VERSITA

ANNUAL OF NAVIGATION 19/2012/part 1

10.2478/v10367-012-0006-8

LUCJAN GUCMA, WIESŁAW JUSZKIEWICZ, KINGA ŁAZUGA
Maritime University of Szczecin

OPTIMAL PLANNING OF POLLUTION EMERGENCY RESPONSE WITH APPLICATION OF NAVIGATIONAL RISK MANAGEMENT

ABSTRACT

According to the HELCOM AIS, there are about 2,000 ships in the Baltic marine area at any given moment. The main environmental effects of shipping and other activities at sea include air pollution, illegal deliberate and accidental discharges of oil, hazardous substances and other wastes, and the unintentional introduction of invasive alien organisms via ships' ballast water or hulls. Original oil pollution model and optimal allocation of response resources was proposed in the paper.

Keywords:

sea pollution model, response resources.

INTRODUCTION

The Baltic Sea is one of the most heavily trafficked seas in the world, accounting for up to 15% of the world's cargo transportation. Both the number and the size of ships have grown in recent years, especially in respect to oil tankers, and this trend is expected to continue.

The main environmental effects of shipping and other activities at sea include air pollution, illegal deliberate and accidental discharges of oil, hazardous substances and other wastes, and the unintentional introduction of invasive alien organisms via ships' ballast water or hulls.

According to the HELCOM AIS, there are about 2,000 ships in the Baltic marine area at any given moment, and each month around 3,500–5,000 ships ply the waters of the Baltic.

The main goal of the research work was the designing and development of oil pollution model and microscopic model of ship traffic, and finally, verification of the correctness of the oil-spill resources allocated along the Baltic coast. Model applies the statistical data obtained by navigational safety assessment model which consist of the frequency, volume, type, location, weather conditions, and sea-state of an oil spill event. Statistical analysis is made with use of historical data to determine the expected volume, type and weather and sea conditions for Baltic Sea region. The algorithm of optimal allocation model of response resources was proposed.

THE ALGORITHM OF OPTIMAL ALLOCATION OF RESPONSE RESOURCES

The main important targets of research were:

1. To identify the high risk areas for ships colliding and grounding in the Baltic Sea.
2. To determine the possible effects of the probable accidents considering average seasonal weather conditions dominating in the Baltic Sea.
3. To propose the possible allocation oil spill resources allowing secure determined segments of coast in the shortest possible time, taking into account the probability of the occurrence of oil spills.

To identify possible collision positions the simplified statistical model was used. The model used real statistical data and achieved results are very close to reality. The most unknown parameter necessary for collision probability assessment on large sea areas is number of ships encounter situations.

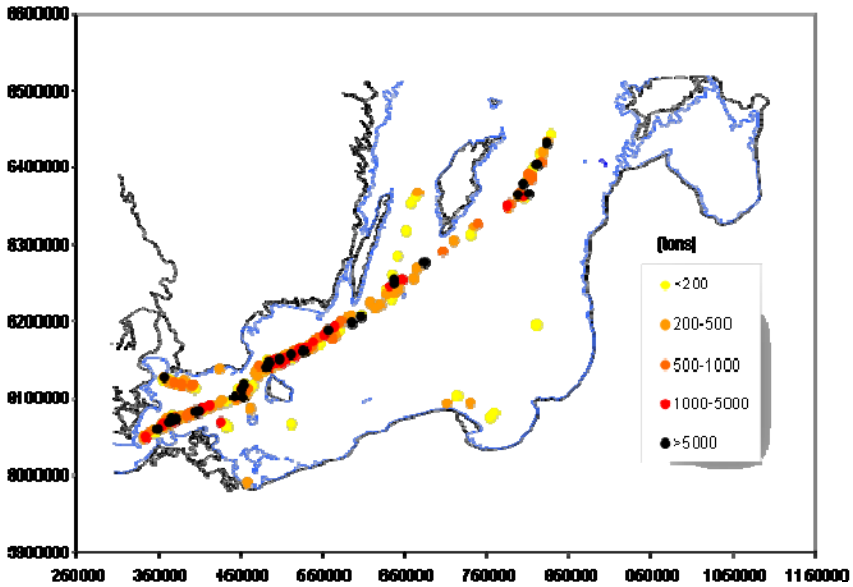

Fig. 1. Results of use statistical model of collision [1]

When an oil spill occurs it is necessary to respond with sufficient cleanup equipment within the shortest possible time in order to protect marine environment and minimize cleanup and damage costs. At Baltic Sea region every country is equipped with their own response resources. Picture below (fig. 2) shows location of those equipment.

