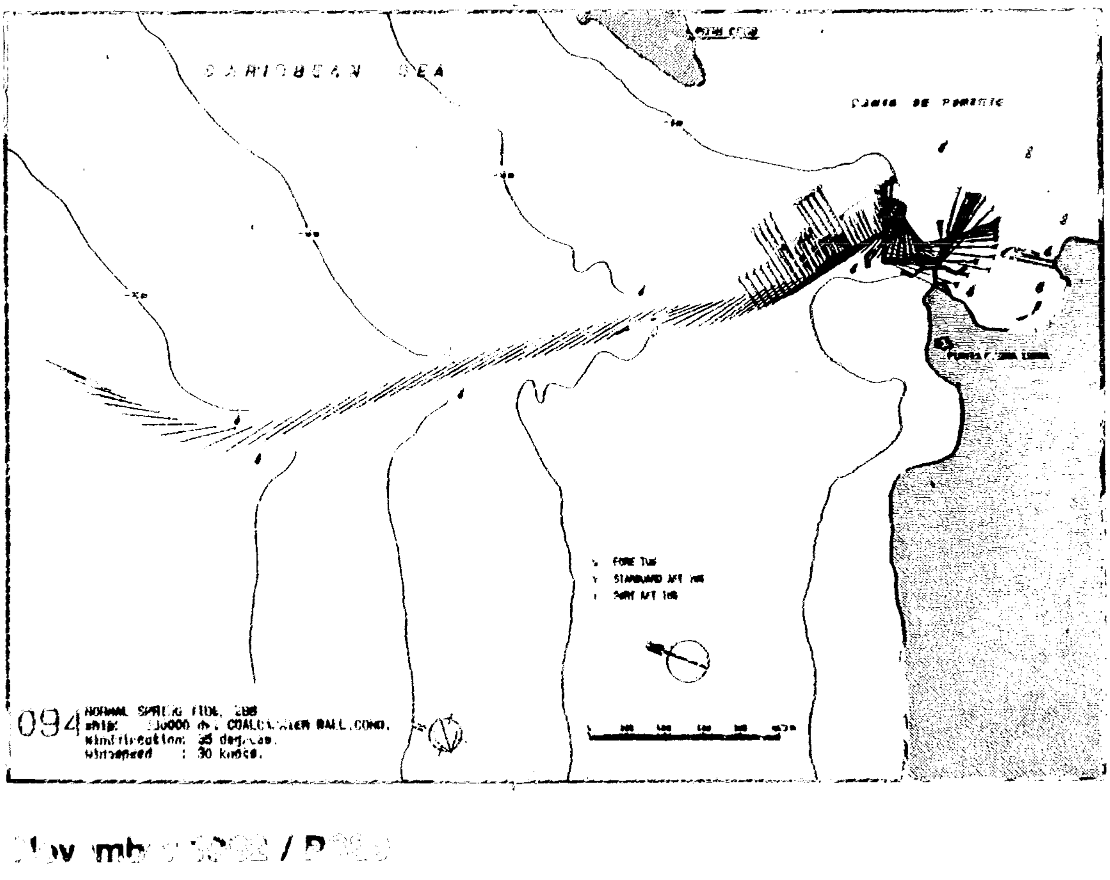
Verhagen

MORRISON - KNUDSEN COMPANY INC.

Cerrejon Coal Project

Vessel manoeuvring study

Main report



November … / P…

PORT AND WATERWAY ENGINEERS

hydronamic bv
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November 1982 / P629

PORT AND WATERWAY ENGINEERS

hydronamic bv

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CERREJON COAL PROJECT
Vessel manoeuvring study
FINAL REPORT

1. INTRODUCTION

1.1. References

Morrison-Knudsen Company, Inc, (M-K) is designing and constructing a new port facility at Bahia de Portete, Departamento de la Guajira, Columbia, for the shipment of coal and for receiving commodities, to support construction and operation of the facility.

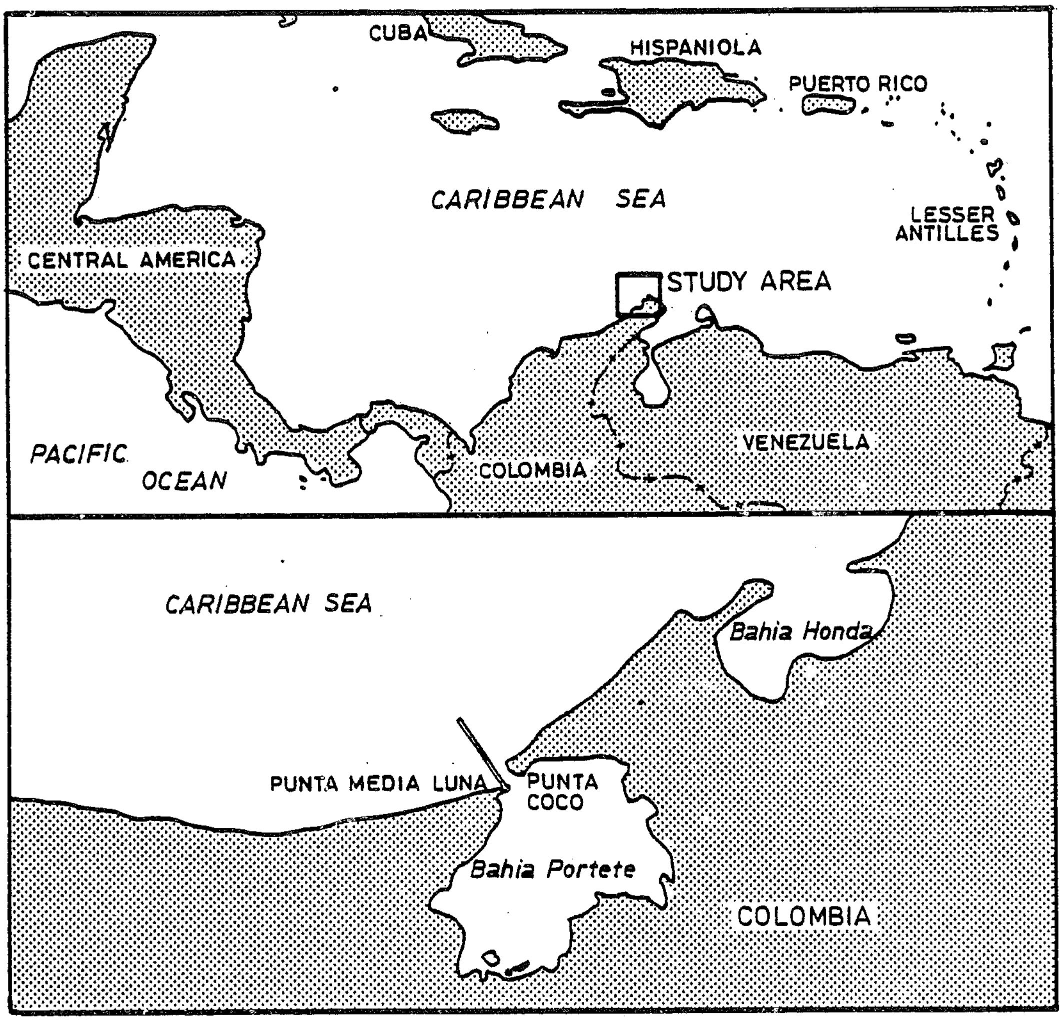


Fig 1.1.: General view, study area.

In order to optimize the harbour design and determine the safety margins, an investigation with the aid of a ship manoeuvring simulater is indispensable.

Morrison-Knudsen Company invited Hydronamic to submit a proposal for the execution of ship manoeuvring simulation tests by letter LTR-SSB-0222 of March 2nd, 1982.

The purpose of the simulation was:

- to confirm that the channel and turning basin were adequately designed for ship operations under severe environmental conditions.
- to assess the requirement for and the use of tugs in harbour operations.
- to help in the development of a port procedure.

Hydronamic submitted its proposal and offer to Morrison-Knudsen Company by letter on March 30th, 1982.

Morrison-Knudsen informed Hydronamic by telex on June 25th 1982, that the simulation study had been awarded to them. The letter of award was received by Hydronamic on June 25th, 1982.

The study has been executed by Mr. R.J.M van Maastrigt and Mr. K.P. Peerlkamp (nautical aspects and ship manoeuvring trials), Captain T. Sanders (ship manoeuvring trials) and Mr. H.J. Verhagen (mathematical tidal model). The work was carried out under the supervision and responsibility of Mr. A.Burgers, head of Hydronamics° Studies and Consultancy Department.
The report has been written and composed by Mr. K.P. Peerlkamp.

1.2. The Present Report

The report deals with the following subjects:

- the input data are described in chapter 2
- chapter 3 describes the final test programme and the pilots° task
- in chapter 4 the pilots give a written comment of their experiences whilst carring out the trials
- the first item of the analysis, the use of tugs is described in chapter 5
- chapter 6 deals with the statistical analysis and the required channel width
- the conclusions and recommendations are written in chapter 7.

The report contains three volumes, viz:

1. Main report

2. Coal carrier (results of trials, figures only)
3. Tanker (results of trials, figures only)

2. INPUT DATA

2.1. General

The study has been carried out with the aid of Hydronamics° manoeuvring simulator. A detailed description is given in annex 1. The calculation model of the manoeuvring simulator is fed with ship- and tug characteristics, a depth and current pattern matrix and a file with positions for the harbour lay-out and navigation marks.
In the following chapters these input data are described.

2.2. Harbour Lay-out and Navigation Marks

The harbour lay-out is simplified and only the relevant nautical marks are given in such a way that the buoys, the berthing places and the line of leading lights are shown. All co-ordinates are related to the co-ordinate system with the zero basis 0, (see figure 2.1) which is also the basis for the matrixes used for input of current and depth contours.

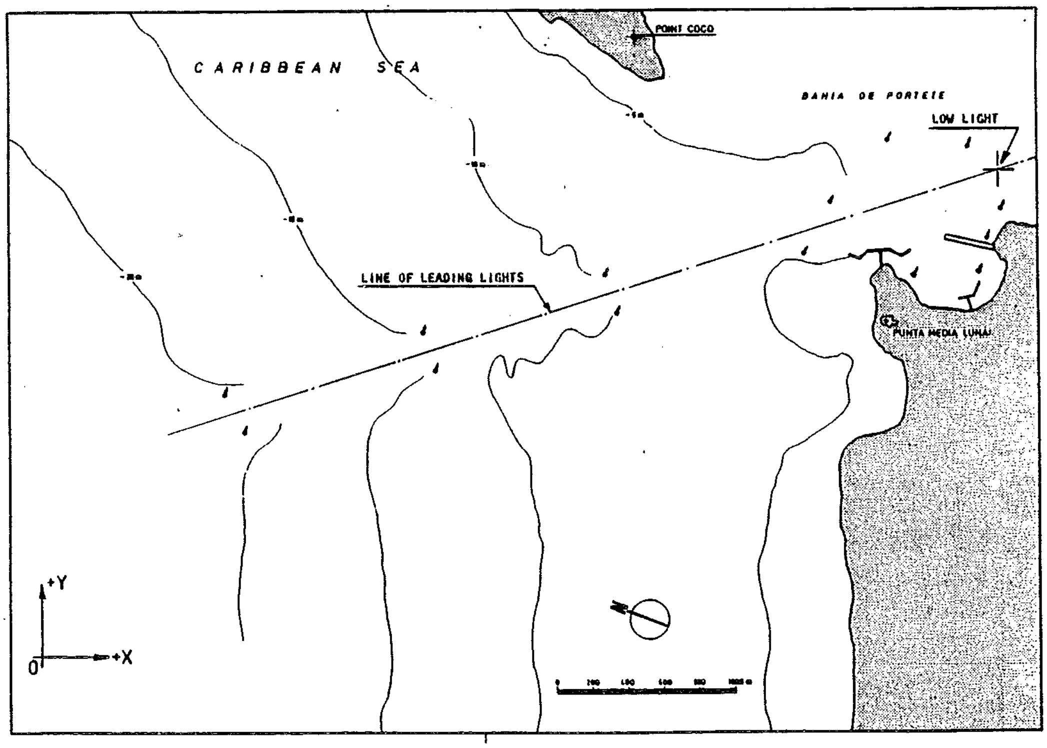


Fig 2.1.: Origin of co-ordinate system.

The starboard buoys are named CER1 to CER4. During the execution of trials, the pilots determined which orders they should give from the observations of radar screen and window view as shown in the two figures below.

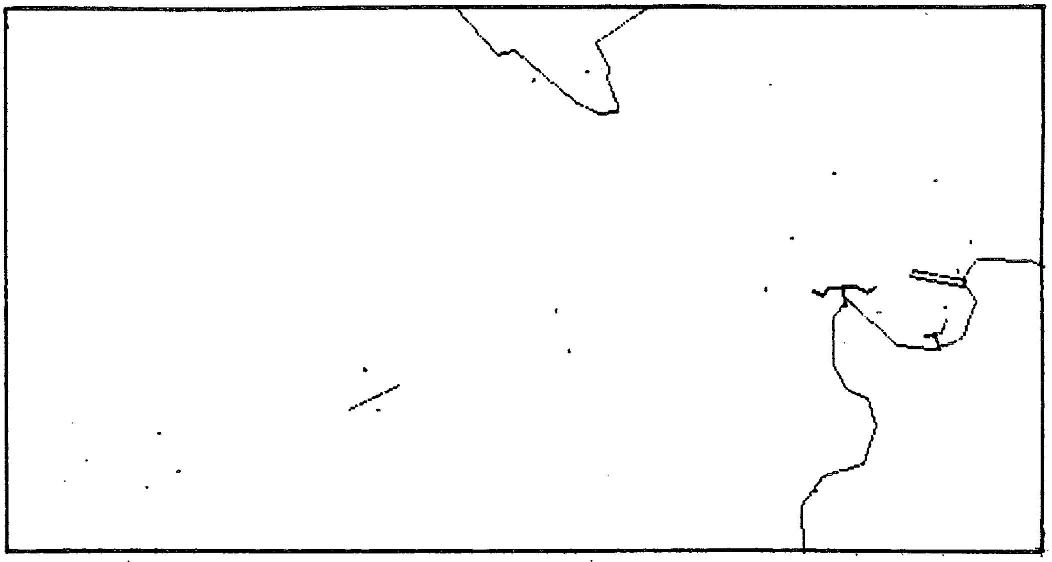


Fig 2.2.: Radar screen.

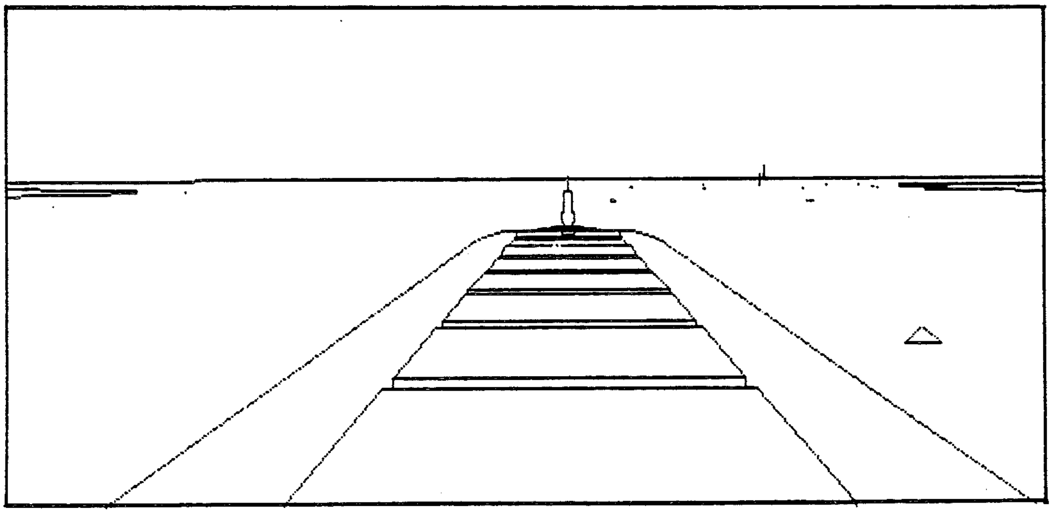


Fig 2.3.: Window view (3D picture)

The information from radar screen and window view is not detailed enough to control the berthing operation. Near the CER4-buoys the range of the radar screen is automatically changed. The picture below shows some steps of a berthing manoeuvre on the detailed radar screen.

