

Extract from the expert opinion on the imaging of movements of the tugboat URAN based on the records in the GNSS receiver and data obtained from the on-board computer.

Data collected from the vessel's on-board ECS in the form of the following files were submitted for the expert analysis:

a) dane.gpx
b) dane_grp.csv
c) dane_rte.csv
d) dane_trk.csv
e) dane_twp.csv
f) dane_wpt.csv

Determining constant parameters of the boat

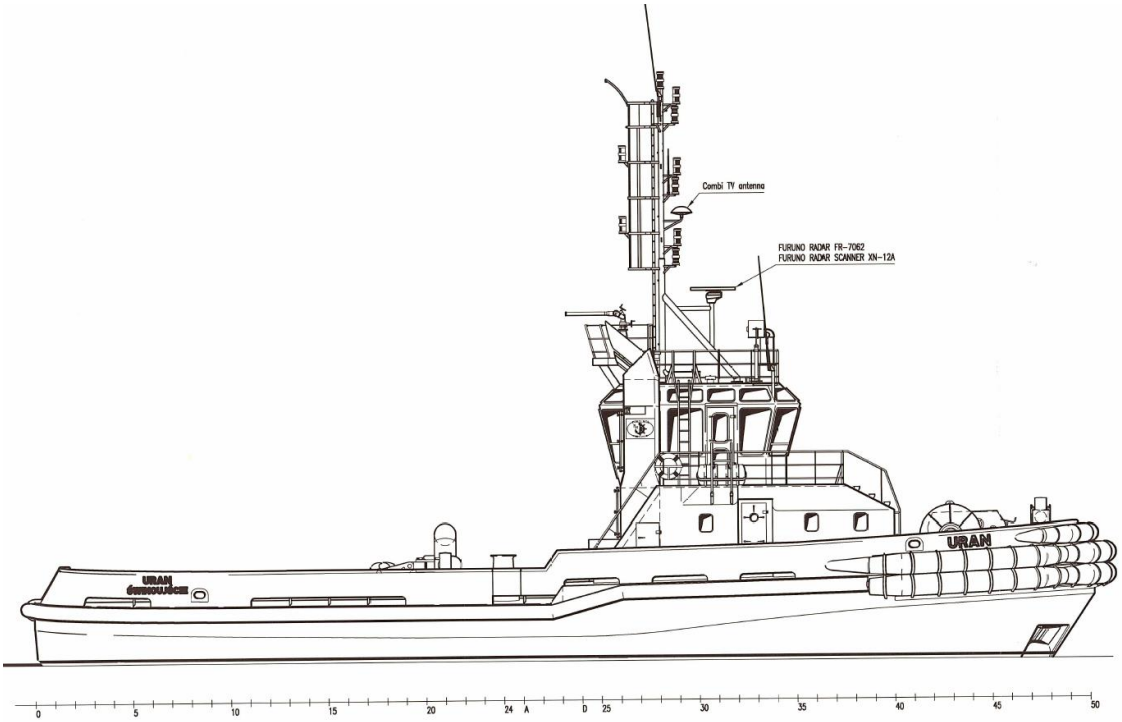


Figure 1. Starboard view of the tugboat URAN

The analysis of the data.gpx file indicates that the ECS (Electronic Charts System) Time Zero Navigator by MaxSea Navigator was installed on board the tugboat. It is an electronic navigation map system functioning under the MS Windows operating system. One of its functionalities is recording of the log of operation of the on-board GNSS subsystem. As a result of the activity, the data.gpx file submitted for examination was created, containing basic navigation data saved in XML format:

1. Latitude φ of the GNSS receiver antenna;
2. Longitude λ of the GNSS receiver antenna;
3. Date and time of measurement of φ and λ.

These are the only navigation data contained in the files submitted for the expert analysis. The following is an example of the data structure:

```
<trkpt lat="54.535251634615" lon="18.5498084507927">
    <time>2020-07-19T00:00:00.3330829Z</time>
</trkpt>
   <trkpt lat="54.5352450006021" lon="18.549723052098">
    <time>2020-07-19T00:00:01.5834607Z</time>
   </trkpt>
```

As you can see, the data structure is clear and simple. The record of a single measurement of position and time is presented between the tags <trkpt…> </trkpt>. An explicit record of the position in degrees is recorded inside these tags, and a time stamp of the automatic measurement between the tags <time>… </time>.

As shown in **Figure 2**, the only GNSS antenna in the inventory is the FURUNO GPS Navigator GP-80 antenna located on one of the main mast crosstrees. According to the measurements, it is located 11.8 m from the bow of the tugboat. This information seems to be reliable, as the same distance was provided by the technical superintendent of the Fairplay Towage Group (shipowner).

