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# Determination of the potential pollution of the port of Świnoujście after collision of ships on the approach track

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**Key words:** PISCES II, oil spill simulation, oil pollution behaviour, Pomeranian Bay region, worst case study

**Abstract**
A key element in ensuring the safety of the port of Świnoujście against oil spills is to ensure combat units are properly equipped with oil spill collecting equipment, and that they have the ability to effectively use the existing resources. All of this should be properly reflected in the port's contingency plans. It is also important to develop tactics for oil spill combat action that take into account both local conditions and worst case scenarios with parallel checking of these scenarios during the exercise and the table-top exercises. The use of computer simulation to forecast oil spill behaviour allows for better arrangement and more efficient use of resources and the optimum development of antipollution action and tactics.

The specific location of the Świnoujście harbour, its breakwaters shape, and that shipping traffic is allowed only on the approaching waterway, may lead one to the conclusion that the port of Świnoujście is completely safe from any possible petroleum pollution after a ships' collision and the antipollution action should focus only on maximising the protection of the coast. To verify this assumption, simulations of an oil spill spreading after a vessels' collision were carried out. The purpose of the simulations was to determine the most unfavourable weather conditions which would lead to the port of Świnoujście being polluted, and to define the best tactics for conducting oil spill combat actions under such conditions. The simulations clearly indicated that, with a particular combination of weather conditions, pollution could occur inside the port. It could result in vessel traffic suspension and huge financial losses. Simulations were conducted using the PISCES II oil spill simulator.

## Introduction

A proper analysis of the effective use of existing resources during antipollution operations in specific emergencies is a very important element in the planning stage. In order to identify the hazards that exist in the area, an analysis of the risk of the hazardous situation should be made, and the main factors affecting the development of the situation should be identified.

In the case of the Świnoujście approach and port area, a serious emergency resulting from a ships' collision may occur only on the approach route to the port or on the anchorages. Because of this oil tanks could be unsealed and petroleum substances could be spilled and pollute the marine environment, the coast, and (in a special situation) the port waters and wharves.

The behaviour of petroleum pollution in water depends on many factors (ITOPF, 2014). Of course, the main hydrometeorological conditions are the currents, winds, and sea state. Due to the short time in which oil pollution can reach the coast, some factors related to the type of oil, such as evaporation or emulsification, are much less important (Jarząbek & Juszkiewicz, 2016a).

The PISCES II oil spill simulator enables modelling of the diffusion processes of oil contaminants in water, and their evaporation and flooding under simulated hydrometeorological conditions. It is possible to simulate the usage of available resources and the oil pollution's interaction with the coast. Meteorological conditions that can be simulated include air and water temperature, wind direction and speed, sea conditions, current parameters, or real recorded data can be used. All these parameters can be dynamically modelled during the simulation. The simulation results can be saved and then analysed.

The earlier simulations concerning the diffusion of oil pollutants (Jarząbek & Juszkiewicz, 2016a) and the effectiveness of the operations conducted (Jarząbek & Juszkiewicz, 2016b) lead to the conclusion that the state of the sea does not significantly affect how pollutants spread in the water and that their lighter fractions evaporate. Emulsification of the oil in different states occurs faster in higher sea states, which was most evident in the medium and heavy oil pollutant simulations.

## Analysis of prevailing hydrometeorological conditions in the Pomeranian Bay area

In the case of modelling oil pollution in area of the port of Świnoujście (approaching fairway and anchorages) it is important to know the prevailing meteorological conditions in the Pomeranian Bay, especially the winds, related currents, and changes in the water level.

The analysis of the weather conditions lead to the conclusion that the wind conditions that would permit the drift of oil pollution towards the port entrance are relatively rare. The backflow of the water into the mouth of the Świna River only occurs in the event of strong north or north-east winds. Based on the analysis of the 2013-15 hydrometeorological observations that were conducted (Łazuga, Gucma & Gucma, 2016) it can be seen that the prevailing winds were predominately in the south-west direction (Figure 1).

An appropriately strong wind is necessary for the phenomenon of backflow in the Świna River to occur. Long-term high winds from a northerly direction mainly occur in the autumn and winter season, although they cannot be entirely disregarded during the other seasons.

Winds generate surface currents in a direction close to that of the wind direction. For strong winds above level 5 on the Beaufort Scale (8.0–10.7 m/s), the difference in currents and winds does not usually exceed 2°, but for weak winds, it can reach as much as 15° (Łazuga, Gucma & Gucma, 2016).