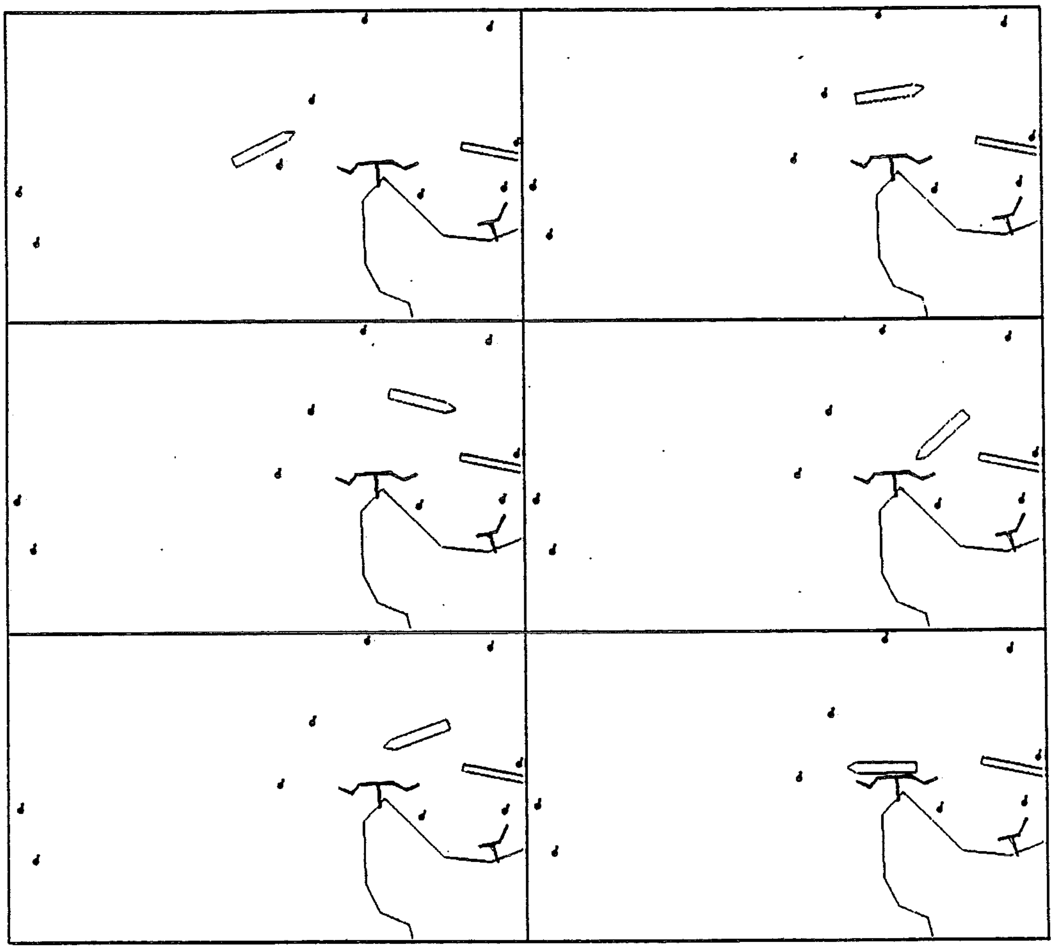


Fig 2.4.: Detailed radar screen

2.3. Ship Characteristics

Two types of ships, a 150,000 dwt coal carrier and a 25,000 dwt tanker have been calibrated in a fully laden and ballasted (40% of dwt) condition.

The table below contains the main dimensions of the two ships

	coalcarrier	tanker	units
length	300	180	m
length (pp)	287	172	m
width	45	22.9	m
draught (laden)	17	10	m
draught (ballast.)	8.7	5.4	m
displacement (laden)	183,000	31,500	ton
displacement (ballast.)	91,600	16,500	ton
propeller	7.5	5.8	m
wind effect. area:			
cross section:			
- laden	800	320	m^2
- ballast	1,174	425	m^2
longitudinal section:			
- laden	2,300	1,310	m^2
- ballast	4,790	2,140	m^2
silhouette:			

Table 2.1 Main dimensions of ships.

The dimensions of the tanker have been changed slightly from those mentioned in our proposal, but more accurate calibration data were available for this type.

During the execution of trials the pilot can only use the manoeuvring status of the engine. He must give machine commands like 'full ahead', 'slow astern', etc.
The table below contains the relation of head RPM and speed for the two types of ships.

engine setting	coalcarrier			tanker		
	RPM	speed (knots)		RPM	speed (knots)	
		laden	ballasted		laden	ballasted
max. RPM	100	15.0	16.9	125	15.6	17.7
FULL	80	12.0	13.5	100	12.6	14.3
HALF	60	9.0	10.0	75	9.4	10.7
SLOW	35	5.3	6.0	40	5.0	5.7
DEAD SLOW	20	3.0	3.4	25	3.1	3.6
STOP	0	0	0	0	0	0

Table 2.2 Relation of head RPM and speed.

The figures on the next pages show a summary of the turning trials. For each type of ship, six turning circles are plotted, three circles at sea speed and maximum RPM and three circles at the engine setting 'SLOW'. The three circles are the result of trials carried out with different rudder angle - wind speed combinations, viz.

trial	starboard rudder	wind speed (knots)
a	35^{o}	0
b	20^{o}	0
c	20^{o}	30
d	35^{o}	30

Table 2.3 Rudder angle - wind speed combinations.

Wind direction is shown by an arrow.

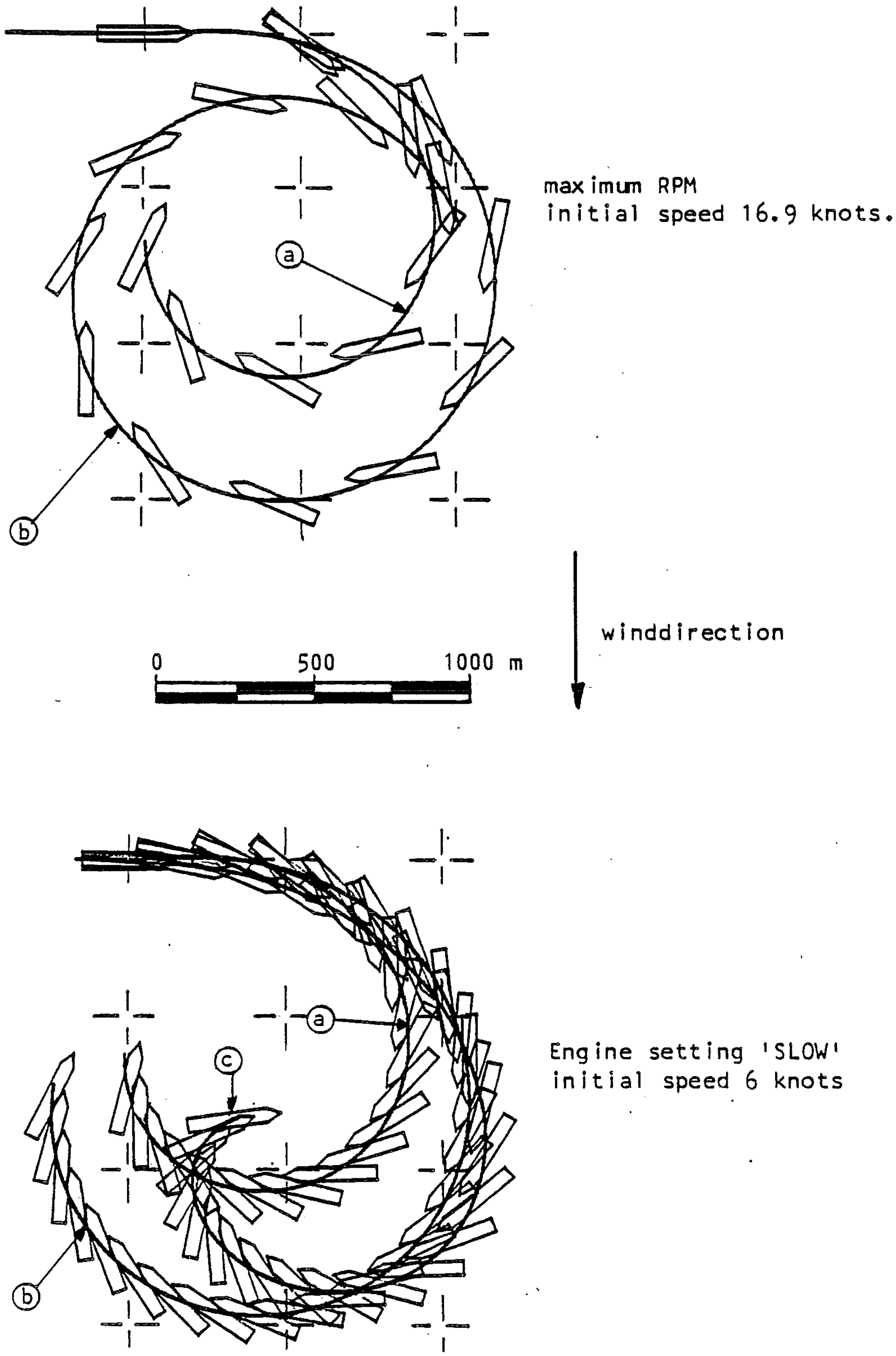


Fig 2.5.: Turning trials of the coal carrier in ballasted condition.

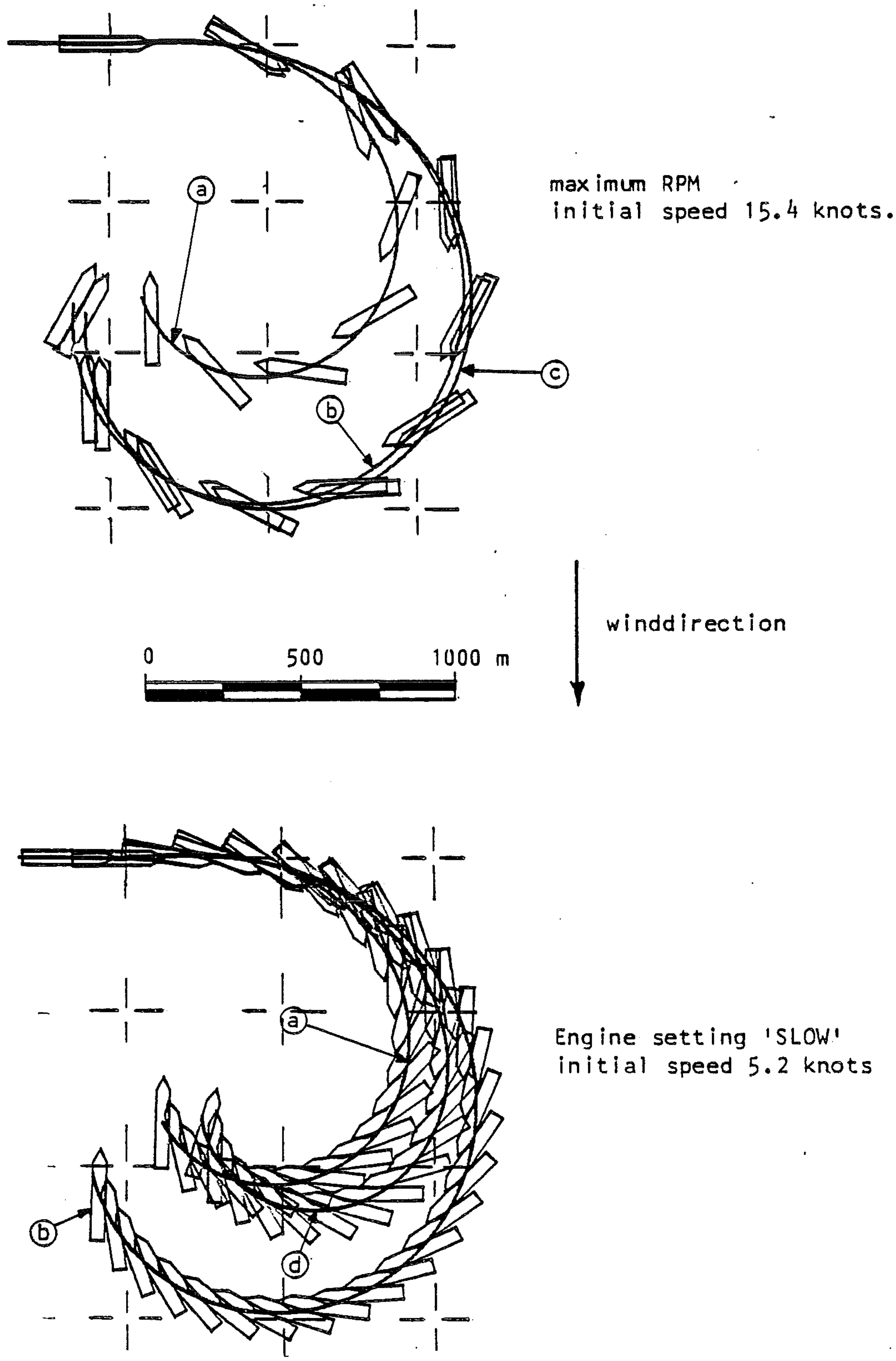


Fig 2.6.: Turning trials of the coal carrier in laden condition.

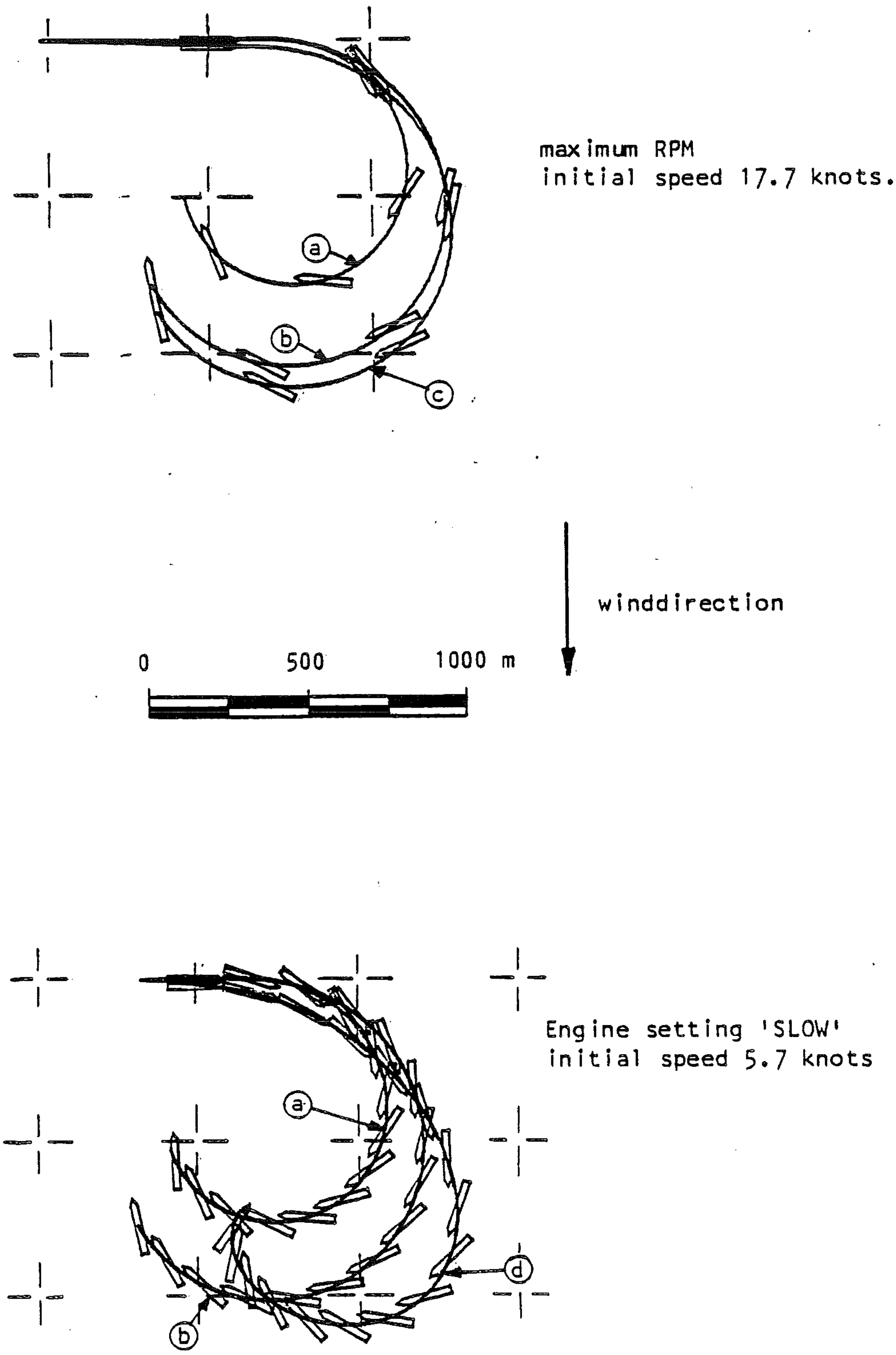


Fig 2.7.: Turning trials of the tanker in ballasted condition.