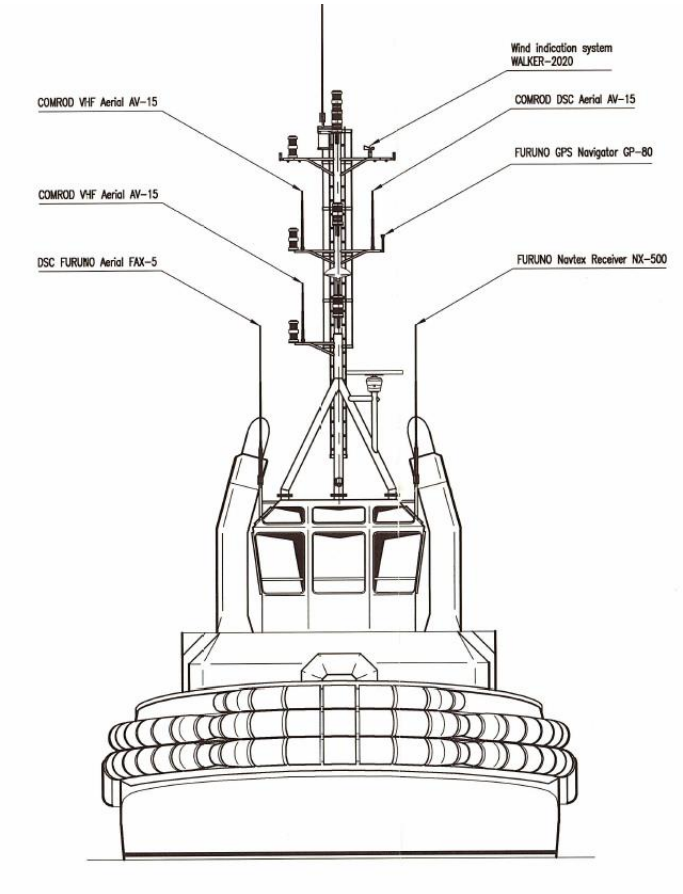


Figure 2. View of the tugboat URAN from the bow

Determining measurement data

Data from the above-mentioned file (data.gpx) was used for further work along with the records acquired from it, covering the date of the accident, i.e. 19 July 2020. 14,713 entries

saved between 00:00:00.3330829 UTC and 23:59:55.7441626 UTC were read from the file. The data was saved in the file 19lipca2020.txt attached to this expert opinion.

Graphical representation of the tugboat's movements is presented in **Figure 3**.

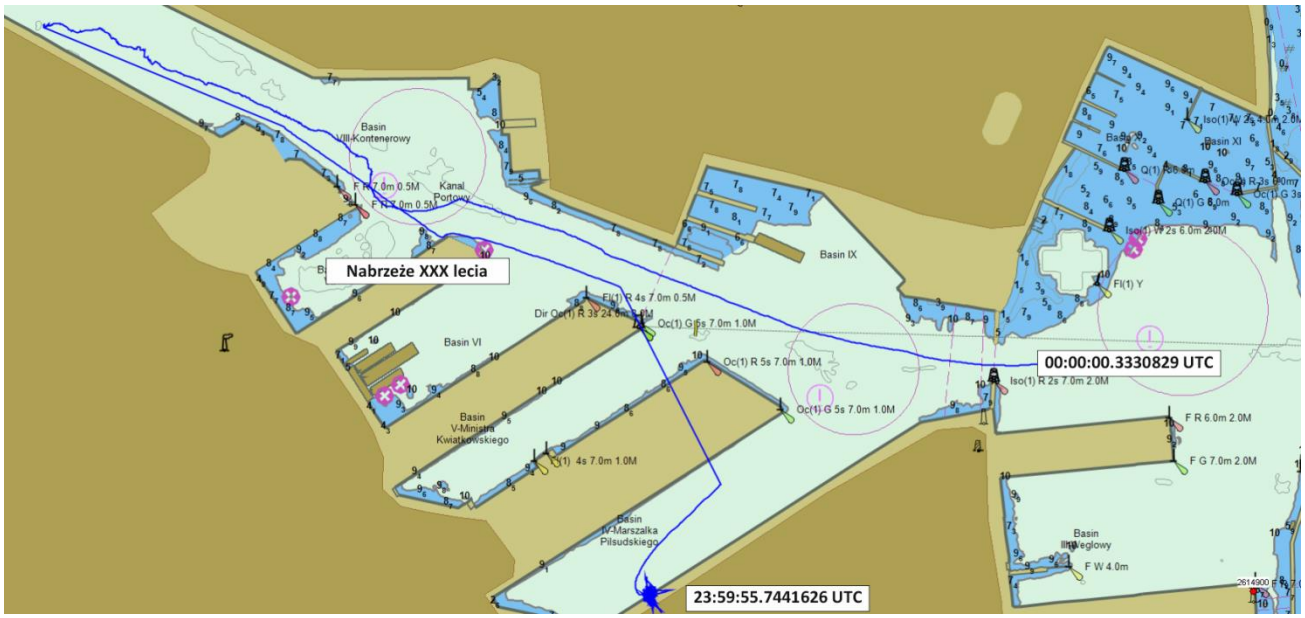


Figure 3. Movements of the tugboat Uran on 19 July 2020 in the Port of Gdynia (blue line)