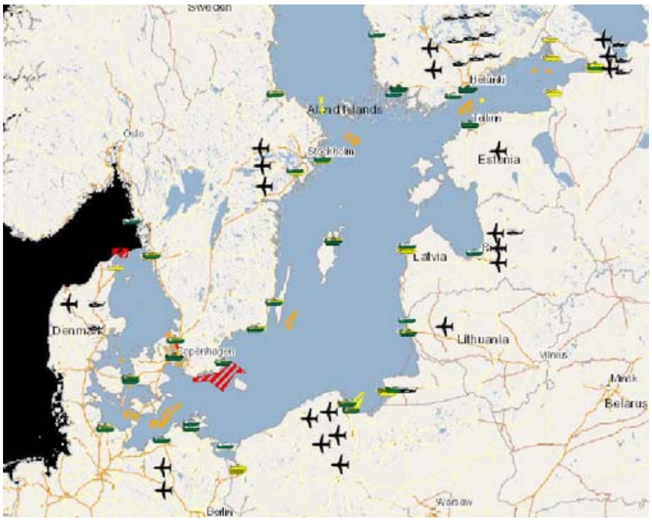

Fig. 2. Response resources allocation in southern Baltic [Helcom]

For better resources allocation the optimization recursive type algorithm was proposed (fig. 3). The main dynamic data used in optimization process are:

- actual resources allocation;
- possible changes of allocation;
- weather conditions data;
- the most probable oil spill accident (calculated in statistical model use).

Model apply the statistical data consist of the frequency, volume, type, location, weather conditions, and sea-state of an oil spill event. Statistical analysis is performed on historical data to determine the expected volume, type and weather and sea conditions for Baltic Sea region. The analysis is performed to determine certain input parameters such as the number and type of equipment required to respond to a given spill and the expected travel times for transporting the equipment from a facility site to spill site. The travel time for response equipment depends on the distance between facility site and the spill site, the type of equipment, and on the weather and sea conditions. After obtain the required data they are used to simulate an oil spill on PISCES II simulator.

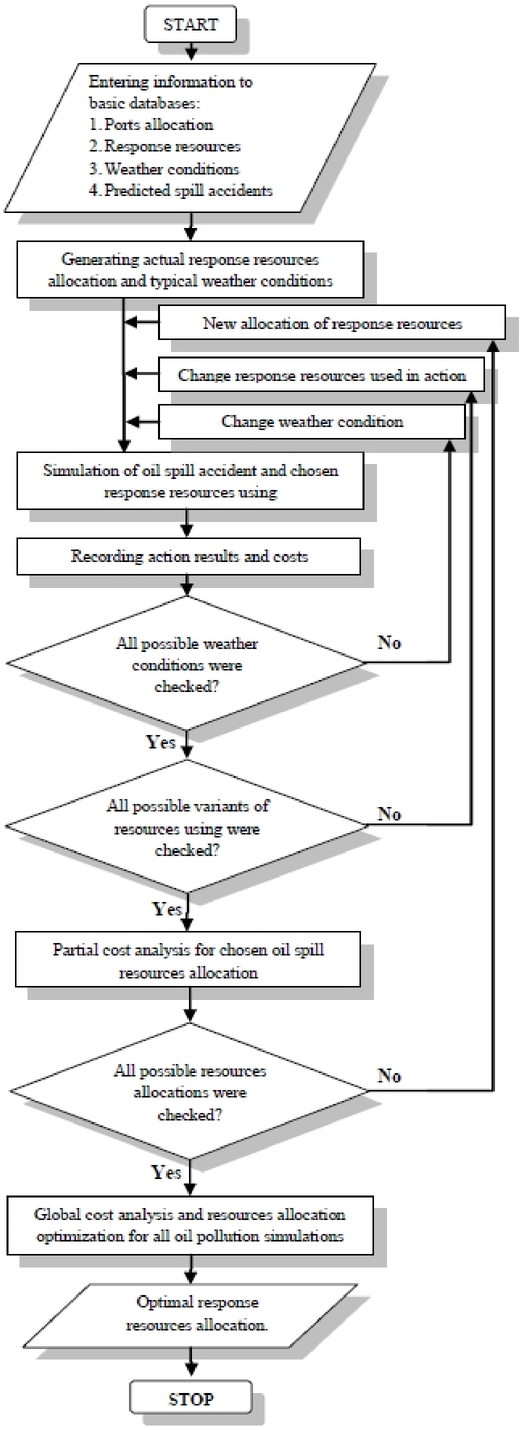

Fig. 3. Model of optimal allocation of response resources [own study]