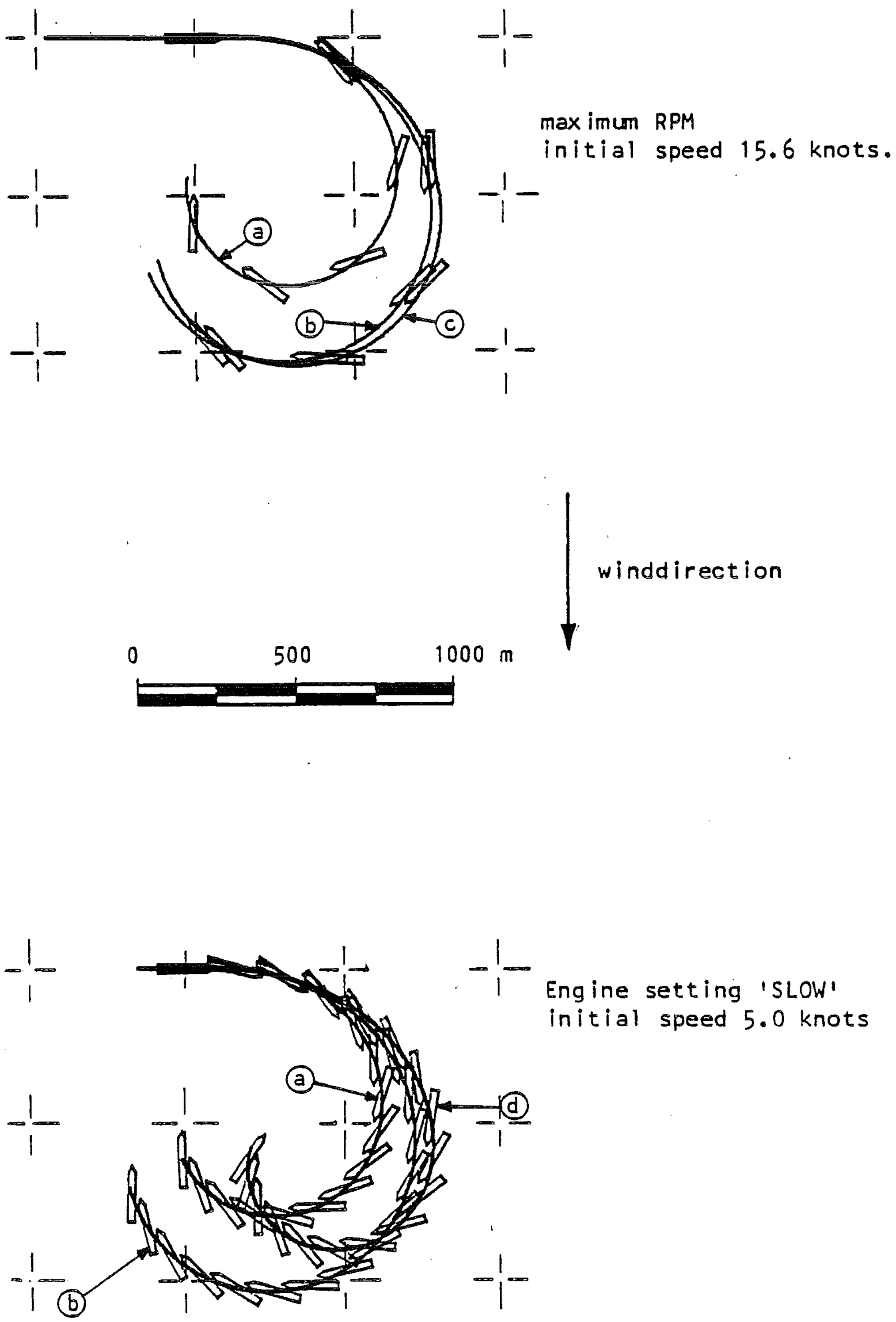


Fig 2.8.: Turning trials of the tanker in laden condition.

2.4. Tug Characteristics

For a reliable determination of tug forces it is important to know the propulsion (type of propeller) of the tugs.
If the tug has the ability to apply a lateral speed, there is a direct relationship between forward speed and the effective towing force. The effective towing force means the transverse component of the towing force.
This relationship is adverse for a conventional tug (one propeller, one rudder) and for a tug equipped with Voight-Schneider propellers good.

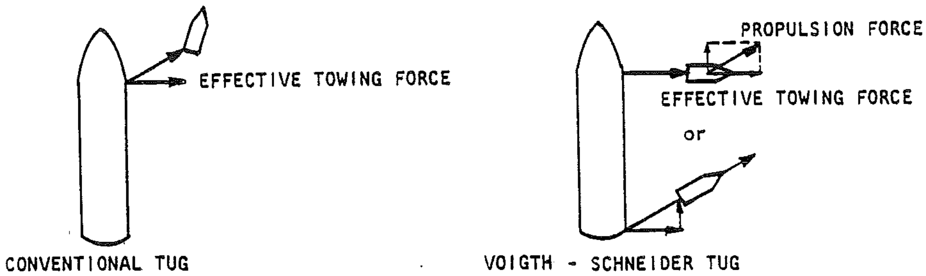


Fig 2.9.: Difference between conventional tug and Voight-Schneider tug.

The drawing below roughly shows the relationship.

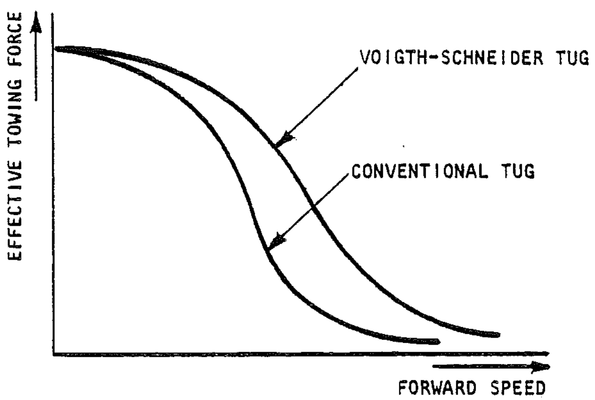


Fig 2.10.: Effective towing force, two types of tugs

2.5. Depth Contours

The drawing below represents the depth contours obtained from the input matrix of the simulation programme.

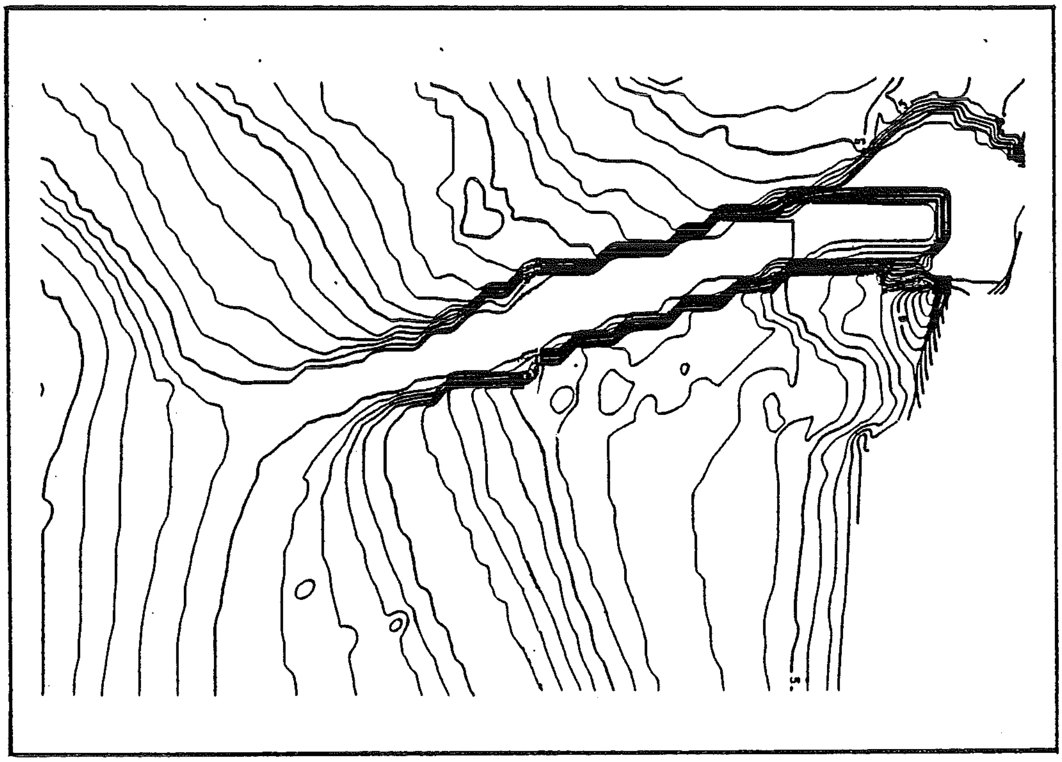


Fig 2.11.: Depth contour lines.

2.6. Current Pattern

2.6.1. Components of the current system

In general, the current system near a tidal inlet has the following components:

- ocean drift currents and wind driven currents,
- tidal longshore currents,

- inlet currents

Ocean drift currents are deep water currents, sometimes influenced by the season and generally with low velocities. Near Bahia de Portete these currents are very weak. According to the South America Pilot (vol. IV) the Gulf Stream passes Bahia de Portete in a westerly, sometimes in a slightly south-westerly, direction. It is also near the end of the Carribbean counter current, which passes in a north-easterly direction. This means that currents will be rather weak here but there is a tendency for the west to south-west direction to prevail, especially during the winter.

Locally, the surface drift current, being part of the Gulf Stream Equatorial System, could be affected by wind, especially in 'dead areas' such as where Bahia de Portete is located.
The prevailing wind direction (NE) and speed (20 knots) could give a south-westerly current with a velocity in the order of 0.5 knot in deep areas.

After evaluating the ocean and wind drift current data concerning the area of interest, the current was found to have a velocity of about 0.5 knot, moving in a south-westerly direction. The variation around this value might be in the order of approx. 0.25 knot.
We have therefore taken 0.5 knot = 0.25 m/s in south-westerly direction as a fixed value for the ocean and wind drift currents.

There is no information available on longshore tidal currents. It is expected however that they will be almost non-existent because of the small tidal difference.

The inlet currents are also tidal, caused by the filling and emptying of the bay. These currents are calculated in chapter 2.6.2. The total current will be found by vectorial addition of the above mentioned 0.25 m/s and the inlet current.

For the direction see figure 2.8, which also indicates the current pattern during slack tide.

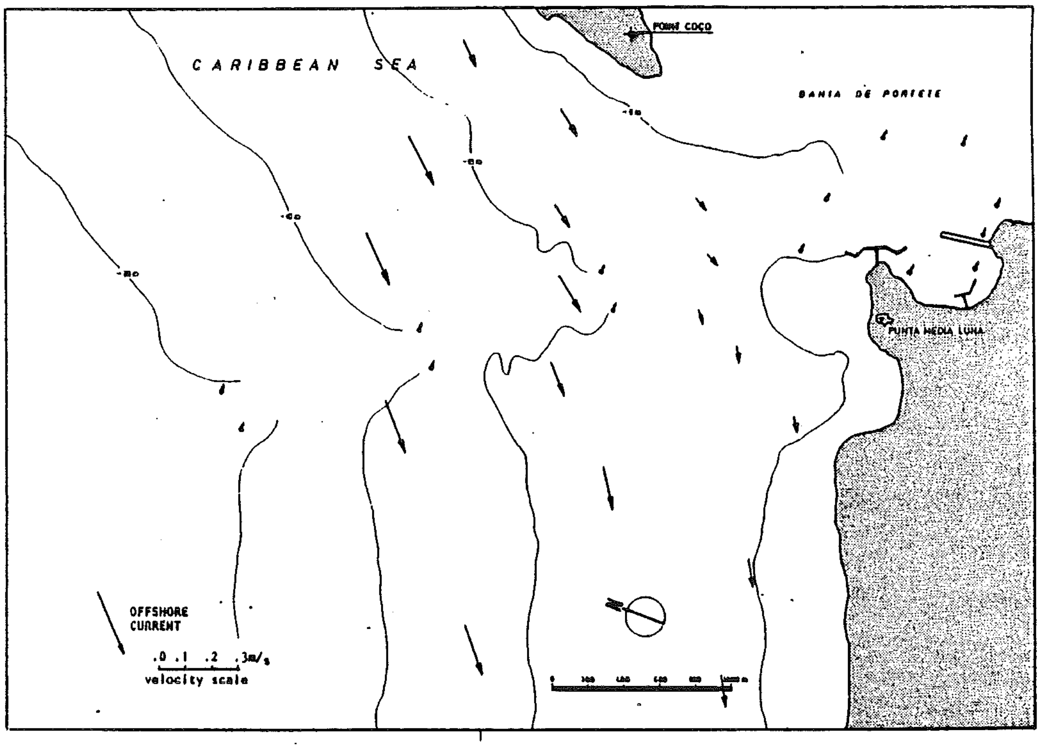


Fig 2.12.: Current pattern at slack tide

2.6.2. Inlet currents

The calculations of the current-pattern have been executed with the computer programme INLET. This programme is an adapted version of the programme described by Seelig, Harris and Herchenroder (A spatially Integrated Numerical Model of Inlet Hydraulics, CERC, 1977).
The mathematical backgrounds of this model are not discussed in this report.
The model works by constructing a flow-net for the inlet to represent the model grid. This net is represented on the figure below. The area of the Bahia de Portete is estimated to be 30 km2.

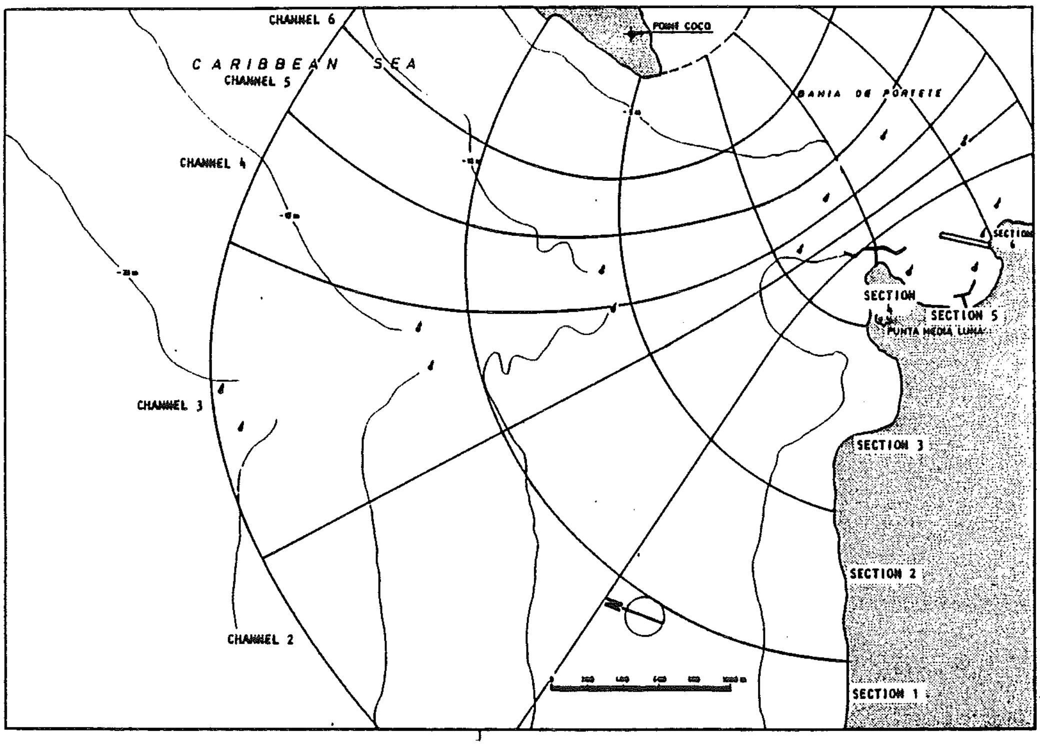


Fig 2.13.: The flow-net representing the model grid.