The Odra Estuary is characterized by small decreases in the water level, and consequently slow flow rates. The greatest changes to the water level

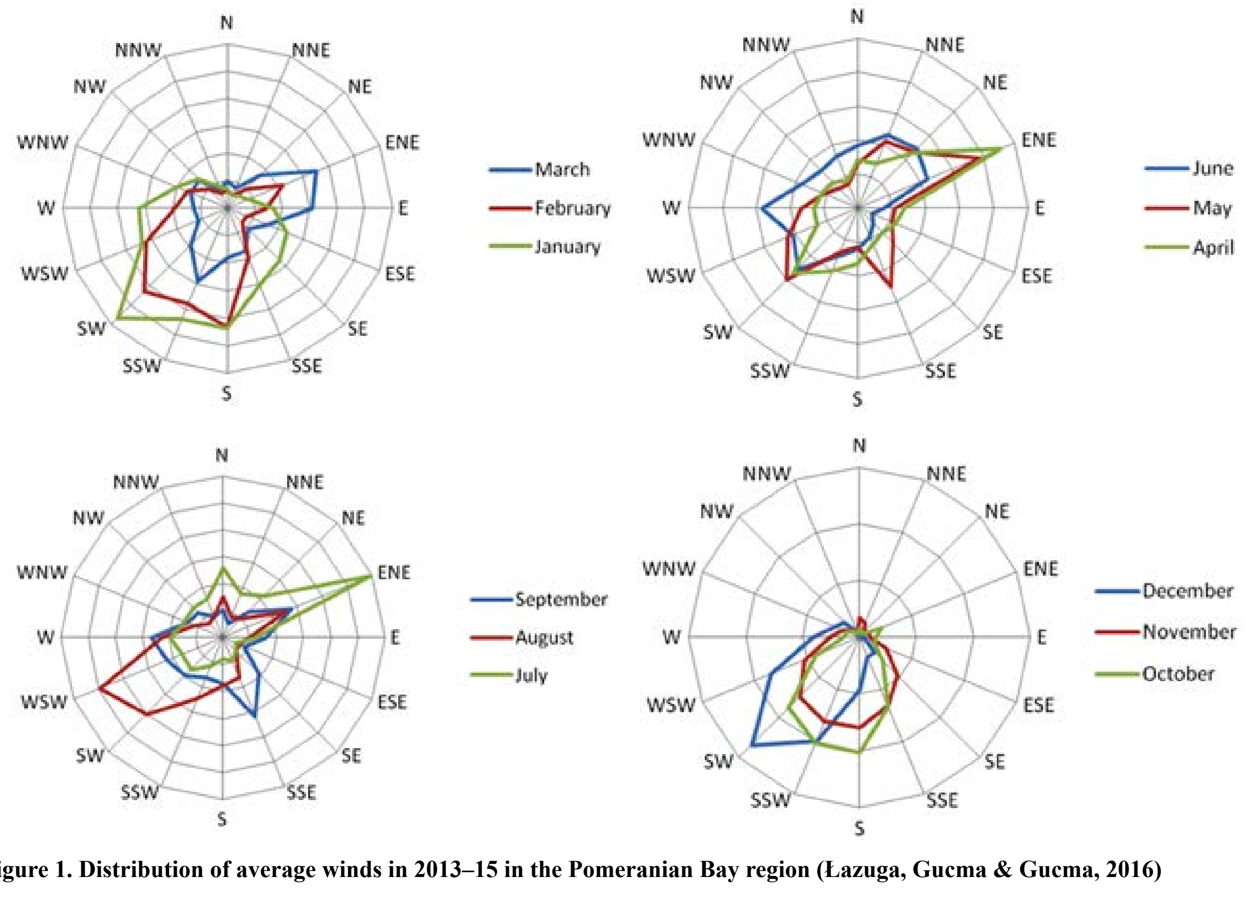



**Figure 1. Distribution of average winds in 2013–15 in the Pomeranian Bay region (Łazuga, Gucma & Gucma, 2016)**

made by the winds are in the Pomeranian Bay area, the Szczecin Lagoon, and the river network of the lower Odra. The wind also affects the surface of the water in the form of wind friction, which causes waves in large areas such as the Lagoon and Lake Dąbie and the wind backflow together with the rising water level (Buchholz, 2007).