SIMULATIONS DESCRIPTION AND RESULTS

Optimization of location response resources depending on reduction of costs is very important. Full complement of planned simulations, based on predicted ships' accidents, should give an answer: whether an allocation of responses or their expansion are necessary. Protection of the Baltic Sea environment without bearing the unnecessary costs is a main purpose of research.

As an example of optimization resources in polish coast the series of the simulation was conducted. To run these simulations spill/accident positions were chosen near ports of Świnoujście, Kołobrzeg and Gdynia. Also those ports were chosen as a possible locations of 'Kapitan Poinc' rescue vessel. In all simulations weather conditions were the same (table 1).

Table 1. Hydrometeorological conditions and spill data for all simulations [own study]

#	Name	Value
1	Water temperature	15°C
2	Air temperature	20 C
3	Sea state	2.5 m
4	Water density	1030 kg/m^3
5	Cloudiness	5

Spill type:	Leak
Type of oil	ADGO
Amount	100 tones

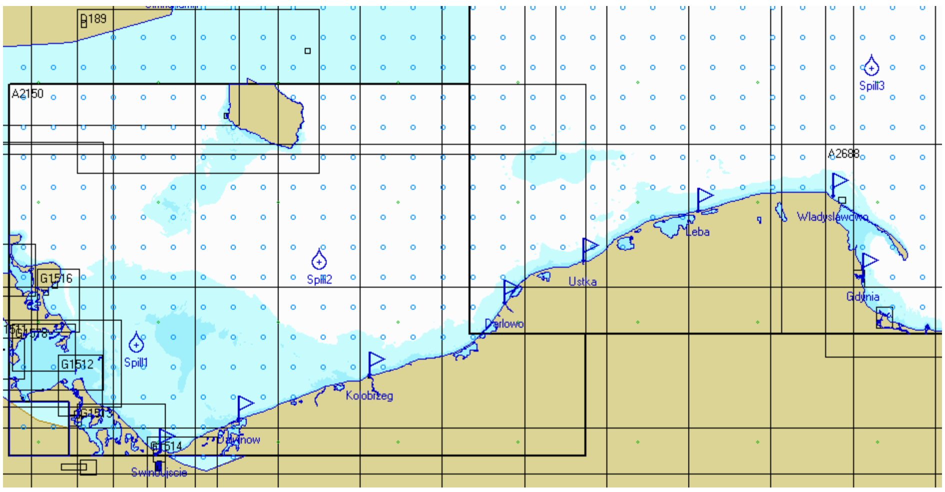

Fig. 4. Oil spills simulated positions[own study]

Every simulation began at the base that when the oil spill accident happened the rescue ship had been moored in the basic harbor so the first period of the action consists in arriving the ship to the catastrophe position and removing oil spill began then. Results of examples of removing action are showed in the next figures.