At sea, a sinusoidal level fluctuation has been assumed because no detailed information on the shape of the water level curve is available to us.
The Manning-coefficient is calculated with the following formula

n = 0.03 - 0.001 * depth (depth in meters)

The time-step used in the model is 240 seconds, which is less than the critical time step needed to keep the numerical process stable (the critical time-step is 425 seconds).

No information is available on the river discharge. Therefore using the little information we could gather about the area the following rough estimations have been made:

catchment area 45 x 45 sqkm
rainfall (maximum month) 400 mm
loss 75%, remains 100 mm

Average discharge in this month:

$0.1 * (45 * 1000)^2$ = 202 million cum/month
= 78 cum/second

Peak flow during this maximum month
2 times average flow = 150 cum/second

The tidal amplitude (normal spring tide) is 0.23 cm (half the tidal range).
A situation with extreme amplitude (1.01 m) has also been calculated. This calculation has been made to simulate the effect of a storm surge.

The following maximum velocities have been found (in m/s):

	present situation		new situation	
	flood	ebb	flood	ebb
normal spring tide	.16	-.20	.31	-.32
storm surge	.81	-.78	.95	-.95
high river runoff			.27	-.35

Table 2.4 Maximum current velocities.

In figures 2.14 - 2.17 the velocities are plotted for the new situations:

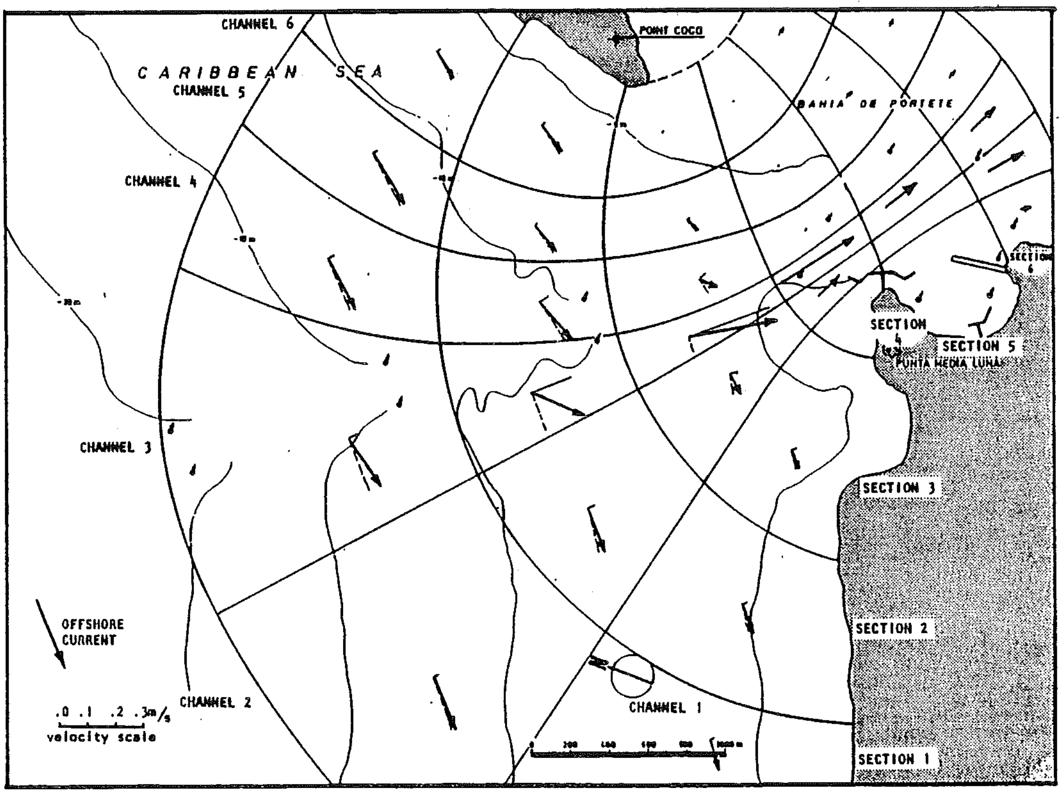


Fig 2.14.: Normal spring tide, flood

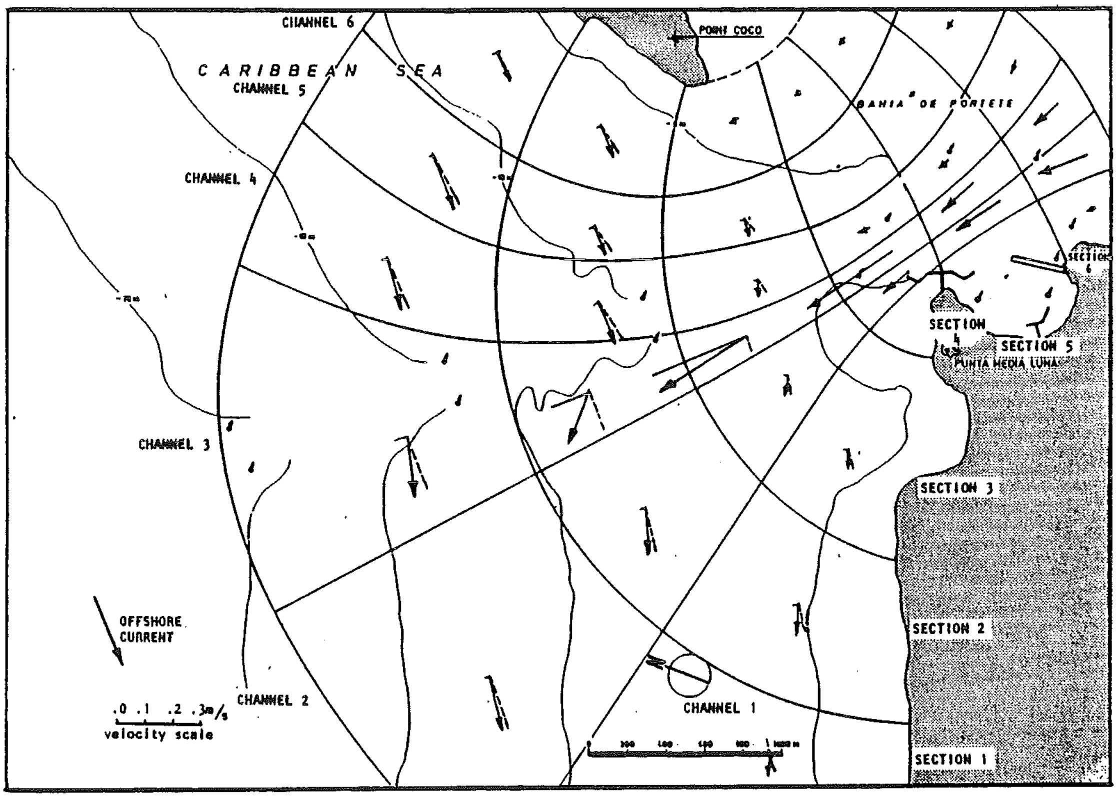
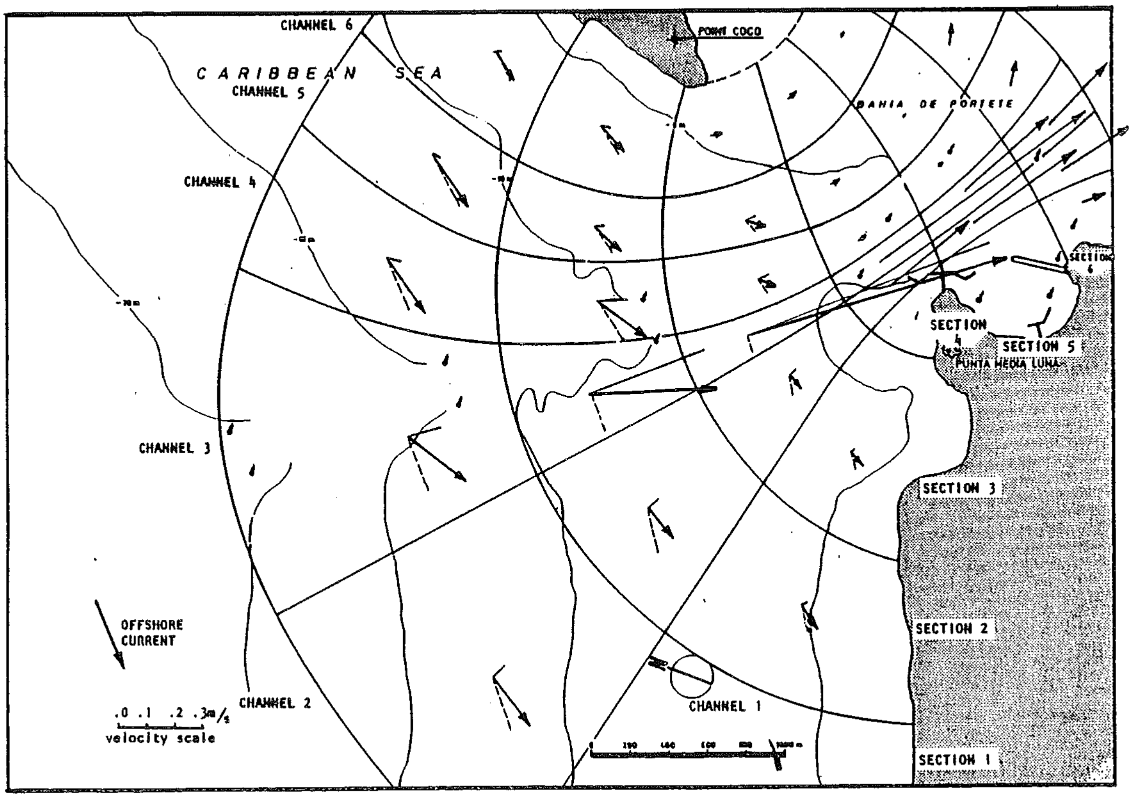


Fig 2.15.: Normal spring tide, ebb

Fig 2.16.: Storm surge, flood



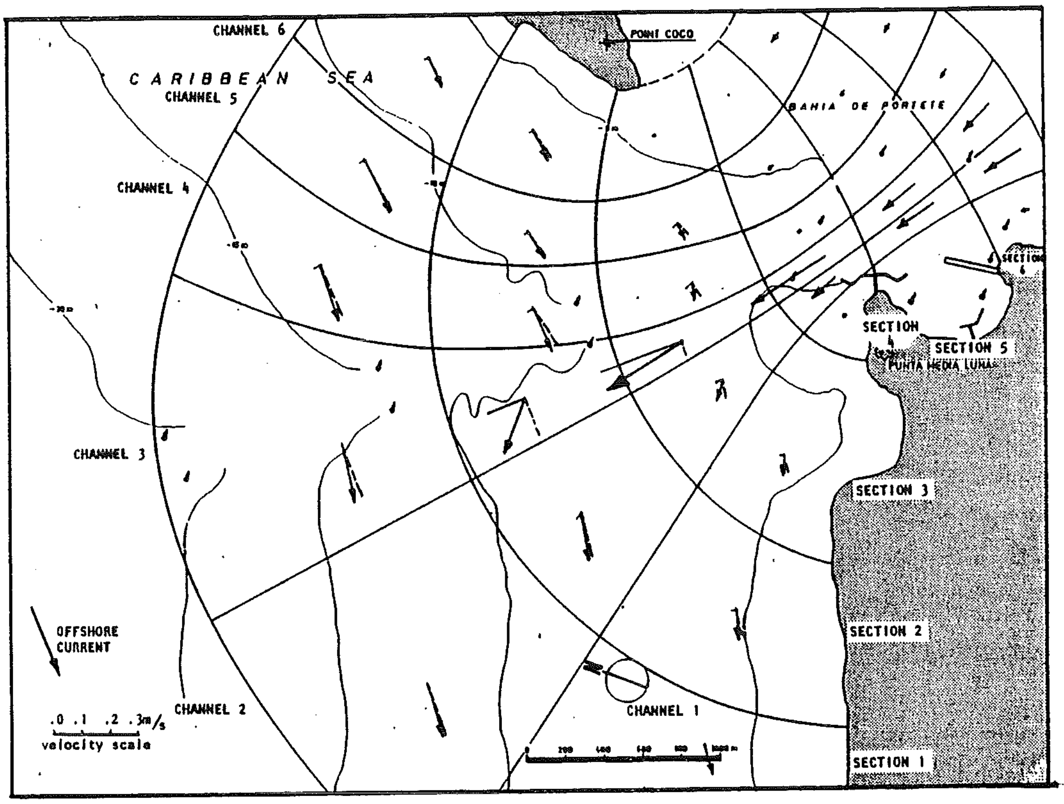


Fig 2.17.: High river runoff, ebb

2.6.3. Concluding remarks

The values, as given in figures 2.12, 2.14 and 2.15 have been used for the manoeuvring simulation, since these are the values that are normally to be expected.

The current patterns which were finally put into the computer are shown in the figures 2.18, 2.19 and 2.20.