## Characteristics of oil spill simulator PISCES II

Simulations of oil spill accidents were performed using the PISCES II oil spill simulator. The simulator has a wide range of capabilities, including the ability to simulate (Transas, 2008):

- sources of spillage, its size and behaviour;
- many types of petroleum products, from light to heavy fuel, which affect the way the spill behaves (emulsification, evaporation, diffusion, etc.);
- the impact of hydrometeorological conditions, primarily including wind and wave modelling, and sea conditions, environmental temperature, salinity, etc. ;
- antipollution action to remove oil contaminants using the available resources (they can be created by the user), taking into account their real-time behaviour.

The PISCES II simulator is a sophisticated simulation tool that was designed for the US Coast Guard. The software meets the requirements of the Oil Pollution Act of 1990. The simulation results have been validated and approved at international level conferences and in publications (Delgado, Kumzerova & Martynov, 2006; Łazuga, 2012; Łazuga, Gucma & Perkovic, 2013; Gucma, Łazuga & Perkovic, 2015; Jarząbek & Juszkiewicz, 2016a, 2016b).

The simulator also has backtracking possibilities for retrospective situation analysis, which allows the determination of the place and time of the accident and who was guilty of spilling the oil. However, it should be noted that the high variability of the factors affecting the spread of oil pollutants means that this analysis should be regarded as imprecise.

## Assumptions of the simulations

Taking into account all the possibilities of the simulator and the weather conditions analysis, it was assumed that the simulations should contain a collision situation occurring on the waterway to the port of Świnoujście resulting in pollution of the analysed area. Analysis of the fate and behaviour was carried out by changing the simulated direction and the force of the wind in terms of the potential pollution of the port of Świnoujście. In addition, the time the spreading pollutants take to reach the shore for simulated weather conditions has been determined, which allowed the determination of the required reaction time  and the potential for using oil spill combating resources.

The main assumptions of the worst-case scenario were as follows: The collision took place on March 6, at 10:38 on the waterway to Świnoujście at Anchorage 2A ($\phi$ = 54°02,131'N, $\lambda$ = 014°14,743'E). The bulk carrier entering the port collided with an oil tanker leaving the port. After the collision, the tanker drifted to Anchorage 2A and grounded at position $\phi$ = 54°03,338'N, $\lambda$ = 014°15,139'E. The position of the collision and the trajectory of the damaged vessel are shown in Figure 2. The characteristics of the units involved in the simulated collision are shown in Table 1.

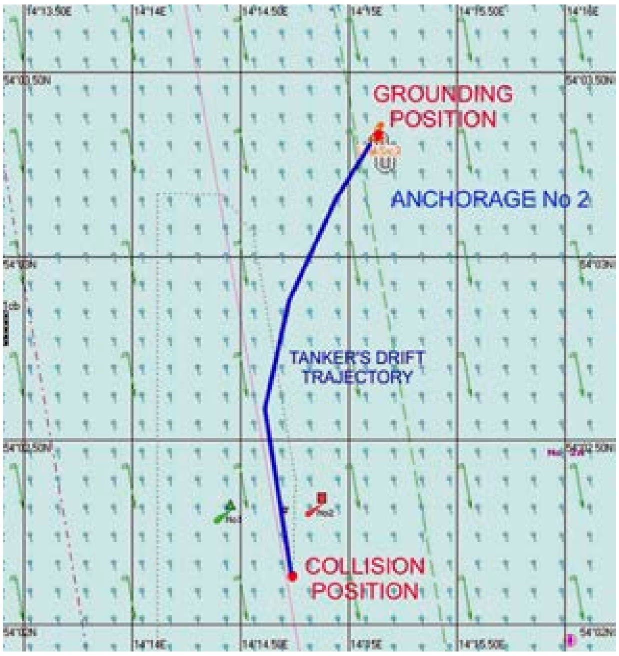



**Figure 2. Collision simulation and trajectory of the damaged unit from collision position to anchorage position**

**Table 1. The main data of the ships that collided**

| Vessel type | | Bulk carrier | Oil tanker |
|---|---|---|---|
| Displacement | [t] | 37330.0 t | 77100 t |
| Maximum speed | [kn] | 13.2 kn | 15.0 kn |
| Length | [m] | 222.6 m | 242.8 m |
| Breadth | [m] | 22.9 m | 32.2 m |
| Draft | [m] | 7.9 m | 12.5 m |
| Height of eye | [m] | 15.0 m | 22.0 m |
| Type of engine | | Steam Turbine (7366 kW) | Slow Speed Diesel (13,610 kW) |
| Thrusters | | Bow: 1 / Stern: 0 | Bow: 0 / Stern: 0 |

Because of the collision, the oil tanker was damaged and **261 tons** of oil substance (type: ARABIAN LIGHT) entered the sea. Its characteristics and simulated leakage rates are shown in Table 2 and Figure 3.