Figure 3 shows that the tugboat came up too close to the corner of the XXX-lecia Quay being the subject of the expert analysis. The time of the closest approach to the quay was determined from the position records at 00:44:52 UTC (02:44:52 CEST). Given the scope of the order, the data covering the last section after a significant change of the tugboat's course before approaching the XXX-lecia Quay was selected for further study.

Determination of the timing was based on the time in the log file. Accuracy and format indicate that the time was taken from the GNSS receiver, so it could not have be manipulated or otherwise electronically processed. Its values were assumed to be certain.

Preparation of research data

Data selected from the extracted ones represent the section from the last significant change of the course until the tugboat's GNSS antenna passes the NE corner of the XXX-lecia Quay, i.e. positions from 00:42:49.409185 UTC until 00:44:52.640704 UTC. They are presented in **Table 1** and **Figure 4**.

The electronic map cell PL5GDYNA.000, 17.19 edition with amendments of 29 June 2020, produced by the Hydrographic Office of the Polish Navy in the WGS84 frame of reference

(compatible with the GNSS) and the compilation scale 1:8000 rendered in the Argus 3.0 (ENC class) navigation programme by NavSim, was selected for the visualisation.

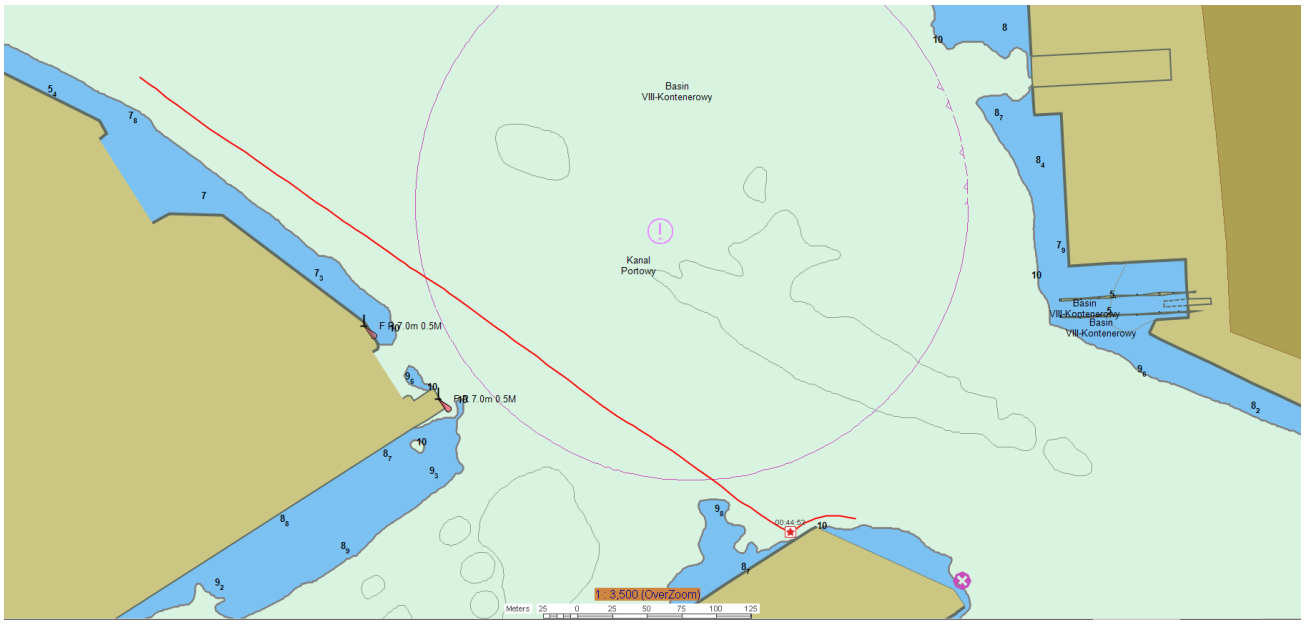


Figure 4. Track record of the tugboat URAN selected for expert analysis (red line)

Table 1. Table of recorded values of the geographical position of the tugboat in the time interval examined