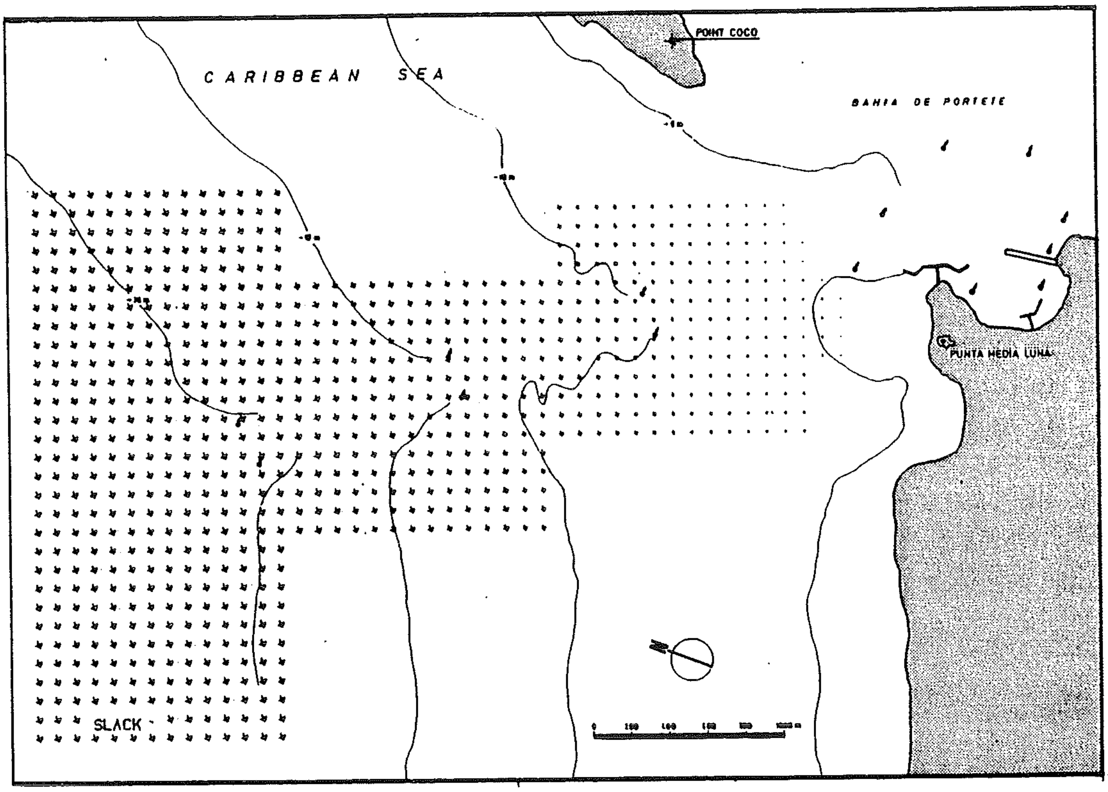
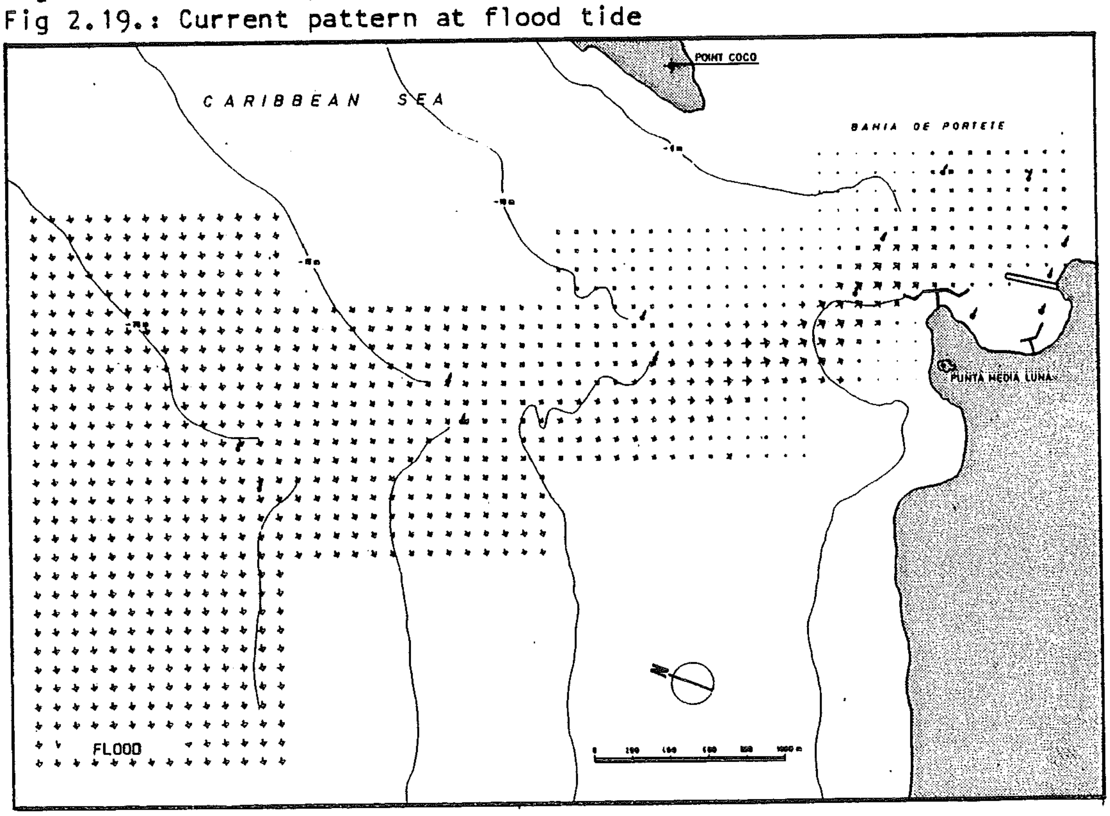


Fig 2.18.: Current pattern at slack tide

Fig 2.19.: Current pattern at flood tide



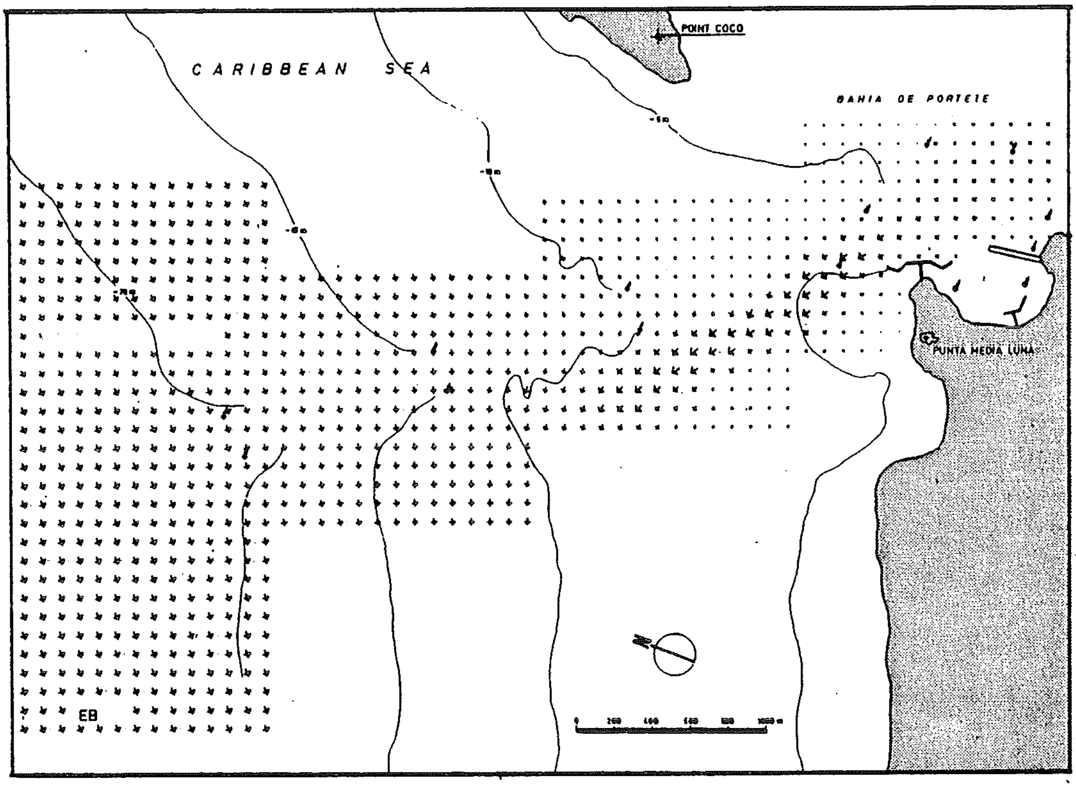


Fig 2.20.: Current pattern at ebb tide.

The values obtained for the case 'high river runoff, ebb' do not differ very much from the normal values and are therefore of no particular interest.

The current velocities occurring during a storm surge are much larger, however. This situation will occur very rarely but navigation will certainly be affected by these high current velocities.
The values indicated by M-K for this case are much lower. This is probably based on the assumption that the new channel will diminish current velocities due to an increase of the overall cross-section of the entrance. The channel to be dredged will, however, attract current, due to the fact that it has less resistance than the remaining part of the entrance.

The difference can be shown clearly using two pages from the computer output (see tables 2.5 and 2.6). These pages are copies from the bulk-output of the INLET-programme.

HYDRONAMIC BV
PORT & WATERWAY ENGINEERS
SLIEDRECHT HOLLAND
****
TIME,HOURS= 25.067

INLET 1
SEA LEVEL,(M) .12
BAY LEVEL,(M) .10
DISCHARGE,(M3/S) .4348E+04

CHANNEL		SECTION 1	2	3	4	5	6
1	LEVEL	.12	.11	.11	.11	.11	.10
1	V(M/S)	.01	.02	.05	.21	.22	.26
1	A(M2)	8568.72	4345.68	2427.25	1660.06	1404.22	2169.35
1	WEIGHT	.01	.02	.03	.08	.07	.13
2	V(M/S)	.04	.05	.13	.74	.64	.39
2	A(M2)	19999.05	8051.28	3499.54	2021.60	2226.58	2236.53
2	WEIGHT	.20	.09	.11	.34	.33	.20
3	V(M/S)	.13	.41	.81	.55	.53	.34
3	A(M2)	22825.72	8350.63	3022.04	1618.93	2229.25	4173.08
3	WEIGHT	.67	.78	.56	.21	.27	.33
4	V(M/S)	.05	.08	.22	.29	.25	.26
4	A(M2)	6882.83	4495.01	3013.59	1854.78	1376.61	1658.93
4	WEIGHT	.08	.08	.15	.12	.08	.10
5	V(M/S)	.03	.03	.12	.19	.22	.26
5	A(M2)	5439.56	2867.19	2777.38	2937.36	2680.93	2296.97
5	WEIGHT	.03	.02	.08	.13	.14	.14
6	V(M/S)	.01	.02	.11	.23	.22	.26
6	A(M2)	4859.87	3834.26	2810.60	2298.88	2298.06	1786.59
6	WEIGHT	.01	.01	.07	.12	.12	.11

MEAN VELOCITY AT THE MINIMUM AREA SECTION= .36 M/SEC
THE MINIMUM AREA IS 12215.65 M2

Table 2.5 Present situation

HYDRONAMIC BV
PORT & WATERWAY ENGINEERS
SLIEDRECHT HOLLAND
****
TIME,HOURS= 25.067

INLET 1
SEA LEVEL,(M) .12
BAY LEVEL,(M) .14
DISCHARGE,(M3/S) .4483E+04

CHANNEL		SECTION 1	2	3	4	5	6
1	LEVEL	.12	.12	.12	.13	.13	.13
1	V(M/S)	.01	.02	.02	.03	.01	.10
1	A(M2)	8568.72	4352.05	2433.77	1666.20	1410.50	2181.02
1	WEIGHT	.01	.02	.01	.01	.00	.05
2	V(M/S)	.04	.05	.05	.34	.45	.47
2	A(M2)	19999.05	8058.09	3505.62	3025.32	4882.25	3896.12
2	WEIGHT	.20	.09	.04	.23	.49	.41
3	V(M/S)	.13	.42	.95	.92	.41	.30
3	A(M2)	22825.72	8354.07	4024.70	3447.12	5260.46	6392.20
3	WEIGHT	.67	.78	.85	.70	.48	.42
4	V(M/S)	.05	.08	.08	.04	.02	.10
4	A(M2)	6882.83	4498.05	3018.18	1859.70	1382.21	1667.82
4	WEIGHT	.08	.08	.05	.02	.00	.04
5	V(M/S)	.03	.03	.04	.03	.01	.10
5	A(M2)	5439.56	2870.06	2783.59	2947.42	2692.55	2309.28
5	WEIGHT	.03	.02	.03	.02	.01	.05
6	V(M/S)	.01	.02	.04	.04	.01	.10
6	A(M2)	4859.87	3840.27	2817.91	2306.57	2307.74	1796.04
6	WEIGHT	.01	.01	.03	.02	.01	.04

MEAN VELOCITY AT THE MINIMUM AREA SECTION= .29 M/SEC
THE MINIMUM AREA IS 15252.32 M2

Table 2.6 New situation

Section 3 is the most interesting section because the highest velocities occur here. The following values can be found:

SECTION 3	present situation	new situation	increase decrease
area (sq.m)	12215	15252	+ 25%
total discharge (cum/s)	4348	4483	+ 3%
max. discharge (cum/s) channel 3	2448	3823	+ 56%
mean velocity (m/s)	.36	.29	- 34%
max. velocity (m/s) channel 3	.81	.95	+ 17%

Table 2.7 Discharge and max. velocity, present and new situation.

The above figures clearly show that the new channel does not greatly change the discharge. This means that the average velocity over the whole entrance will be decreased (by 34%) but that the distribution of the velocity will alter considerably. Consequently, the maximum velocity (which occurs in the channel) increases by 17%. This redistribution can also be clearly seen in the table below where the discharges in section 3 are given (in cum/s).

channel no:	1	2	3	4	5	6	all
present situation	121	455	2440	663	333	309	4330
new situation	49	175	3823	241	111	113	4513

Table 2.8 Discharges in section 3.

In order to remain as close as possible to our original proposal and quotation, and since we consider 'normal spring tide, ebb and, flood' and 'slack tide' as the most realistic operating conditions (figures 2.18 - 2.20), we have only simulated these conditions during our trials. Simulation of the extreme condition of 'storm surge', with the indicated much higher values and their unfavourable consequences for the manoeuvring, is thus not included in our test programme.

2.7. Wind data

The trials had to be distributed over the following conditions:

- entering and leaving,
- ship°s type,
- current pattern,
- wind.

Taking the three current patterns, given in section 2.6.3. and two ship types, both entering and leaving, each combination of these variables required 18 trials to be made with different wind speed - wind direction combinations (total of trials is 216).

The 18 trials had to be divided according to the measured wind speeds and directions in 'Punta Media Luna'. Table B of M-K report TC 33010-10/March 1980 was used and is reproduced on the next page.

TABLE B

PERCENT FREQUENCY OF ONE-HOUR AVERAGE WIND SPEED CORRECTED TO THE 10-METER ELEVATION VS. WIND DIRECTION AT PUNTA MEDIA LUNA

Speed (Knots)	WIND DIRECTION								
	N	NE	E	SE	S	SW	W	NW	TOT
0-4	.1	.1	.2	.0	.1	0.0	.0	.0	.7
5-9	.4	.5	1.2	.2	.2	.0	.1	.1	2.8
10-14	.7	3.3	4.3	.1	.1	0.0	.5	.0	9.1
15-19	.9	12.4	14.9	.1	.0	0.0	.1	0.0	28.5
20-24	1.6	16.6	21.9	.1	0.0	0.0	0.0	0.0	40.1
25-29	.8	6.2	9.7	.0	0.0	0.0	0.0	0.0	16.7
30-34	.0	.7	1.2	0.0	0.0	0.0	0.0	0.0	2.0
35-39	0.0	.1	.0	0.0	0.0	0.0	0.0	0.0	.1
40+	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	4.6	40.0	53.5	.7	.4	.0	.7	.2	

When three wind speed classes are considered, 10, 20 and 30 knots, the following distribution can be made according to the frequency of occurrence of wind speed for all directions:

wind class	perc. of occurrence	number of trials
10 (0 - 14 knots)	12.6%	2
20 (15 - 24 knots)	68.6%	12
30 (25 - 40 knots)	18.8%	4

The 20 knots wind class is very important since it occurs 68.6% of the time.

It is clear that it is more difficult to enter or leave in a 20 knot rather than in a 10 knot wind and therefore we thought it better to make only 3 trials for the 10 knots situation, 9 for the 20 knots and 6 for the 30 knots.
The wind classes can be divided over the various directions according to their occurrence. The table below shows the percentage of occurrence of the wind direction for the three wind speed classes.

wind speed class	wind direction							
	N	NE	E	SE	S	SW	W	NW
10	1.2	3.9	5.7	0.3	0.4	0	0.6	0.1
20	2.5	29.0	35.8	0.2	0	0	0.1	0
30	0.8	7.0	10.9	0	0	0	0	0

The following table shows the result, when the trials are divided according to the percentage of occurrence of wind speed and wind direction.

wind speed class	wind direction		Total
	NE	E	
10	1	2	3
20	4	5	9
30	2	4	6

Since in practice there is always some variation in direction within the wind direction class, the trials were carried out with a random distribution of the following wind directions:

Class	wind directions for random distribution				
NE	35^o	40^o	45^o	50^o	55^o
E	80^o	85^o	90^o	95^o	100^o

direction according to magnetic north (0°)

2.8. Ships° Starting Positions

We have assumed that the ships which approach the channel entrance, come directly from the sea, or from the waiting area, planned south-west of the channel.
The channel entrance can be approached from the south-west or north-west, or from any direction inbetween e.g. west. The computer has picked at random, from the multitude of choices available, the starting positions for the simulation runs. The figure below shows the choosen starting positions.