**Table 2. Oil spill properties (Transas, 2008)**

| Name | ARABIAN LIGHT | Distillation curve | |
|---|---|---|---|
| | | Temperature | Fraction |
| Density | 0.858 g/cm$^3$ | 60°C | 2% |
| Surface tension | 16.8 dyn/cm | 100°C | 7% |
| Viscosity | 16.3 cSt | 140°C | 12% |
| Maximum water content | 87% | 200°C | 22% |
| Emulsification content | 0% | 250°C | 31% |
| Pour point | −53°C | 300°C | 40% |
| Flash point | −20°C | 350°C | 49% |
| | | 400°C | 57% |

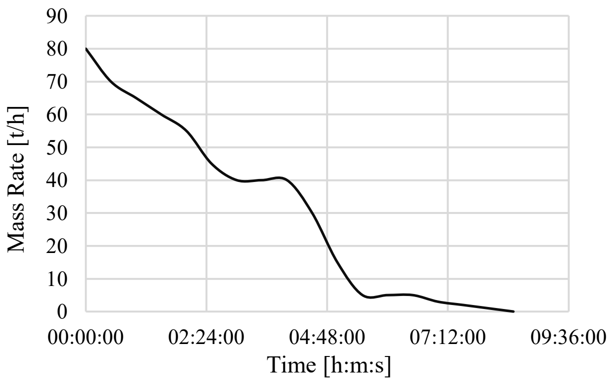



**Figure 3. Oil spill rate changes during the simulation**

During the spill simulation, no antipollution action was taken to remove the oil contaminants, which made it possible to determine the time of their arrival at the coast (Impact Time) and to determine the most unfavourable hydrometeorological conditions that would cause pollution inside the port of Świnoujście. The quantity of pollutants in the port of Świnoujście and in the LNG outer port was recorded by the model.

An example of wind and current field distribution used during the simulations is shown in Figure 4.

It was initially assumed that the most unfavourable conditions that would cause pollution inside the harbour waters were strong northerly winds causing backflow in the Odra River.

Therefore, for simulation purposes, according to the strong northerly winds a field of currents was simulated, which pushed the water of the Pomeranian Bay to the port of Świnoujście. In each simulation