Simulation No. 1

Spill site: 54°18,189 N
014°08,339 E

'Kapitan Poinc' location: Gdynia

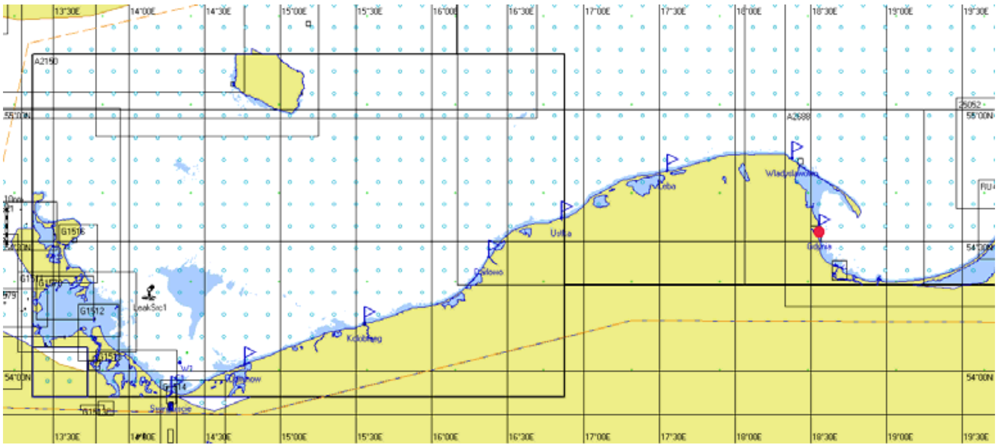

Fig. 5. Simulation 1 — oil spill and rescue ship positions [own study]

Table 2. Spill history — simulation No. 1

#	Time	Amount spilled, t	Amount floating, t	Amount evaporated, t	Amount dispersed, t	Amount sunk, t	Amount recovered, t	Amount floating mixture, t	Amount recovered mixture,t	Max thickness, mm	Slick area, nm^2	Viscosity, cSt
1	"0:00"	0	0	0	0	0	0	0	0	0	0	
2	"1:00"	99,2	95,5	0,2	3,6	0	0	145	0	5,8	0	98
3	"2:00"	100	92,4	0,7	6,9	0	0	234	0	3,6	0,1	402
4	"3:00"	100	90,3	1,4	8,3	0	0	285	0	3,4	0,1	767
5	"4:05"	100	88,2	2,3	9,5	0	0,1	301	0,2	2,1	0,1	1032
6	"5:05"	100	84	3,5	11,1	0	1,4	292	4,9	1,7	0,2	1241
7	"6:05"	100	79,3	4,8	13	0	2,9	277	10,1	1,6	0,2	1467
8	"7:05"	100	74,4	6,2	15,2	0	4,3	259	14,8	1,4	0,3	1731
9	"8:05"	100	68,9	7,6	17,4	0	6,1	240	21	1,3	0,3	2030
10	"9:05"	100	63,6	9	19,7	0	7,8	221	27,2	1	0,3	2353
11	"10:05"	100	58,3	10,1	21,8	0	9,8	202	34,2	1	0,3	2681
12	"11:05"	100	53,6	11,2	23,8	0	11,5	185	39,9	0,7	0,3	3008

#	Time	Amount spilled, t	Amount floating, t	Amount evaporated, t	Amount dispersed, t	Amount sunk, t	Amount recovered, t	Amount floating mixture, t	Amount recovered mixture,t	Max thickness, mm	Slick area, nm^2	Viscosity, cSt
13	"12:05"	100	48,7	12,1	25,6	0	13,6	168	47,1	0,8	0,3	3330
14	"13:05"	100	43,2	12,9	27,3	0	16,5	149	57,2	0,8	0,3	3637
15	"14:05"	100	38,2	13,6	28,9	0	19,2	131	66,5	0,7	0,3	3928
16	"15:05"	100	33,5	14,2	30,4	0,1	21,8	115	75,4	0,8	0,2	4202
17	"16:05"	100	29,3	14,7	31,8	0,1	24,1	100	83,2	0,6	0,2	4454
18	"17:05"	100	24,9	15,2	33,1	0,2	26,7	85,3	92	0,5	0,2	4681
19	"18:05"	100	21	15,6	34,2	0,2	29	71,8	100	0,5	0,2	4878
20	"19:05"	100	17,8	15,9	35,2	0,3	30,8	60,9	106	0,5	0,2	5045
21	"20:05"	100	14,5	16,2	36	0,4	32,9	49,5	113	0,5	0,1	5187
22	"21:05"	100	11,9	16,4	36,7	0,5	34,5	40,4	119	0,4	0,1	5305
23	"22:05"	100	9,5	16,6	37,4	0,6	35,9	32,4	124	0,4	0,1	5400
24	"23:05"	100	7	16,7	37,9	0,7	37,7	23,6	129	0,4	0,1	5472
25	"24:05"	100	4,8	16,8	38,3	0,8	39,2	16,2	135	0,4	0,1	5526
26	"25:05"	100	3,7	16,9	38,6	1	39,8	12,6	136	0,4	0,1	5562
27	"26:05"	100	2,7	17	38,9	1,1	40,4	9	139	0,4	0	5586
28	"27:05"	100	1,5	17	39	1,2	41,2	5	141	0,4	0	5598
29	"28:05"	100	1,1	17	39,1	1,4	41,4	3,6	142	0,3	0	5602
30	"29:05"	100	0,5	17,1	39,2	1,5	41,7	1,8	143	0,3	0	5609