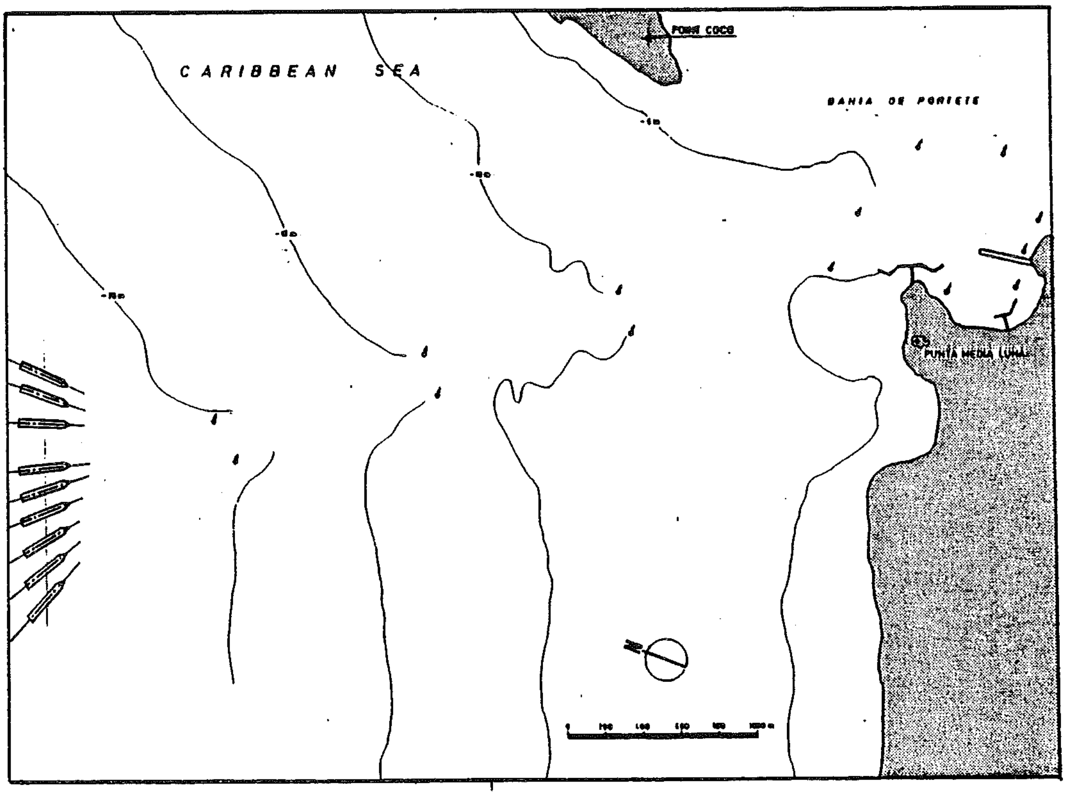


Fig 2.21.: Starting positions, entering manoeuvres.

3. FINAL TEST PROGRAMME

3.1. Number of Trials

In the first assignment Hydronamic had from Morrison-Knudsen Company, Inc., 216 trials were specified. This number had to be split up equally for entering and leaving manoeuvres and for the three current conditions. The detailed distribution of trials according to wind speed and wind direction is given in chapter 2.7.
Hydronamic informed M.K. in a letter dated September 2, 1982 that it is unneccessary to extend the number of trials in order to test the advantage of a radio-positioning information system. By reducing the number of outbound manoeuvres, we can find space to carry out trials with this system to see whether the channel width can be reduced.
We have reduced the outbound manoeuvres to 54. The remaining trials have been divided equally over the two ship types, the three current patterns and wind speeds.

The starting data for a simulation trial are contained systematically in a file. The data are rearranged at random. The trials are then followed in sequence. In this way, the pilots information, instead of becoming routine, appraoches the actual situation i.e. he does not know until shortly before a trial which ship, current, wind and starting position the simulation run will have.
The table on the next pages gives a review of the starting information for all 162 trials.
The columns contain the following data:

1. Type of ship indicated by the file number (this file contains the ship characteristics); 15 = coal carrier laden; 16 = coal carrier ballasted; 17 = tanker laden; 18 = tanker ballasted.

2. Number of file with depth contours and current pattern; 1 = normal spring tide, flood; 2 = normal spring tide, ebb; 3 = slack tide.

3. Wind speed (knots).

4. Wind direction (relative to chart north).

5. Heading. 1)

6. RPM.

7. Rate of turn (°/min).

8. Speed longitudinal (knots).

9. Speed transverse (knots).

10. X-co-ordinate start position (m) 1).

11. Y-co-ordinate start position (m) 1).

12. Starting time of manoeuvre in hours after high water.

13. Tidal amplitude.

14. Current correction factor.

15. Number autopilot file.

16. Indication sail in "I" and out "U".

1) Relative to axis in co-ordinate system as given in figure 2.1. Heading is given in degrees (clockwise = positive) with respect to positive y-axis. Direction of y-axis relative to chart North is 70°.

Starting data (continued).

15	2	30	100	272	0	,0	,0	,0	4800	2560	3,00	,36	1	1	U
16	1	20	100	83	60	,0	9,0	,1	160	1440	9,00	,36	1	1	I
16	2	20	100	65	35	,0	6,0	,2	160	1200	3,00	,36	1	1	I
17	1	30	100	99	40	,0	5,1	,0	160	1850	9,00	,36	1	1	I
17	3	30	100	99	75	,0	8,8	-,1	160	1850	3,00	,36	1	1	I
16	1	30	100	92	35	,0	6,9	,1	160	1672	9,00	,36	1	1	I
16	2	20	100	92	35	,0	6,2	,1	160	1672	3,00	,36	1	1	I
17	2	20	100	92	75	,0	9,0	,1	160	1672	3,00	,36	1	1	I
17	3	20	100	92	40	,0	7,0	,0	160	1672	6,00	,36	1	1	I
18	3	20	100	287	0	,0	,0	,0	5300	2612	6,00	,36	1	1	U
15	1	20	100	268	0	,0	,0	,0	4800	2552	9,00	,36	1	1	U
15	2	20	100	266	0	,0	,0	,0	4800	2554	3,00	,36	1	1	U
17	1	30	100	50	40	,0	5,3	,3	160	915	9,00	,36	1	1	I
17	2	20	100	50	40	,0	6,7	,3	160	915	3,00	,36	1	1	I
17	2	20	100	50	75	,0	8,8	,3	160	915	3,00	,36	1	1	I
16	2	20	100	41	35	,0	5,5	,0	160	735	3,00	,36	1	1	I
16	3	20	100	41	60	,0	8,7	,0	160	735	6,00	,36	1	1	I
18	2	10	100	281	0	,0	,0	,0	5300	2615	3,00	,36	1	1	U
18	2	30	100	281	0	,0	,0	,0	5300	2605	3,00	,36	1	1	U
16	3	30	100	114	60	,0	9,0	,2	160	1935	6,00	,36	1	1	I
17	2	30	100	114	75	,0	9,0	,2	160	1935	3,00	,36	1	1	I
18	3	20	100	288	0	,0	,0	,0	5300	2605	6,00	,36	1	1	U
16	1	10	100	60	35	,0	6,0	,0	160	1056	9,00	,36	1	1	I
17	2	10	100	60	40	,0	5,3	-,1	160	1056	3,00	,36	1	1	I
18	1	30	100	284	0	,0	,0	,0	5300	2606	9,00	,36	1	1	U
15	3	30	100	270	0	,0	,0	,0	4800	2557	6,00	,36	1	1	U
18	1	10	100	283	0	,0	,0	,0	5300	2607	9,00	,36	1	1	U
18	2	30	100	283	0	,0	,0	,0	5300	2607	3,00	,36	1	1	U
15	3	20	100	270	0	,0	,0	,0	4800	2549	6,00	,36	1	1	U
16	1	20	35	83	60	,0	9,0	,0	160	1440	9,00	,36	1	1	I
18	1	30	35	285	0	,0	,0	,0	5300	2610	9,00	,36	1	1	U
18	3	10	35	287	0	,0	,0	,0	5300	2610	6,00	,36	1	1	U
15	1	20	35	267	0	,0	,0	,0	4800	2551	9,00	,36	1	1	U
15	1	30	35	270	0	,0	,0	,0	4800	2552	9,00	,36	1	1	U
18	2	20	35	281	0	,0	,0	,0	5300	2612	3,00	,36	1	1	U
16	3	20	35	92	60	,0	9,0	,0	160	1672	6,00	,36	1	1	I
15	1	30	35	272	0	,0	,0	,0	4800	2553	9,00	,36	1	1	U
16	1	10	35	40	60	,0	9,0	,0	160	735	9,00	,36	1	1	I
18	1	10	35	285	0	,0	,0	,0	5300	2605	9,00	,36	1	1	U
16	2	20	35	60	60	,0	9,0	,0	160	1056	3,00	,36	1	1	I
15	2	30	35	268	0	,0	,0	,0	4800	2556	3,00	,36	1	1	U
18	2	30	35	284	0	,0	,0	,0	5300	2607	3,00	,36	1	1	U
15	2	10	35	268	0	,0	,0	,0	4800	2547	3,00	,36	1	1	U
15	2	20	35	271	0	,0	,0	,0	4800	2549	3,00	,36	1	1	U
15	1	20	35	272	0	,0	,0	,0	4800	2549	9,00	,36	1	1	U
16	2	10	45	83	60	,0	8,5	,1	160	1440	3,00	,36	1	1	I
16	2	30	40	83	35	,0	6,0	,0	160	1440	3,00	,36	1	1	I
17	1	20	45	83	40	,0	6,9	,1	160	1440	9,00	,36	1	1	I
17	2	20	45	83	40	,0	5,8	,0	160	1440	3,00	,36	1	1	I
16	3	30	45	65	35	,0	7,0	,2	160	1200	6,00	,36	1	1	I
17	1	30	40	65	40	,0	5,3	,2	160	1200	9,00	,36	1	1	I
17	2	20	40	65	40	,0	6,5	,2	160	1200	3,00	,36	1	1	I
17	3	20	45	65	40	,0	6,2	,3	160	1200	6,00	,36	1	1	I
18	2	20	40	287	0	,0	,0	,0	5300	2610	3,00	,36	1	1	U

Starting data (continued).

18	3	20	45	288	0	,0	,0	,0	5300	2620	6,00	,36	1	1	U
16	1	20	45	92	60	,0	9,0	,1	160	1672	9,00	,36	1	1	I
16	2	20	45	92	35	,0	5,5	,1	160	1672	3,00	,36	1	1	I
16	3	20	45	92	35	,0	5,5	,0	160	1672	6,00	,36	1	1	I
17	1	30	40	92	75	,0	9,0	,0	160	1672	9,00	,36	1	1	I
17	3	20	40	92	40	,0	6,4	,0	160	1672	6,00	,36	1	1	I
18	1	30	45	283	0	,0	,0	,0	5300	2613	9,00	,36	1	1	U
18	1	20	40	282	0	,0	,0	,0	5300	2615	9,00	,36	1	1	U
18	2	20	40	283	0	,0	,0	,0	5300	2605	3,00	,36	1	1	U
16	1	20	45	114	60	,0	9,0	,2	160	1935	9,00	,36	1	1	I
17	1	20	40	114	40	,0	6,2	,2	160	1935	9,00	,36	1	1	I
17	2	20	45	114	75	,0	9,0	,2	160	1935	3,00	,36	1	1	I
17	2	30	40	114	75	,0	8,8	,2	160	1935	3,00	,36	1	1	I
15	1	10	45	267	0	,0	,0	,0	4800	2545	9,00	,36	1	1	U
18	3	30	40	288	0	,0	,0	,0	5300	2615	6,00	,36	1	1	U
15	3	30	45	269	0	,0	,0	,0	4800	2545	6,00	,36	1	1	U
16	2	20	45	60	60	,0	8,8	,0	160	1056	3,00	,36	1	1	I
16	3	20	45	60	35	,0	6,5	,0	160	1056	6,00	,36	1	1	I
17	1	10	45	60	40	,0	5,0	,0	160	1056	9,00	,36	1	1	I
15	2	20	45	273	0	,0	,0	,0	4800	2546	3,00	,36	1	1	U
18	1	20	45	287	0	,0	,0	,0	5300	2606	9,00	,36	1	1	U
15	3	20	45	270	0	,0	,0	,0	4800	2558	6,00	,36	1	1	U
16	2	20	50	70	60	,0	9,0	,0	160	1320	3,00	,36	1	1	I
16	1	30	50	83	35	,0	7,0	,0	160	1440	9,00	,36	1	1	I
18	3	30	55	283	0	,0	,0	,0	5300	2620	6,00	,36	1	1	U
18	1	20	50	284	0	,0	,0	,0	5300	2620	9,00	,36	1	1	U
18	2	10	55	284	0	,0	,0	,0	5300	2620	3,00	,36	1	1	U
17	3	10	55	65	75	,0	9,0	,2	160	1200	6,00	,36	1	1	I
15	3	20	50	268	0	,0	,0	,0	4800	2550	6,00	,36	1	1	U
17	3	20	55	99	75	,0	9,0	,0	160	1850	6,00	,36	1	1	I
17	1	20	55	92	40	,0	6,5	,0	160	1672	9,00	,36	1	1	I
17	2	30	50	92	75	,0	9,0	,1	160	1672	3,00	,36	1	1	I
17	3	20	50	92	40	,0	6,2	,0	160	1672	6,00	,36	1	1	I
16	2	30	55	114	35	,0	5,5	,2	160	1934	3,00	,36	1	1	I
17	1	20	50	50	75	,0	9,0	,3	160	915	9,00	,36	1	1	I
17	2	10	55	50	75	,0	9,3	,3	160	915	3,00	,36	1	1	I
17	3	30	50	50	75	,0	8,8	,3	160	915	6,00	,36	1	1	I
17	3	10	50	41	40	,0	5,7	-,1	160	735	6,00	,36	1	1	I
16	1	20	50	114	35	,0	6,5	,2	160	1935	9,00	,36	1	1	I
16	3	10	55	114	60	,0	8,9	,2	160	1935	6,00	,36	1	1	I
16	3	20	50	114	60	,0	8,5	,2	160	1935	6,00	,36	1	1	I
16	3	30	50	114	60	,0	7,8	,2	160	1935	6,00	,36	1	1	I
17	2	20	50	114	40	,0	5,6	,2	160	1935	3,00	,36	1	1	I
15	2	30	55	267	0	,0	,0	,0	4800	2555	3,00	,36	1	1	U
16	1	30	55	60	60	,0	9,0	,0	160	1056	9,00	,36	1	1	I
15	3	30	55	267	0	,0	,0	,0	4800	2547	6,00	,36	1	1	U
15	3	10	55	273	0	,0	,0	,0	4800	2559	6,00	,36	1	1	U
16	2	30	85	70	60	,0	9,0	,0	160	1320	3,00	,36	1	1	I
16	3	20	80	70	60	,0	8,0	,0	160	1320	6,00	,36	1	1	I
18	1	10	85	281	0	,0	,0	,0	5300	2610	9,00	,36	1	1	U
16	3	20	80	83	60	,0	8,5	,1	160	1440	6,00	,36	1	1	I
17	3	20	85	83	40	,0	7,2	,0	160	1440	6,00	,36	1	1	I
17	3	30	80	83	40	,0	5,8	,0	160	1440	6,00	,36	1	1	I
17	3	30	80	83	40	,0	5,5	,0	160	1440	3,00	,36	1	1	I

Starting data (continued).