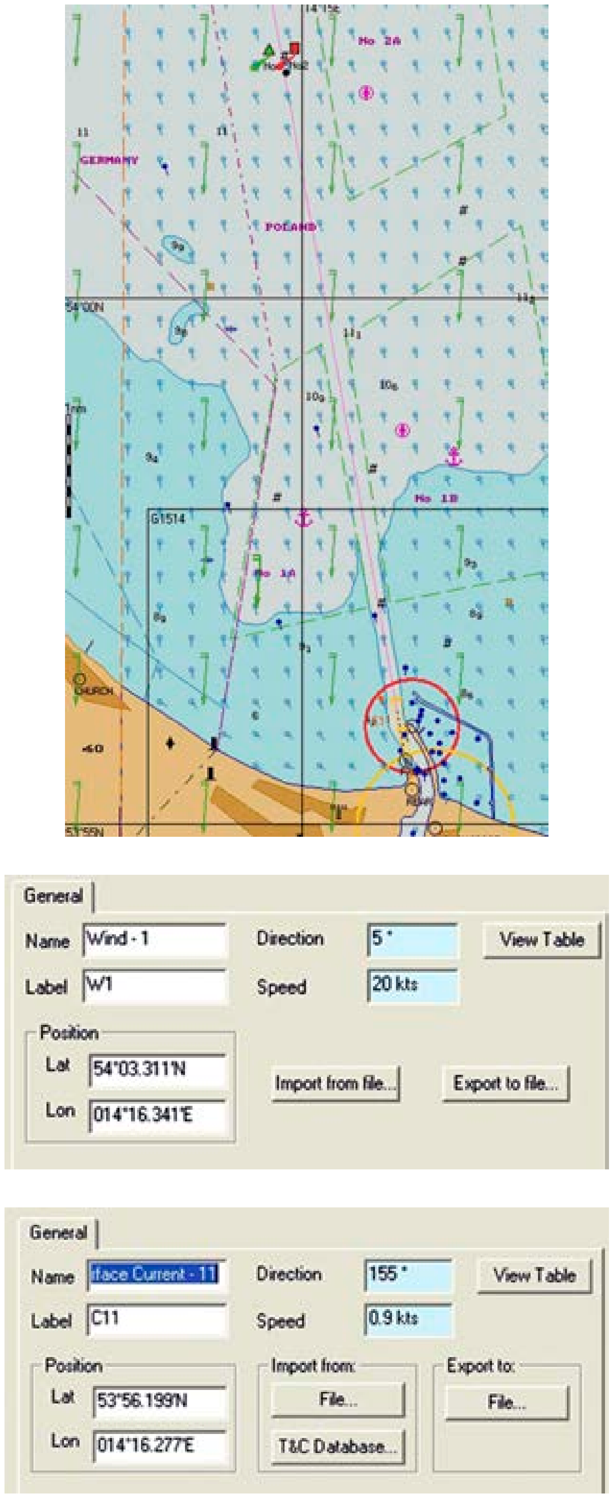



**Figure 4. Example of wind field and surface currents (wind simulation from direction 005°)**

scenario, the same current field was used. The wind direction was changed in the simulations in the range from 340° to 015° (change of direction every 5°) and the wind force was changed from 15 to 25 knots (with an interval of 5 knots).

The general characteristics of the simulated currents were as follows:

- near the collision position the field of currents was modelled with the parameters: direction 170° and a force about 1.5 knots;
- near the coast the force of the currents gradually decreased until it reached the value of approx. 1.0 knot;
- in the area of the breakwaters the force of the currents decreased to about 0.8–0.9 knots and directions depended on the formation of the shoreline and the breakwaters;
- inside the port the current force was 0.5–0.6 knots and corresponded to the direction of the harbour channel.

Other hydrometeorological conditions were simulated as follows:

- water temperature: 10°C;
- air temperature: 15°C;
- wave height: 1.5 m.

## Simulation results

During the spill simulation, the time of the oil impact was recorded, as well as the amount of contamination that entered the port, divided into pollutants inside the port of Świnoujście and the basin of the LNG terminal. During the simulation the movement of the oil slick was analysed. The port contamination phases during the simulation example are shown in Figure 5. The chart screenshots presented are oriented towards the north. Their main purpose is to show the key phase of the movement of the oil pollution near the harbour entrance.

During the research 24 simulations were carried out for different wind directions and wind forces. The final data from the recorded results are shown in Table 3.