No.	Latitude [°]	Longitude [°]	Time of taking the measurement of the geographical position [UTC]
0	54.5415399999945	18.5155166666667	2020-07-19 00:42:49.409185
1	54.5414899999954	18.5156399985475	2020-07-19 00:42:50.602314
2	54.5414649996888	18.5156983341175	2020-07-19 00:42:51.773262
3	54.5414066663375	18.5158233323343	2020-07-19 00:42:53.276554
4	54.5413533336795	18.5159483351543	2020-07-19 00:42:54.444401
5	54.5413283332889	18.5160099987932	2020-07-19 00:42:57.008958
6	54.5412783330292	18.5161316689411	2020-07-19 00:43:00.133719
7	54.5412500000892	18.516194998916	2020-07-19 00:43:01.635874
8	54.5411999997332	18.5163166644608	2020-07-19 00:43:02.963746
9	54.5411766675374	18.5163783327028	2020-07-19 00:43:04.472155
10	54.5411283333478	18.5165033355228	2020-07-19 00:43:06.976943
11	54.5410833336524	18.5166300000757	2020-07-19 00:43:07.517412
12	54.5410583330956	18.5166900019816	2020-07-19 00:43:10.326281
13	54.5410083325036	18.5168150001985	2020-07-19 00:43:11.005441
14	54.5409049991713	18.5170583312882	2020-07-19 00:43:12.059957
15	54.5408566666929	18.5171833341081	2020-07-19 00:43:13.504156
16	54.5408066658527	18.517304999653	2020-07-19 00:43:14.967508

17	54.5407816671602	18.517368334231	2020-07-19 00:43:16.350002
18	54.5407299999547	18.5174916661118	2020-07-19 00:43:17.684374
19	54.540706667489	18.5175516680178	2020-07-19 00:43:20.195617
20	54.5406800004254	18.5176149979927	2020-07-19 00:43:21.190689
21	54.5406049990997	18.5177983317795	2020-07-19 00:43:22.719966
22	54.5405800002831	18.5178633326935	2020-07-19 00:43:24.038723
23	54.5405549994165	18.5179250009355	2020-07-19 00:43:26.540148
24	54.5405083328039	18.5180483328163	2020-07-19 00:43:30.885198
25	54.5404833339278	18.5181100010583	2020-07-19 00:43:32.722326
26	54.5404066659528	18.5182933348451	2020-07-19 00:43:34.236572
27	54.5403583328815	18.518418333062	2020-07-19 00:43:36.174149
28	54.5403333339131	18.518478334968	2020-07-19 00:43:37.571748
29	54.5403083328947	18.5185399986068	2020-07-19 00:43:40.418709
30	54.5402850001868	18.5186049995208	2020-07-19 00:43:43.425432
31	54.5402366669708	18.5187299977377	2020-07-19 00:43:44.819868
32	54.5401883336973	18.5188533342217	2020-07-19 00:43:46.771391
33	54.5401650009205	18.5189166687997	2020-07-19 00:43:48.442111
34	54.5401383335013	18.5189783324385	2020-07-19 00:43:50.785531
35	54.5400866675122	18.5190999979833	2020-07-19 00:43:51.286644
36	54.5400383340602	18.5192233344673	2020-07-19 00:43:53.295764
37	54.5400100002553	18.5192849981062	2020-07-19 00:43:54.124934
38	54.5399316671159	18.519469998229	2020-07-19 00:43:57.308578
39	54.5399066658503	18.519530000135	2020-07-19 00:43:58.141199
40	54.5398816666039	18.519591668377	2020-07-19 00:44:00.478768
41	54.5398300002884	18.5197133339218	2020-07-19 00:44:01.650046
42	54.5397800002191	18.5198333331306	2020-07-19 00:44:03.672619
43	54.5397283337742	18.5199549986754	2020-07-19 00:44:05.658974
44	54.5396766672636	18.5200733315482	2020-07-19 00:44:06.162039
45	54.5395999998008	18.520249999991	2020-07-19 00:44:09.007489
46	54.5395750003657	18.5203100018969	2020-07-19 00:44:10.846194
47	54.5395216673376	18.5204300011058	2020-07-19 00:44:12.013129
48	54.5394716668888	18.5205500003146	2020-07-19 00:44:14.353421
49	54.539418333725	18.5206650005153	2020-07-19 00:44:16.028147
50	54.5393450004691	18.5208483343021	2020-07-19 00:44:17.195838
51	54.5393216672079	18.520909997941	2020-07-19 00:44:18.197112
52	54.539300000265	18.520971666183	2020-07-19 00:44:20.542407
53	54.539279999643	18.521035000761	2020-07-19 00:44:21.212484
54	54.539255000011	18.5210933317278	2020-07-19 00:44:23.715173
55	54.539210000275	18.5212183345478	2020-07-19 00:44:26.560206