17	1	20	85	65	75	.0	8.7	-.2	160	1200	9.00	.36	1	1	I
17	1	30	85	99	75	.0	9.2	-.1	160	1850	9.00	.36	1	1	I
16	1	20	80	92	35	.0	5.5	.1	160	1672	9.00	.36	1	1	I
16	1	20	85	92	60	.0	9.0	.1	160	1672	9.00	.36	1	1	I
16	2	20	85	92	60	.0	8.5	.1	160	1672	3.00	.36	1	1	I
16	2	20	80	92	60	.0	9.0	.1	160	1672	3.00	.36	1	1	I
16	3	10	80	92	35	.0	6.7	.0	160	1672	6.00	.36	1	1	I
17	3	20	85	92	40	.0	6.0	.1	160	1672	6.00	.36	1	1	I
17	2	30	85	93	40	.0	6.0	.1	160	1672	3.00	.36	1	1	I
18	3	10	80	284	0	.0	.0	.0	5300	2612	6.00	.36	1	1	U
17	1	30	85	50	40	.0	5.2	.3	160	915	9.00	.36	1	1	I
16	1	10	80	41	60	.0	9.0	.0	160	735	9.00	.36	1	1	I
16	1	30	85	41	60	.0	9.0	.0	160	735	9.00	.36	1	1	I
16	3	30	80	41	60	.0	9.0	.0	160	735	6.00	.36	1	1	I
17	3	20	85	41	40	.0	6.5	.0	160	735	6.00	.36	1	1	I
18	3	30	80	283	0	.0	.0	.0	5300	2605	3.00	.36	1	1	U
16	1	30	80	114	35	.0	6.5	.2	160	1935	9.00	.36	1	1	I
16	3	20	80	114	35	.0	6.7	.2	160	1935	6.00	.36	1	1	I
17	1	20	80	114	75	.0	9.2	.2	160	1935	9.00	.36	1	1	I
17	2	10	85	114	75	.0	9.0	.2	160	1935	3.00	.36	1	1	I
17	2	20	80	114	40	.0	6.5	.2	160	1935	3.00	.36	1	1	I
15	1	30	80	269	0	.0	.0	.0	4800	2555	9.00	.36	1	1	U
15	2	10	80	270	0	.0	.0	.0	4800	2546	3.00	.36	1	1	U
16	1	20	80	60	35	.0	7.0	.0	160	1056	9.00	.36	1	1	I
16	2	30	80	60	60	.0	8.8	.0	160	1056	3.00	.36	1	1	I
17	1	20	80	60	40	.0	6.5	-.1	160	1056	9.00	.36	1	1	I
17	3	30	80	60	75	.0	9.0	-.1	160	1056	3.00	.36	1	1	I
15	1	10	80	268	0	.0	.0	.0	4800	2547	9.00	.36	1	1	U
15	3	10	80	272	0	.0	.0	.0	4800	2558	6.00	.36	1	1	U
16	1	20	90	70	35	.0	8.0	.0	160	1320	9.00	.36	1	1	I
18	2	10	90	282	0	.0	.0	.0	5300	2610	3.00	.36	1	1	U
16	3	20	90	83	60	.0	8.0	.1	160	1440	6.00	.36	1	1	I
17	1	10	90	83	75	.0	8.5	.1	160	1440	9.00	.36	1	1	I
17	1	20	90	83	40	.0	5.5	.0	160	1440	9.00	.36	1	1	I
17	2	30	95	83	40	.0	6.5	.0	160	1440	3.00	.36	1	1	I
16	3	10	95	65	35	.0	6.5	.2	160	1200	6.00	.36	1	1	I
16	3	30	90	92	60	.0	9.0	.1	160	1672	6.00	.36	1	1	I
17	3	30	95	92	75	.0	9.0	.0	160	1672	3.00	.36	1	1	I
18	3	10	90	284	0	.0	.0	.0	5300	2613	6.00	.36	1	1	U
17	1	20	90	50	75	.0	9.1	.2	160	915	9.00	.36	1	1	I
16	2	30	90	41	35	.0	7.0	.0	160	735	3.00	.36	1	1	I
17	3	20	90	41	75	.0	8.5	.0	160	735	6.00	.36	1	1	I
15	2	10	90	272	0	.0	.0	.0	4800	2545	3.00	.36	1	1	U
16	2	10	95	114	60	.0	8.7	.2	160	1935	3.00	.36	1	1	I
16	2	30	95	114	35	.0	6.5	.2	160	1935	3.00	.36	1	1	I
17	1	10	95	114	40	.0	6.0	.2	160	1935	9.00	.36	1	1	I
17	2	30	95	114	40	.0	6.7	.2	160	1935	3.00	.36	1	1	I
17	3	10	90	114	75	.0	9.2	.2	160	1935	6.00	.36	1	1	I
15	1	10	90	270	0	.0	.0	.0	4800	2546	9.00	.36	1	1	U
16	1	30	90	60	35	.0	6.7	.0	160	1056	9.00	.36	1	1	I
16	2	10	95	60	60	.0	9.0	.0	160	1056	3.00	.36	1	1	I
16	3	30	95	60	35	.0	6.5	.0	160	1056	6.00	.36	1	1	I
17	2	20	90	60	75	.0	9.1	.0	160	1056	3.00	.36	1	1	I
15	3	10	90	271	0	.0	.0	.0	4800	2557	6.00	.36	1	1	U

3.2. Pilot°s Task

In a simulator investigation it is important to give the pilot a well defined task. When these tasks are not described clearly, the possibility arises of the investigation being disturbed by deviate manoeuvres.
We gave the pilot the following task;
Sail the ships as safely as possible into and out of the harbour. Your navigational aids are the buoys and the line of leading lights, shown on one screen. The leading lights are only visible in the outside (window) view. The other screen informs you about ship°s status.

Heading, longitudinal (speed-x) and transversal (speed-y) speed, rudder angle and the revolutons of the propeller are indicated. The following is a copy of the instrumentation panel.

```
  HEADING    SPEED-X    SPEED-Y
 144.3 DEG    7.0 KTS     .2 KTS <|          BRIDGE COMMANDS
                                  |
  RUDDER     REVOLUTIONS          | PROP REVOLUTIONS:?30
  -15 DEG       28 RPM            |
                                  | YOUR HEADING     :?365
        0        PULL       10    |
       90 /==== DIR===|     92    |      AUTOPILOT ON
          /1            2|        |
          \4            3|        |
        0 \====PULL===|      0    | ENTER COMMANDS FOR TUG2 ?10 TONS
      270         DIR       270   | PULLING DIRECTION ?180
```

Fig 3.1. Instrumentation panel.

It is necessary to give orders as you would at sea like 'SLOW AHEAD' for the engine or heading '140' or 'port 10'.

The tugs are attached to the ship near the CER1 buoy (entering). You can use 3 tugs, one at the bow the other two port and starboard aft. You can order the tugs to tow or to push in a certain direction with a certain force (max. 40 tons each tug).
Every trial starts with the information on screen i.e. which ship type you have to bring in or take out, and what kind of external circumstances you have to reckon with.
We suggest you reduce the ship°s speed near the CER 1-buoy to 7 knots, between the CER2 and CER3-buoy to 5 knots and at the edge of the turning basin, to 3 knots.

Incoming ships have to swing around before berthing. The figure below indicates the berth for the coal carrier and the tanker.

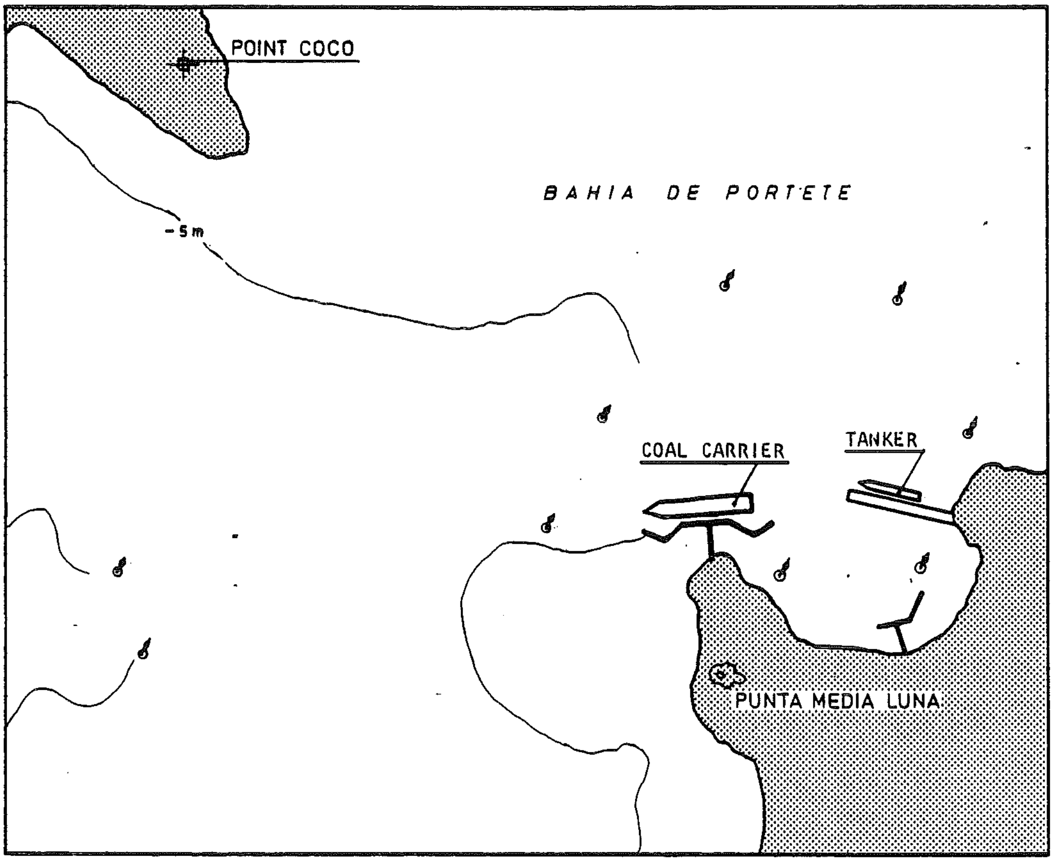


Fig 3.2. Location of berths.

When the turn is completed, you bring the ship roughly alongside the berth, reducing longitudinal and transversal speed, and the rate of turn to zero. You can then consider the trial as finished.
A leaving manoeuvre begins at a certain distance from the berth with a forward speed equal to zero. There are no speed limitations in the channel. You can stop the trial a quarter of a mile after passing the CER1-buoy.

3.3. Elucidation of trail results

The results of all manoeuvres are contained in two volumes viz: 'COAL CARRIER' and 'TANKER'.
Each manoeuvre is summarized on two pages, viz:

- one page with a track record of ship's path and the used tug forces,

- a second page containing the following data divided into three parts:

  - The ship°s heading or course, the swept path sailed by the ship (swept path indicates the outer limits sailed either side of the ship) and the rudder angle,

  - the pilot commands concerning RPM and tug force,

  - the actual propeller RPM, the ship°s speed over the ground (speed doppler log) and the ship°s speed relative to the water (speed log, dotted line).

The tidal and wind conditions prevailing during sailing are mentioned on each first page.
Moreover, the wind direction is also indicated by an arrow, in relation to north, at the bottom of the page

On each second page the data are recorded relative to ship's location.
The buoys are named CER 1, 2, 3, 4, number 1 being at the entrance to the channel. The centres of the coal terminal and commodities pier are also indicated by a dotted line.
The channel and turning circle are shown in the upper part of each second page by little triangles at the buoys' locations.
The actual propeller RPM sometimes differs from the RPM ordered by the pilot: this is happened if the pilot gave different commands at short intervals; the engine had no time to adapt to the ordered RPM.
When the pilot has ordered: 'tug 1 has to tow with 40 tons', 'T140' is written in the middle section. 'Tug 2 has to tow with 20 tons' is written 'T220'. Sometimes the pilot has asked the tug to push, mostly with 40 tons, and this is recorded as 'T2##' to show clearly the difference between pushing and towing.

The difference between the speed over the ground (doppler log) and the speed relative to the water (log) is small in the middle reach of the channel and increases in the turning basin. This difference is caused by the current.
For example: if there is a flood current, the log will indicate a lower speed than the doppler log near the CER4 buoy.

4. PILOTS' COMMENTS

After every nautical investigation with the aid of the manoeuvring simulator, we asked the pilot to comment on the set of trials he had just finished. This verbal information sometimes reveal important points, which disappear in the statistical analysis. We have selected the following points from pilots° comments:

1. There was a great difference in difficulty between the entering and leaving manoeuvres. The limiting speed when entering, made the manoeuvre more difficult.

2. For leaving, two tugs towed the ship (coal carrier and tanker) away from her berth. The engine was ordered to slow. When the CER4 buoy was passed the tugs could go back to their station.
   The engine was set to half or to full and with a drift angle of 1 degree near the CER4, and 3 degrees near the CER1 buoy (caused by current) the ship left the channel. Only the tanker (in ballast condition) gave a little trouble, if the tugs cast off too early in a strong wind (see trial 025 and 035).

3. To pass through the channel safely, with a ballasted coal carrier was more difficult than with a laden tanker.

4. Passing through the channel was based upon an equilibrium between drift angle and forward speed the whole way.

5. When coming from the open sea, east of the continuation of the channel it was more difficult to pass through the first pair of buoys (CER1) than when approaching from the west. The turn to port caused a transversal speed to starboard, which was intensified by a current and wind. The coal carrier especially was hindered by this effect, which was caused by a large wind effective area and a relatively small draught.

   When the starting position was somewhat more westerly, the difficulty was not passing between the CER1 pair of buoys, but to find the equilibrium drift angle at the right moment. The turn to starboard gave a transversal speed to port. Current and wind diminish this speed. When the ship was in line with the leading lights, the current and wind effect turned the direction of transversal speed to starboard. Then it was necessary to introduce a drift angle to port.
   If the pilot gave this order too late or early, passing the second pair of buoys (CER2) could sometimes give difficulty. (see coal carrier trial 155, 187).

6. Once in the channel the forward speed had to be decreased. To keep the ship in line with the leading lights, the drift

angle had to be increased, even though the wind remained the same.

7. Between CER2 and CER3 the current pattern changed. The current velocity was less. A new equilibrium between forward speed and drift angle had to be determined.

8. After passing the CER3 pair of buoys, the angle of drift chosen was sometimes too small, which caused troubles near the CER4 buoy. Two things can be done in such a situation; let the tugs push or tow or increase the revolutions of the propeller. Both methods have been carried out.

9. Before the turning circle was entered (passing the CER4 buoy) the preparation for the turn had already been started. Some pilots preferred to swing round to starboard, others to port. The swing to starboard started just in front of the CER 4-buoy, by giving a little starboard rudder (5-10 degrees, see coal carrier trial 174) or by using the wheel effect of the propeller if the engine setting was 'astern' (trial 129 of the coal carrier). This eliminated the drift angle. See also point 11.

   The other method, the swing to port, started by increasing the drift angle and at the same time decreasing the speed.
   A drift angle of 20-25 degrees could occur between the buoys CER4 and CER5 (coal carrier trials 103 and 142) if there were strong winds.

10. The ships had to swing around as much as possible in front of their berth.

11. If there were strong winds the pilots preferred to swing with the bow into the wind. The large drift angle formed the beginning of the turning manoeuvre and the wind assisted in stopping the ship. We used ships with right turning propellers. When the speed was less than 3 knots, the wheel effect of the propeller swung the ship to starboard.
    The method of swinging, into the wind worked against this wheel effect, but it was safer. The wheel effect helped to turn the ship when swinging to starboard, but to stop the ship was more difficult, because the reverse power of the ship°s engine had only about 50 - 75 % of the forward power and it was not only the ship°s speed which had to be reduced, but the wind-force had also to be compensated.

12. Some pilots preferred to sail faster through the channel to reduce the drift angle (see trial 102).
    The speed was up to 6 knots until the CER3 was reached.

The two concluding remarks refer specifically to the 150,000 dwt coal carrier.

- Entering the channel would be easier (and safer) if space between the CER1 pair of buoys was widened (for example by repositioning at the 19 m depth contour line).

- The turning manoeuvre should take place in front of the berth, but the CER5 buoy was in the way when swinging the coal carrier. It would be better to change the shape of the turning circle (see figure below).