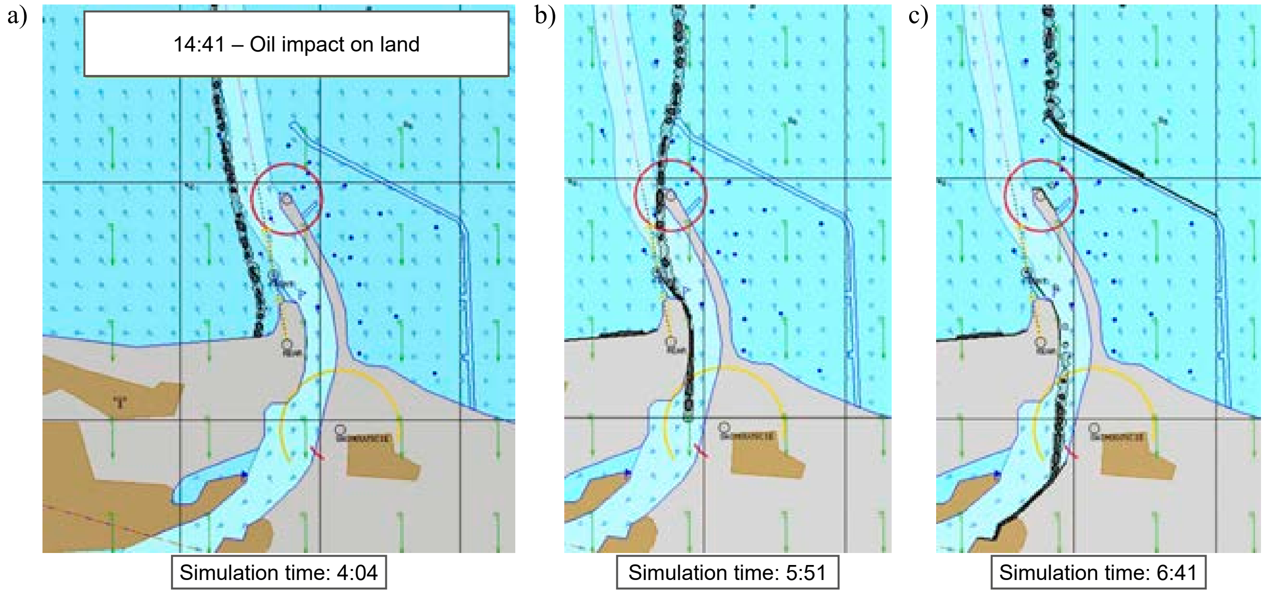



**Figure 5. An example of the simulation of oil pollutants with a wind direction of 000° and a speed of 25 knots: a) the moment of oil impact on land; b) oil spills slides down the western breakwater and drifts inward to the harbour area; c) oil pollution is blocked by the LNG port breakwater and drifts toward the beach east of the port entrance**

**Table 3. Results of the spills obtained during the simulations**

| Wind direction [deg] | Wind speed 15 kn | | | Wind speed 20 kn | | | Wind speed 25 kn | | |
|---|---|---|---|---|---|---|---|---|---|
| | Oil impact time [h:m] | Oil pollution in Port of Świnoujście [t] | Oil pollution in LNG Terminal [t] | Oil impact time [h:m] | Oil pollution in Port of Świnoujście [t] | Oil pollution in LNG Terminal [t] | Oil impact time [h:m] | Oil pollution in Port of Świnoujście [t] | Oil pollution in LNG Terminal [t] |
| 340° | 8:33 | 0 | 0 | 7:08 | 0 | 0 | 6:10 | 0 | 0 |
| 345° | 6:01 | 0 | 0 | 5:05 | 0 | 0 | 4:29 | 0 | 0 |
| 350° | 5:14 | 0 | 0 | 4:30 | 0 | 0 | 3:59 | 0 | 0 |
| 355° | 5:00 | 0.7 | 10.1 | 4:30 | 18.3 | 2.6 | 4:12 | **22.3** | 2.8 |
| 000° | 5:08 | 44.2 | 0.4 | 4:33 | 23.8 | 1.0 | 4:04 | 20.8 | 1.9 |
| 005° | 5:04 | 35.8 | 0.5 | 4:31 | **129.6** | 0 | 4:05 | 0 | 0 |
| 010° | 5:03 | **139.0** | 0 | 4:32 | 0 | 0 | 4:07 | 0 | 0 |
| 015° | 5:05 | 0 | 0 | 4:36 | 0 | 0 | 4:06 | 0 | 0 |

During the simulation shown in Figure 5, 20.8 tons of oil pollution was recorded inside the port area. The change in the wind direction by 5° slightly changed the direction of the main stream of pollution outside the port's western breakwater and the port waters were not polluted. After the results of this case were analysed together with the other simulations where significant port contamination occurred (139 tons and 129.6 tons of oil), it was decided to simulate the wind blowing from the direction 003°. With the wind in this direction, 103.9 tons of oil flowed into the port.

Such a significant change in the amount of oil inside the port indicates how particular details (the starting and border conditions) may affect the proper pollution risk assessment for Świnoujscie harbour. This is mainly due to the shape of the port entrance and traffic conditions. The possibility of oil intrusion inside the port with a backflow of 0.5 knots is presented in Figure 6.