56	54.5391866669363	18.5212783318506	2020-07-19 00:44:27.892708
57	54.5391400007864	18.5214033346706	2020-07-19 00:44:29.957365
58	54.5391166674075	18.5214649983095	2020-07-19 00:44:31.075719
59	54.5390933340151	18.5215250002155	2020-07-19 00:44:32.415464
60	54.5390149991081	18.5217066676663	2020-07-19 00:44:35.875974
61	54.538989999313	18.5217666649691	2020-07-19 00:44:37.756093
62	54.5389400002445	18.5218900014531	2020-07-19 00:44:40.440123
63	54.5388883327313	18.5220133333339	2020-07-19 00:44:41.436889
64	54.538798332965	18.5222049988008	2020-07-19 00:44:43.027747
65	54.5387749993899	18.5222650007068	2020-07-19 00:44:45.618906
66	54.53875333419	18.5223266643456	2020-07-19 00:44:46.458412
67	54.5387049991517	18.5224466681576	2020-07-19 00:44:48.034621
68	54.5386583324486	18.5225666673664	2020-07-19 00:44:50.969289
69	54.5386166668058	18.5226883329112	2020-07-19 00:44:51.470208
70	54.5385900004049	18.5227950014319	2020-07-19 00:44:52.640704

Calculations and visualisation

The next part focused on determining the route, course and speed of the vessel on the studied section of navigation. Points on the route from **Table 1** are presented in **Figure 5**.

Figure 5. Graphical presentation of data from Table 1

Determining the actual course and route

Two methods were selected to determine the tugboat's course: graphical and calculative. First, the COG (Cours Over Ground) value was read from the navigation system used in the test between position 0 and 69. The course KR = 125° was read.

For accuracy, the orthodromic method was used for calculations. For this purpose, a computer programme was written in Python 3.0:

```
#©2020 Jacek Pietraszkiewicz; ZeglugaPoOrtodromie
import math
from math import cos
def zapis(stopnie):
  x1 = math.modf(stopnie)
  c_s = x1[1]
  c_m = x1[0]
  tekst = ("{:.0f}".format(c_s)+"* "+ "{:.1f}".format(c_m*60)+"'")
  return tekst

fi_1_s = 54.5415399999945
la_1_s = 18.5155166666667
fi_2_s = 54.5386166668058
la_2_s = 18.5226883329112

print("A(", fi_1_s,"N", la_1_s, "E)")
print("B(", fi_2_s,"N", la_2_s, "E)")
a = 90 - fi_2_s
b = 90 - fi_1_s
if math.fabs(la_2_s - la_1_s) <= 180:
  C = math.fabs(la_2_s - la_1_s)
elif math.fabs(la_2_s - la_1_s) > 180:
  C = 360 - math.fabs(la_2_s - la_1_s)

print("\na=", zapis(a),"\nb=", zapis(b),"\nC=", zapis(C))

ortodroma_Nm =
(math.acos(math.cos(math.radians(fi_1_s))*math.cos(math.radians(fi_2_s))*math.cos((math.radian
s(la_2_s) -
math.radians(la_1_s)))+(math.sin(math.radians(fi_1_s))*math.sin(math.radians(fi_2_s))))/(math.
pi*2/360))*60
ortodroma_m = ortodroma_Nm * 1852

ortodroma_s =
(math.acos(math.cos(math.radians(fi_1_s))*math.cos(math.radians(fi_2_s))*math.cos((math.radian
s(la_2_s) -
math.radians(la_1_s)))+(math.sin(math.radians(fi_1_s))*math.sin(math.radians(fi_2_s))))/(math.
pi*2/360))

print("Długość ortodromy:","{:4.2f}".format(ortodroma_m),"m")

c_A = (math.cos(math.radians(a))-
(math.cos(math.radians(b))*math.cos(math.radians(ortodroma_s))))/(math.sin(math.radians(b)) *
math.sin(math.radians(ortodroma_s)))

print("\nA=", zapis(math.acos(c_A)/(math.pi*2/360)) )

c_B = (math.cos(math.radians(b)) - math.cos(math.radians(a)) *
math.cos(math.radians(ortodroma_s)))/(math.sin(math.radians(a)) *
math.sin(math.radians(ortodroma_s)))

print("B=", zapis(math.acos(c_B)/(math.pi*2/360)))

print("Płynąc na wschód:")
alfa = c_A
beta = 180 - (math.acos(c_B)/(math.pi*2/360))

print("Kąt wyjścia   =", zapis((math.acos(alfa)/(math.pi*2/360))))
```

```
print("Kąt podejścia =", zapis(beta))
```

The following was calculated from the above:

Distance between position P_0 and P_{69} = 565.03 m

Exit course KR_w = 125° 5.4'

Approach course KRp = 125° 5.8'

Both methods showed a similar result. It should be assumed that the tugboat was following the course KR = 125° with slight deviations.