Simulation No. 2

Spill site: 54°18,189 N
014°08,339 E

'Kapitan Poinc' location: Kołobrzeg

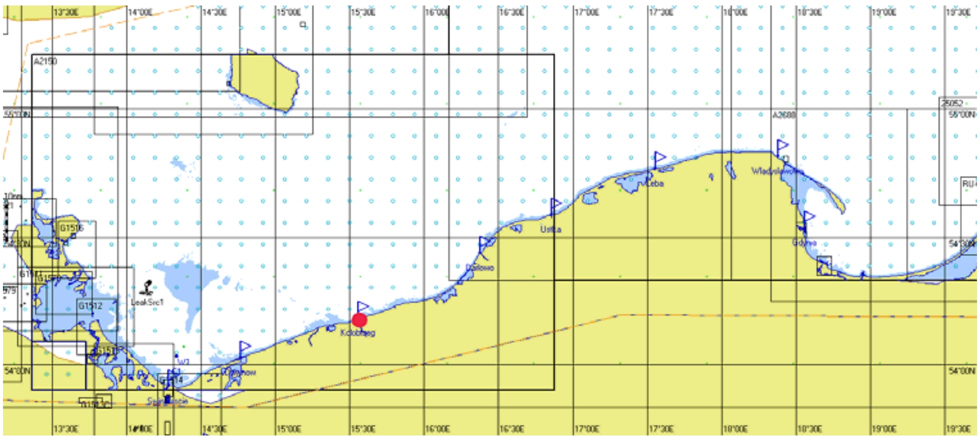

Fig. 6. Simulation 2 — oil spill and rescue ship positions [own study]

<u>Simulation No. 3</u>

Spill site:	54°18,189 N 014°08,339 E
'Kapitan Poinc' location:	Świnoujście

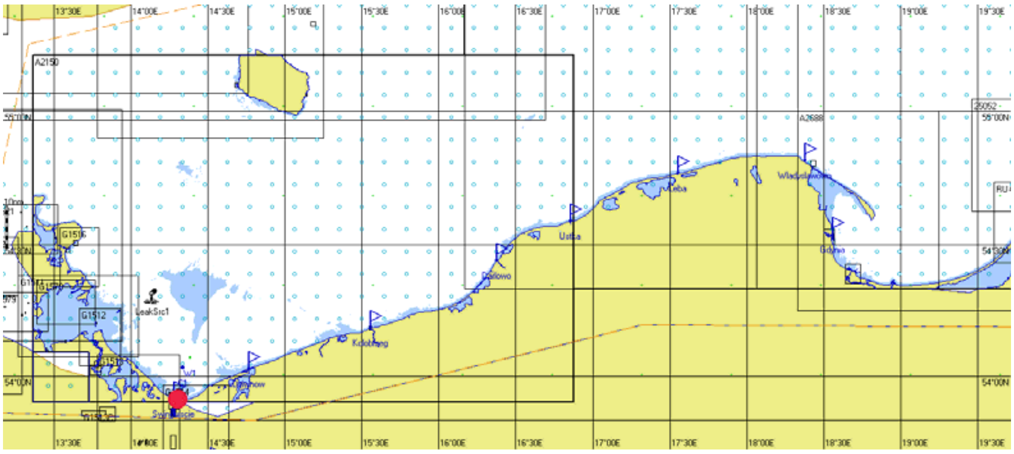

Fig. 7. Simulation 3 — oil spill and rescue ship positions[own study]

For other oil spill accidents the same way of simulation were carried out. Runs of example simulation are showed in fig. 8–10.