The additional element recorded during the simulations was the first impact position (FIP) of the oil pollution. These positions are shown in Figure 7. In most cases, the FIP did not differ significantly for a given wind direction when changing its strength. A special situation occurred when the wind direction was from 355°, when the vast majority of

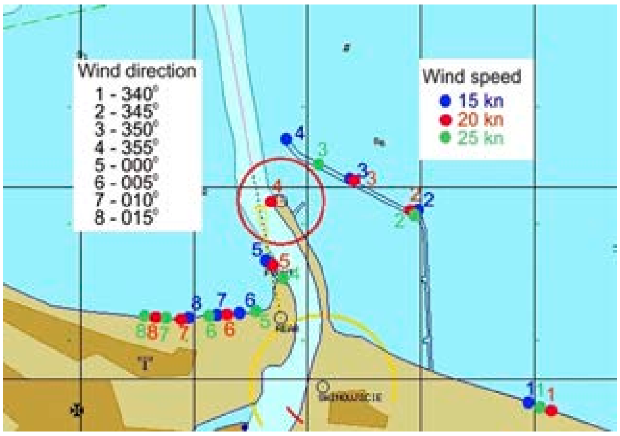


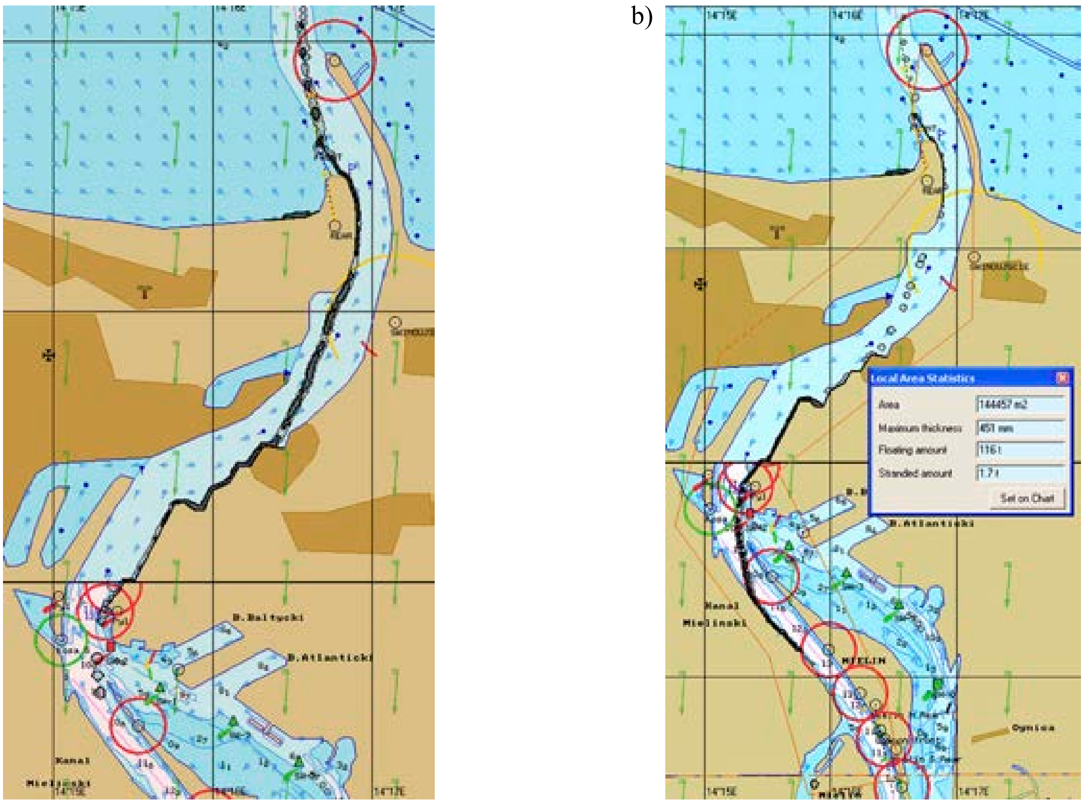

**Figure 7. First Impact Positions of oil pollutants for wind velocities of 15, 20, and 25 knots**

the pollution slipped past the inner side of the west port's head and drifted with an input current into the interior of the port towards the Szczecin Lagoon.

## Conclusions

The simulated results that have been presented in the paper clearly showed that, despite the favourable configuration of the port of Świnoujście, the pollution of the port waters cannot be completely excluded. Collision between ships on the fairway and the leakage of fuel, combined with unfavourable

a) b)




Simulation time: 4:03

Simulation time: 12:41

**Figure 6. Movement of oil pollution through the port of Świnoujście without any antipollution action**

hydrometeorological conditions, may cause a threat to the port's waters. An additional factor that should be taken into account is the external LNG Terminal. The need to close the port and take long-term anti-pollution action may threaten Polish energy security.

During the simulations that were conducted, an attempt was made to determine the impact of hydrometeorological conditions on the port's contamination risk. Through analysis of the simulation results it has been shown that even minor changes in wind direction (e.g. as described in section 4) can greatly change the amount of pollution that reach the port's waters.