Determining the speed of the tugboat movement

To determine the speed, it was necessary to determine the distance between the extreme positions on the course P_0 and P_{70}, and the difference of measurement times of these positions. Similarly to the case of the course, a programme was written to calculate the above-mentioned values, also based on the orthodromic equations:

```
# code=UTF-8
#©2021 Jacek Pietraszkiewicz;
# Program przeliczajacy z pozycji i czasu pobranego z CSV lat[ss.sssss], lon[sss.ssss],
# time[rrrr,mm,dd,gg,mm,ss,ms]
    # droge, czas i predkosc.

import csv
import math
import datetime
import os


def ortodroma(fi_1_s, la_1_s, fi_2_s, la_2_s):
    ortodroma_nm = ((math.acos(math.cos(math.radians(fi_1_s)) * math.cos(math.radians(fi_2_s))
* math.cos((math.radians(la_2_s) - math.radians(la_1_s))) + (math.sin(math.radians(fi_1_s)) *
math.sin(math.radians(fi_2_s)))) / (math.pi * 2 / 360)) * 60)
    ortodroma_m = (ortodroma_nm * 1852)
    return ortodroma_nm, ortodroma_m


szer = list([])
dlug = list([])
czas = list([])

with open('Z:/Python/proby/uran20przeduderzeniem.csv') as csvfile:
    readCSV = csv.reader(csvfile, delimiter=",")

    for row in readCSV:
        try:
            szer.append(float(row[1]))
            dlug.append(float(row[2]))
            a = int(row[3])  # rok
            b = int(row[4])  # miesiac
            c = int(row[5])  # dzien
            d = int(row[6])  # godzina
            e = int(row[7])  # minuta
            f = int(row[8])  # sekunda
```

```
            g = int(row[9])  # milisekunda
            g = g / 1000000
            g = int(round(g - int(g), 6) * 1000000)
            x = datetime.datetime(year=a, month=b, day=c, hour=d, minute=e, second=f,
microsecond=g)
            czas.append(x)
        except ValueError:
            continue

D_nM = []
D_m = []
d_t = []

for i in range(len(szer) - 1):
    x, x_m = ortodroma(szer[i], dlug[i], szer[i + 1], dlug[i + 1])
    D_nM.append(x)
    D_m.append(round(x_m, 2))
    d_t.append(czas[i + 1] - czas[i])
trasa = 0
time = d_t[1] - d_t[1]

for i in range(len(D_m)):
    trasa = trasa + D_m[i]
    time = time + d_t[i]

s = time.seconds
sm = time.microseconds / 1000000

time = s + sm
print("Trasa= ", "{:6.2f}".format(trasa), " m")
print("Czas= ", "{:6.2f}".format(time), "s")
print("Średnia predkość [m/s] = ", round((trasa / time), 1))
print("Średnia predkość [kt] = ", round(trasa / time * 3600 / 1852, 1))

odcinek = 0
odcinek_t = d_t[1] - d_t[1]

for i in range(len(D_m)):
    odcinek = odcinek + D_m[i]
    odcinek_t = odcinek_t + d_t[i]

    if i % 7 == 0 and i > 0:
        s = odcinek_t.seconds
        sm = odcinek_t.microseconds / 1000000
        odcinek_t = s + sm
        print("ODCINEK", i // 7)
        print("Trasa= ", "{:6.2f}".format(odcinek), " m")
        print("Czas= ", "{:6.2f}".format(odcinek_t), "s")
        print("Średnia predkość [m/s] = ", round((odcinek / odcinek_t), 1))
        print("Średnia predkość [kt] = ", round(odcinek / odcinek_t * 3600 / 1852, 1))
        print("*" * 30)
        odcinek = 0
        odcinek_t = d_t[1] - d_t[1]

for i in range(len(D_m)):
    print(
        "{:2.0f}".format(i + 1) + ".",
        "{:5.2f}".format(D_m[i]),
        "m - ",
        "{:5.2f}".format((d_t[i].seconds + d_t[i].microseconds / 1000000)),
        "s = ",
        "{:5.2f}".format(D_m[i] / (d_t[i].seconds + d_t[i].microseconds / 1000000)),
        "m/s   [",
        "{:4.1f}".format(round(D_m[i] / (d_t[i].seconds + d_t[i].microseconds / 1000000) *
3600 / 1852, 1)), "kt #]")
```

Calculation results:

Route D = [P_{70} – P_0] = 572.82 m

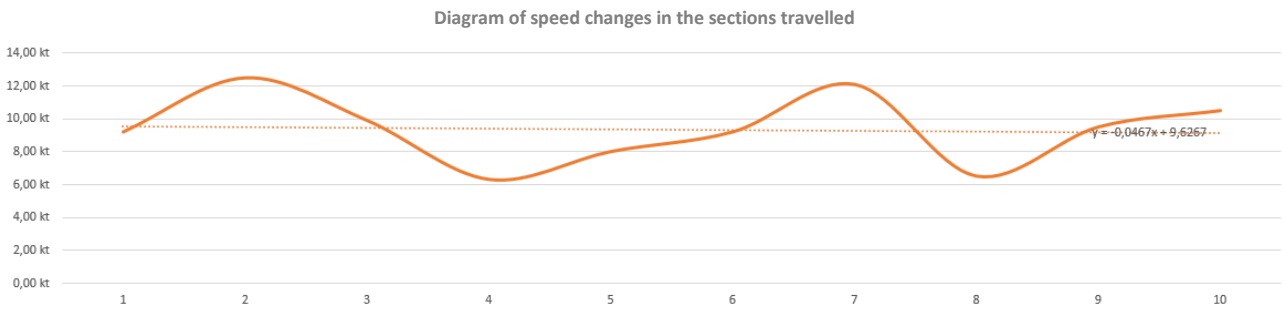
Sailing time for t_D = 123.23 s

Average speed $v_{śrD}$ = 4.6 m/s = 9.0 knots

In the next step, an attempt was made to check whether the tugboat crew changed their speed as they approached the quay. For this purpose, the route was divided into sections of 7 measurements and with the above-mentioned programme, the distance and speed in individual sections were calculated. The results are presented in the table below:

Table 2. Table of measurements of the tugboat movements before the collision

SECTION	ROUTE [M]	TIME [S]	SPEED [M/S]	SPEED [KNOTS]
Section 1 [P_7 – P_0]	63.95	13.55	4.7	9.2
Section 2 [P_{14} – P_7]	67.67	10.54	6.4	12.5
Section 3 [P_{21} – P_7]	53.55	10.53	5.1	9.9
Section 4 [P_{28} – P_{21}]	53.05	16.38	3.2	6.3
Section 5 [P_{35} – P_{28}]	53.31	12.88	4.1	8.0
Section 6 [P_{42} – P_{35}]	58.40	12.36	4.7	9.2
Section 7 [P_{49} – P_{42}]	71.64	11.54	6.2	12.1
Section 8 [P_{56} – P_{49}]	42.44	12.76	3.3	6.5
Section 9 [P_{63} – P_{56}]	64.17	13.07	4.9	9.5
Section 10 [P_{70} – P_{63}]	60.54	11.2	5.4	10.5



Taking into account the maximum speed of the tugboat V_{max} = 13.2 kt, it should rather be assumed that the observed high speed values (v > 12 kt) should be considered as measurement errors of the GNSS device. On this basis, the expert believes that an independent GNSS receiver with poor accuracy was connected to the on-board ECS.

Determining the time and place of the incident

As shown in **Figure 6**, a slight change of the course to the left from 125° to 113.3° is visible from position 69.

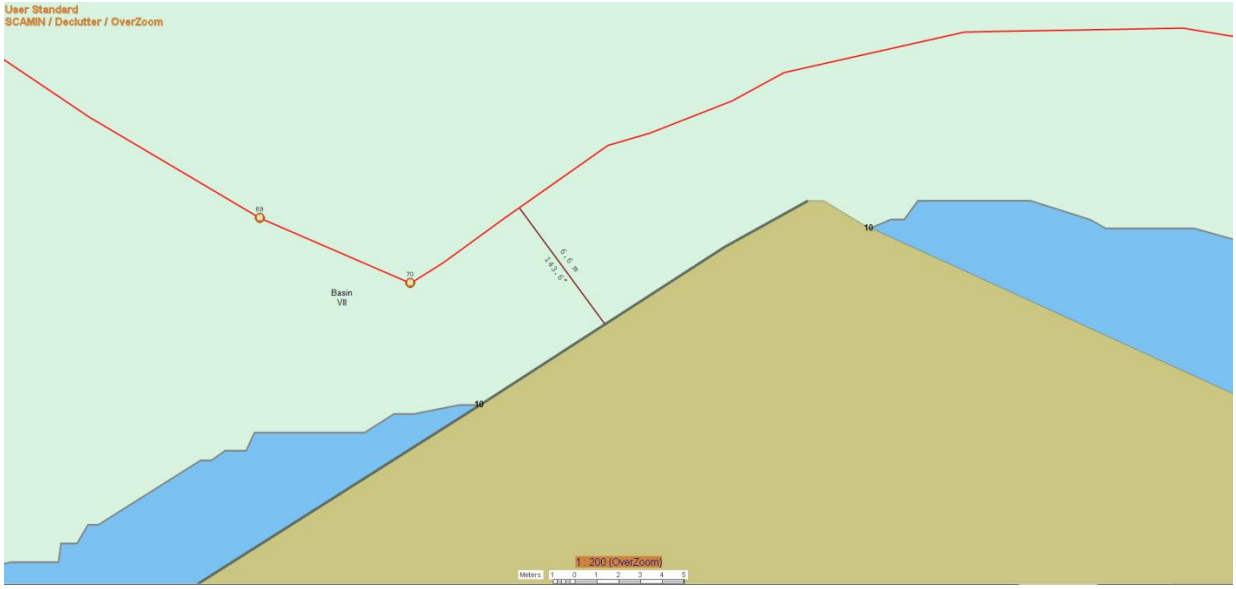


Figure 6. Measurement trace of the tugboat's GNSS antenna at the XXX-lecia Quay.