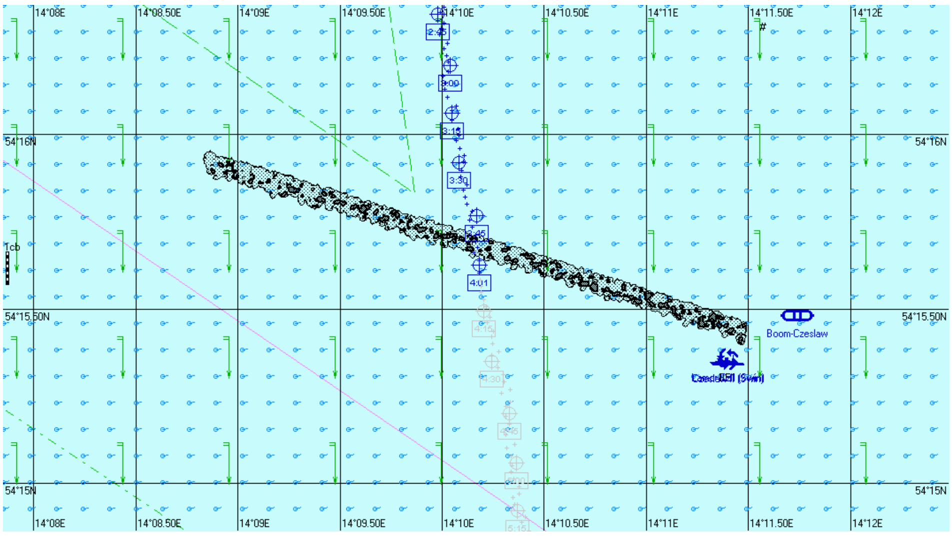

Fig. 8. Oil spill removing action — beginning phase [own study]

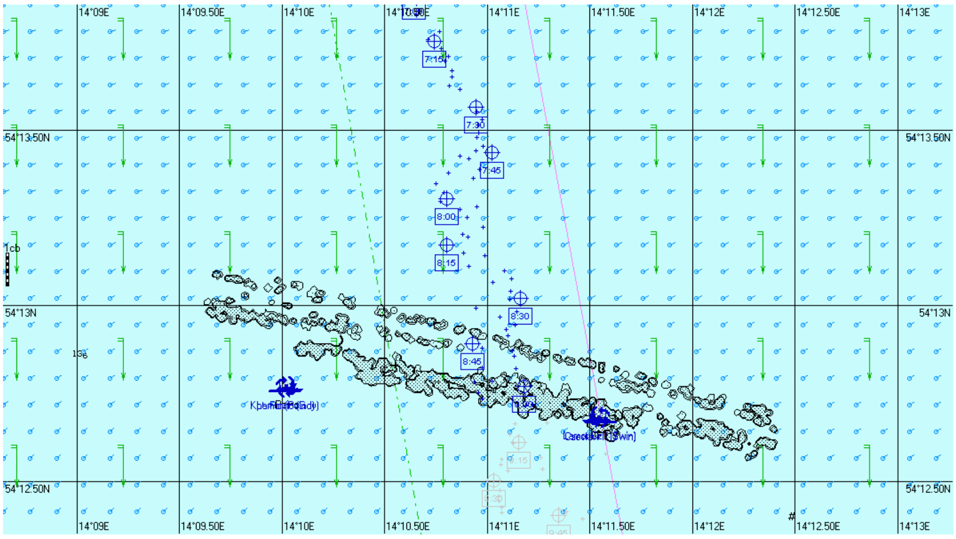

Fig. 9. Oil spill removing action — central phase [own study]