The most unfavourable combinations of wind direction and speed, during the backflow occurrence, have been identified. The most unfavourable winds, together with the simulated current field, were winds blowing from the directions 000° to 010°.

The worst cases of wind direction and wind speed combinations were as follows:

- 010°/15 knots – 139.0 tons of oil pollution reached the port (about 53% of the total spillage);
- 005°/20 knots – 129.6 tons of oil pollution reached the port (about 49% of the total spillage);
- 003°/15 knots – 103.9 tons of oil pollution reached the port (about 40% of the total spillage).

However, it should be noted that the direction and force of the wind, in combination with the bathymetry of the water area, has a significant influence on the distribution of sea currents, and hence on the way in which the oil contaminants moved.

The results that have been presented in this paper are important for the establishment of optimal tactics to combat pollution during an oil spill on the approach to Świnoujście under unfavourable northerly winds and the occurrence of backflow in Świna River. The timeframes obtained from the simulations (from 4 to 5 hours) show that the proper tactic is to deploy the oil spill combat equipment at the location of the oil spill in parallel with the mobilization of land combat forces to secure the entrance of the port of Świnoujście.

Of course, the simulation results are connected to the specific area for which they were carried out and the selected weather conditions. In this case, this applies to the port of Świnoujście and the most unfavourable weather conditions (backflow, northerly winds).

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The contents of this paper are the sole responsibility of the authors and can in no way be taken to reflect the views of the European Union, the Managing Authority or the Joint Secretariat of the South Baltic Cross-border Cooperation Programme 2014–2020.

## References

1. Bucholz, W. (2007) *Hydrological conditions of the Odra estuary* (*Warunki hydrologiczne estuarium Odry*). IV Konferencja „Regionalne problemy gospodarki wodnej i hydrotechniki", 21–22.06.2007 Widuchowa (in Polish).
2. Delgado, L., Kumzerova, E. & Martynov, M. (2006) Simulation of oil spill behaviour and response operations in PISCES. *WIT Transactions on Ecology and the Environment* 88, pp. 279–292.
3. Gucma, L., Łazuga, K. & Perkovic, M. (2015) *Optimal allocation of response resources model verification on the example of oil spill on the Pomeranian Bay*. Proc. of 16th International Congress of the International Maritime Association of the Mediterranean, Pula, Croatia.
4. ITOPF (2014) *Fate of marine oil spills.* Technical information paper. [Online] Available from: http://www.itopf.com/knowledge-resources/documents-guides/document/tip-2-fate-of-marine-oil-spills/ [Accessed: September 01, 2017]
5. Jarząbek, D. & Juszkiewicz, W. (2016a) Analysis of the impact of selected hydrometeorological conditions on the accuracy of oil spill simulations on the PISCES II simulator. *Scientific Journals of the Maritime University of Szczecin, Zeszyty Naukowe Akademii Morskiej w Szczecinie* 46 (118), pp. 36–42.
6. Jarząbek, D. & Juszkiewicz, W. (2016b) *Analysis of the impact of weather condition on the effectiveness of oil spill recovery operation in simulated condition* (*PISCES II*). The XXth International Scientific and Technical Conference "The role of navigation in support of human activity at sea", 8–9 Nov. 2016, Gdynia.
7. Łazuga, K. (2012) Testing of an oil spill mathematical model contained in PISCES II simulator, *Scientific Journals Maritime University of Szczecin, Zeszyty Naukowe Akademia Morska w Szczecinie* 32 (104) z. 2, pp. 105–109.
8. Łazuga, K., Gucma, L. & Gucma, M. (2016) Analysis of hydro-meteorological conditions in the area of the Port of Świnoujście between 2011–2015, *Scientific Journals of the Maritime University of Szczecin, Zeszyty Naukowe Akademii Morskiej w Szczecinie* 46 (118), pp. 203–208.
9. Łazuga, K., Gucma, L. & Perkovic, M. (2013) M/t „Baltic Carrier" accident. The reconstruction of oil spill with PISCES II simulator application. *Scientific Journals Maritime University of Szczecin, Zeszyty Naukowe Akademia Morska w Szczecinie* 36 (108) z. 1, pp. 110–115.
10. Transas (2008) PISCES II User Manual (version 2.93), Transas Ltd.