A significant change of the antenna course from 113.3° to 54.8° is visible in position 70.

The tugboat's waterline was marked to scale on the graphical imaging. On this basis, the probable place of the incident was determined (**Figure 7**), identified at approx. 15÷16 m from the NE corner of the quay. The vessel probably hit the quay at an angle of about 56°, temporarily slowing down to 1.9 knots with the engines running all the time, bouncing off it and moving along the quay. This is evidenced by the distance of the parallel trace of the antenna from the quay (6.6 m > 5.01 m (half the width of the vessel)) and long deep scratches on the chine. Subsequent measurements after the impact show that after bouncing and sliding off the quay the tugboat was gaining speed again.

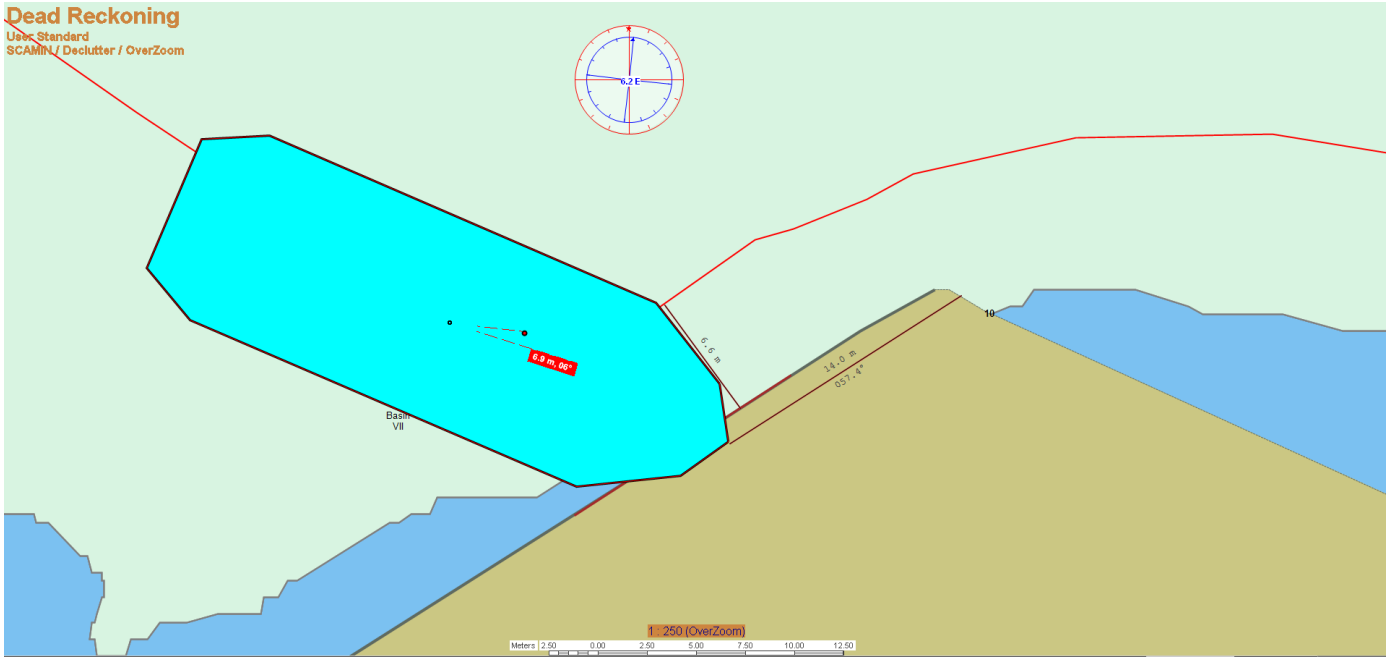


Figure 7. Place of the incident (00:44:52.6 UTC]

Table 3. Table of measurements of the tugboat movements after the collision

SECTION	ROUTE [M]	TIME [S]	SPEED [M/S]	SPEED [KNOTS]
Section 1 [P_{71} – P_{70}]	1.76	1.84	0.96	1.9
Section 2 [P_{72} – P_{71}]	3.46	2.17	1.59	3.1
Section 3 [P_{73} – P_{72}]	5.78	1.01	5.74	11.2
Section 4 [P_{74} – P_{73}]	2.01	0.50	4.00	7.8