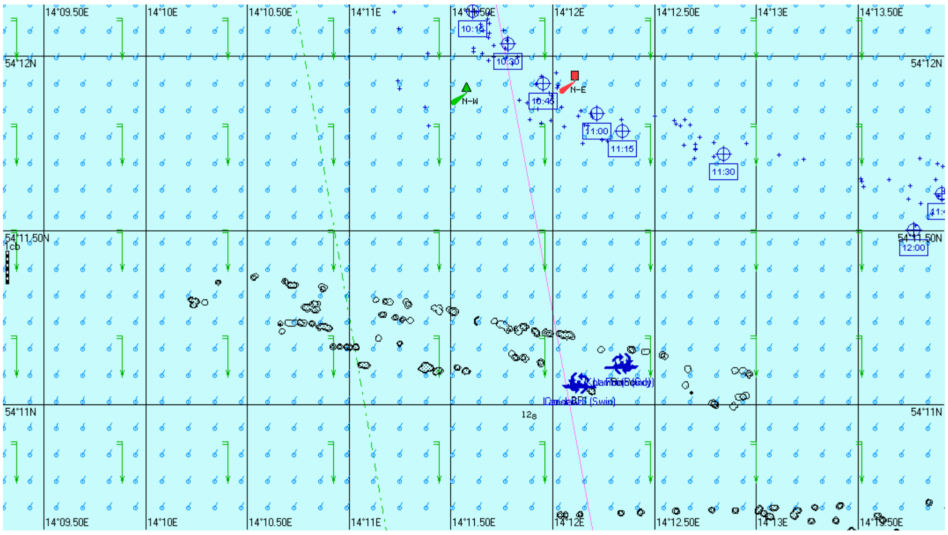

Fig. 10. Oil spill removing action — final phase [own study]

SUMMARY

Spill positions, possible 'Kapitan Poinc' locations and distances between those points are shown in fig. 11. Results of simulations, their efficiency and the necessary time to the oil spill removing are shown in table 3.

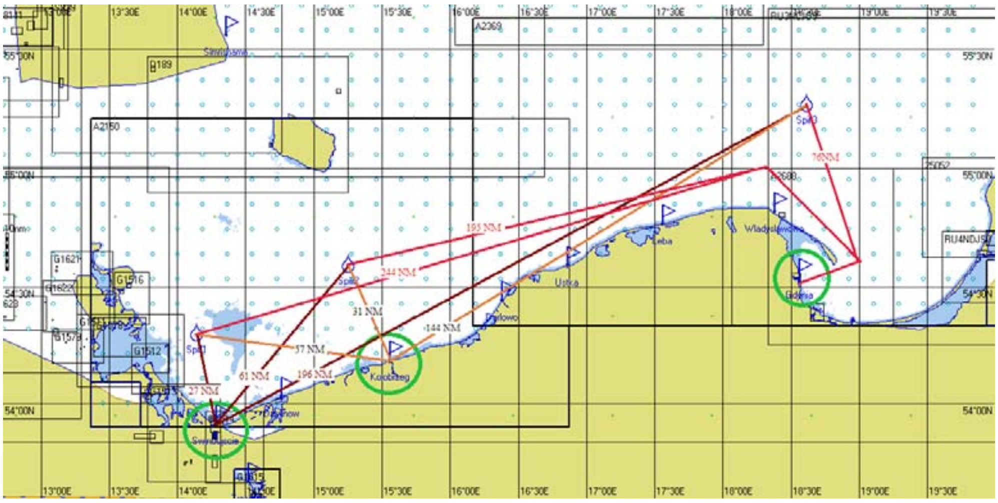

Fig. 11. All simulated scenarios comparison [own study]

Table 3. Results of simulations [own study]

Simulation No.	Oil spill position	‘Kapitan Poinc’ location	Distance beetween spill position and ‘Kapitan Poinc’ location	Time of simulation [h]
1	54°18,189 N 014°08,339 E	Gdynia	244,0	30
2		Kołobrzeg	57,0	15
3		Świnoujście	26,8	16
4	54°35.845 N 015°14,939 E	Gdynia	195,0	26
5		Kołobrzeg	31,0	13
6		Świnoujście	60,5	15
7	55°16.459 N 018°36,727 E	Gdynia	76,0	18
8		Kołobrzeg	144,0	23
9		Świnoujście	196,0	28

Average the time of the action running is shortest for Kołobrzeg location (17 hours). The next preferable port is Świnoujście (19,67 hour) and the last is Gdynia (24,67 hour). Of course these simple simulation can show analyzing method use but it should be taken into consideration both different weather condition (winter, summer etc.) and more possible accidents scenarios. Every decision about resources allocation should be taken under financial and efficiency criteria.

REFERENCES

[1] Gucma L., Przywarty M., The Model of Oil Spills Due to Ships Collisions in Southern Baltic Area, Conference proceedings TRANS'NAV 2007 'Advances in Marine Navigation and safety of sea transportation', monograph, edited by Adam Weintrit, The Nautical Institute, Gdynia 2007.

[2] PISCES II User Manual, Transas Ltd, 2008.

[3] Specification for PISCES II, Transas Ltd, 2007.

[4] The national plan to combat hazards and pollution of the marine environment, Maritime Search and Rescue, Gdynia 2005.

Received May 2012
Reviewed October 2012