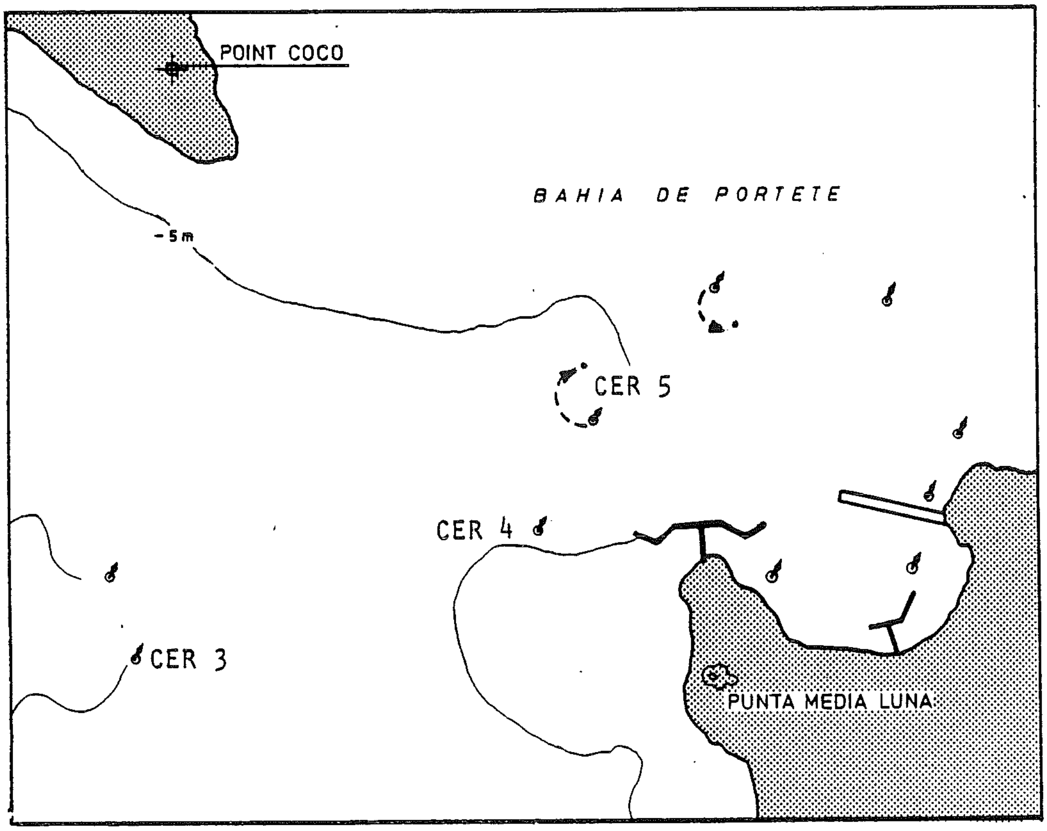


Fig 4.1. Repositioning of buoys.

5. THE USE OF TUGS

One of the tasks of this nautical investigation was: 'to assess the requirements for and the use of tugs in harbour operations'

For the analyses of tug forces we can choose from two methods:
- a pure statistical method, determining the standard deviation of tug force and direction.
- a more intuitive method using the results of pilots° experience at the end of a trial and maximum recorded tug forces.

We use the first method when we have to determine the necessary bollard pull, the second when we have to investigate the satisfactory use of a given number of tugs with a given maximum bollard pull.

In our opinion, the second method is the better for this task.

The following remarks are particularly pertinent to the entering manoeuvres:

- The exact moment that the tugs had to be used, depended on how the manoeuvre was progressing. If the manoeuvre threatened to go too much to leeward, the tugs were first used between buoys CER3 and CER4. Usually, the tugs started to push or tow after passing the CER4-buoy.

- The tugs were usually first used to start the turn and not to keep the ship in line during the stopping manoeuvre.
  The pilots reduced the ship's speed enough to start the turning manoeuvre and move smoothly into the stopping manoeuvre.

- While the turning manoeuvre for both ships takes place just in front of their berthing places, the tanker uses the tugs at a later stage, thus more southerly in the turning basin.

- When the foreward speed was nearly reduced to zero, the pilot used the total available bollard pull to swing around as fast as possible.
  A frequently used method to swing to port was to order tug 1 (starboard fore) to push transversely and tug 2 (starboard aft) and tug 3 (port aft) to tow to starboard. Tug 3 towed at an angle of 30° slanting backwards, as towing transversely would mean the rope came against the stern and probably being damaged.
  Tug 3 assisted in stopping the ship.
  The maximum used tug forces acting on the ship during the first stage of turning in the X and Y-direction were as indicated below:

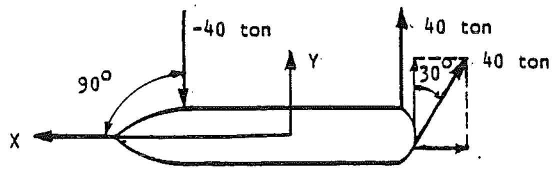


Fig 5.1. The maximum used tugforces.

- If the ship was completely controlled by tugs, the pilot sometimes used the main engine to increase the rate of turn and to compensate the backward force of tug 3, by ordering half or full ahead and hard rudder to port. This was only a short action, otherwise the forward speed increased too much.

- The main engine was normally used, forewards or backwards, merely to better the position of the ship for berthing. The tugs pushed or towed perpendicular to the ship.

- The pilot always tried to approach the berth slightly obliquely, either bow or stern first. 10–20 m before the berth, the ship was positioned completely parallel to it.
  The pilot was asked to stop the trial here, when all movement had ceased.

- During the turning manoeuvre the wind played an important part, especially in the last stage of the operation, when the ship was coming parallel to her berth.
  The turn took place (the closest point) 0.2 – 0.5 times the ship's length outside the berth.

To actually berth her, the two starboard tugs pushed. It now depended on the wind speed how difficult it was to control the transverse speed.
In a 10 knot wind there was no problem and there was no difficulty in a 20 knot wind, but if the wind was 30 knots it was difficult to stop the ship with the three available tugs.
It was necessary to tow at maximum power for about 4 minutes to reduce the transverse speed from 0.5 to 0.4 knots. This meant that the last stage of the berthing manoeuvre had to be carried out very carefully.
Any velocity towards the berth was the result of the wind force plus not enough tug force.
This was counteracted by increasing the pulling power to starboard.
The dimensions of the coal carrier specified by M-K for the trials, caused it to be sensitive to wind forces. Three tugs, each of 40 tons bollard pull, would be insufficient for a safe berthing manoeuvre.

- The force caused by the current was small when compared to the force caused by a strong wind. The effect of current was more clearly felt in the last stage of the berthing operations of the coal carrier. The current turned the ship making the manoeuvre somewhat more difficult. In the case of a 30 knot wind and an ebb current, the total tug force was hardly enough.

Only the entering manoeuvres have so far been discussed, as the leaving manoeuvres created no problems. The procedure was that two tugs towed the ship transversely away from her berth. When the ship was about 0.5 times a ship's breadth from the berth, the pilot ordered 'slow ahead'. The ship carefully left her berthing place. Only the ballasted tanker gave some trouble when the tugs were sent away too early in a 30 knot wind.

The following concluding remarks can be made:

- The tugs were mostly used for a combined turning/stopping manoeuvre and were only used to keep the ship in the channel when the pilot did not choose the right drift angle.

- To swing the ship around, maximum available bollard pull was used.

- The total available bollard pull (3 times 40 tons) was enough for the tanker under all conditions and for the coal carrier up to a wind speed of 20 knots.

- The leaving manoeuvres gave no problems.

6. REQUIRED CHANNEL WIDTH

6.1. General

The required channel width is determined by putting the sailed manoeuvres into a statistical analysis. The data were first divided into four groups viz.: entering and leaving, tanker and coal carrier. Secondly we put each group of trials into an overall statistical analysis. This could be done since the conditions sailed represent more or less the average for a whole year.

The channel width at each location can now be determined by drawing a line which indicates a certain (small) chance of ships that could pass this line. This line represents a certain frequency of exceedance: a 1 per cent frequency line means that, on average, only 1 per cent of the ships is expected to exceed this line.

The difficulty is, of course, which percentage to take for this exceedance frequency.
In our opinion a frequency of approximately 0.01 per cent should be taken (0.01 per cent means 1 per 10.000 ships) for the following reason.

The total probability of a ship stranding (exceeding the bottom borders) while the channel is operative should not be more than, say, 10-15 per cent. This means that during the economical lifetime of the channel of, say, 15 years (when coal production, ship type etc. remain the same) there is a chance that an accident could occur. During this period of 15 years approx. 1500 entries with the considered ship size may be expected (100 per year).

The individual chance per entering manoeuvre can then be calculated with the formula:

$$1 - (1 - f)^{N} = P$$

where: N = the total number of sailings during the lifetime
f = the individual average chance per sailing
P = the total chance that the phenomenon considered will occur during the considered period.

The above formula closely resembles a statistical Poisson distribution.

For f = 0.01 per cent the value of P = 14 per cent which is according to our requirements.

(In the case of f = 0.1 per cent the total chance P that a stranding will occur during the period of 15 years would be 78 per cent, which means that there is indeed a fair chance that such a stranding could really occur).

Plots with the 1 and 0.01 per cent exceedance frequency lines for the different types of ships are shown in the next pages. These plots are based on the simulated trials and that is a limited number (a limited sample) of manoeuvres carried out in the new situation. The plots are only intended to show the differences in sailing of the different types of ships.

The figures 6.1 - 6.8 contain the plots of the statistical analysis for the entering and leaving coal carrier and for the entering and leaving tanker. The results of the analysis for each situation consist of two plots. The first plot shows the

- extreme limits of sailing during manoeuvring trials
- path width with a 1 per cent exceedance frequency
- path width with a 0.01 per cent exceedance frequency

The second plot shows the result of the statistical analysis of the different parameters like rudder angles, speed, revolutions of propeller, etc..

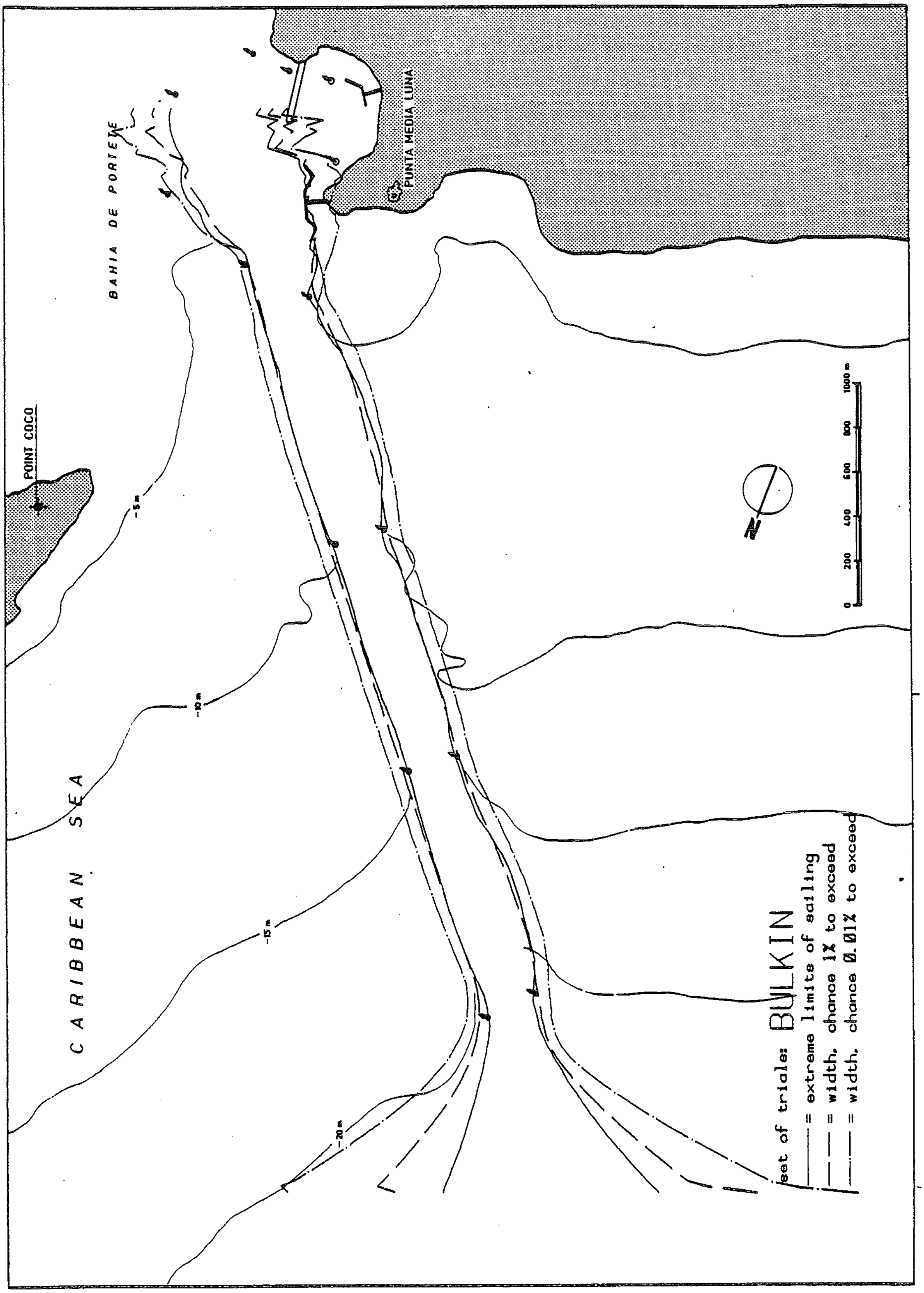


Fig 6.1.: Exceedance frequency lines. Entering coal carrier

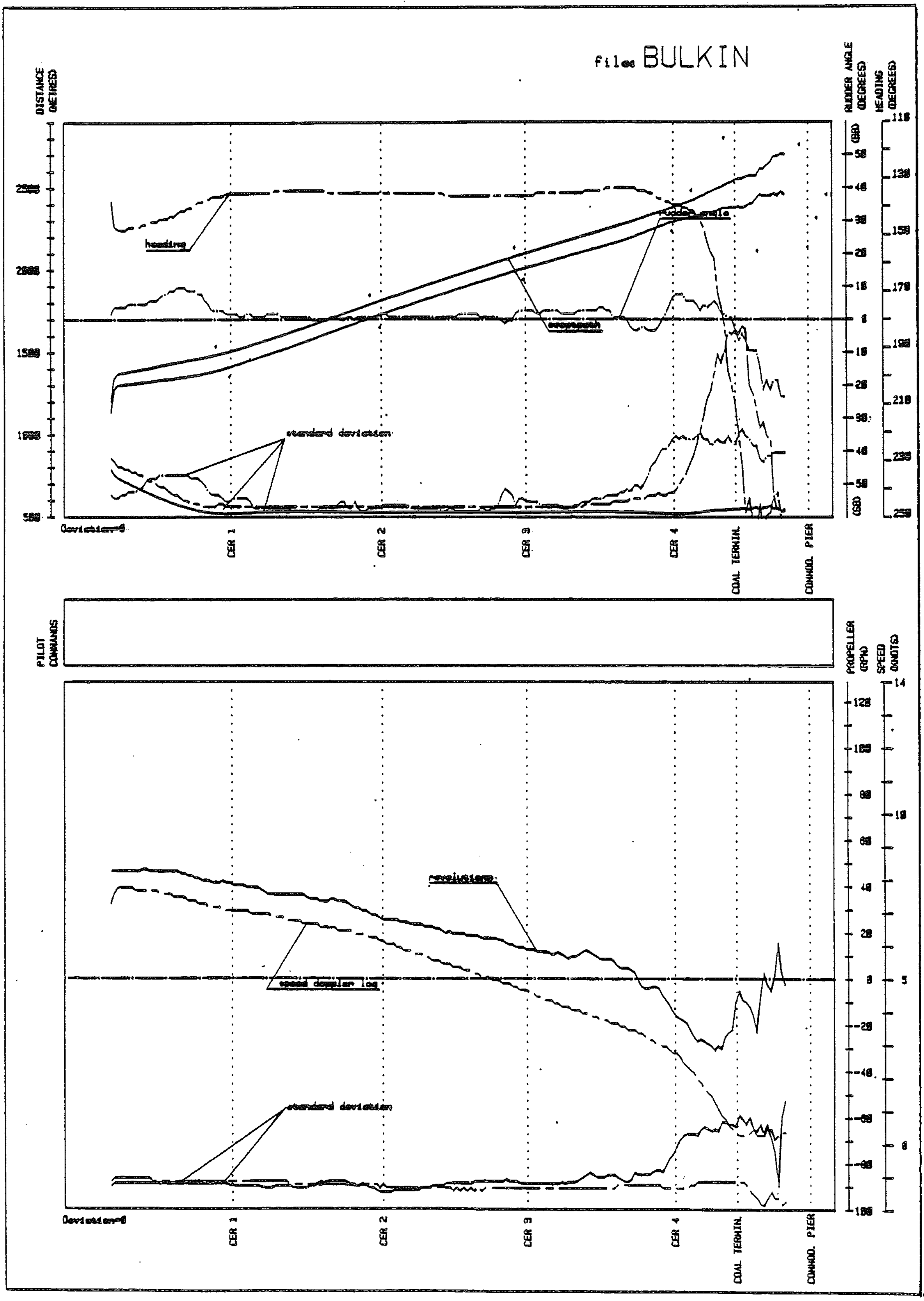


Fig 6.2.: Manoeuvre parameters and trial results. Coal carrier entry.

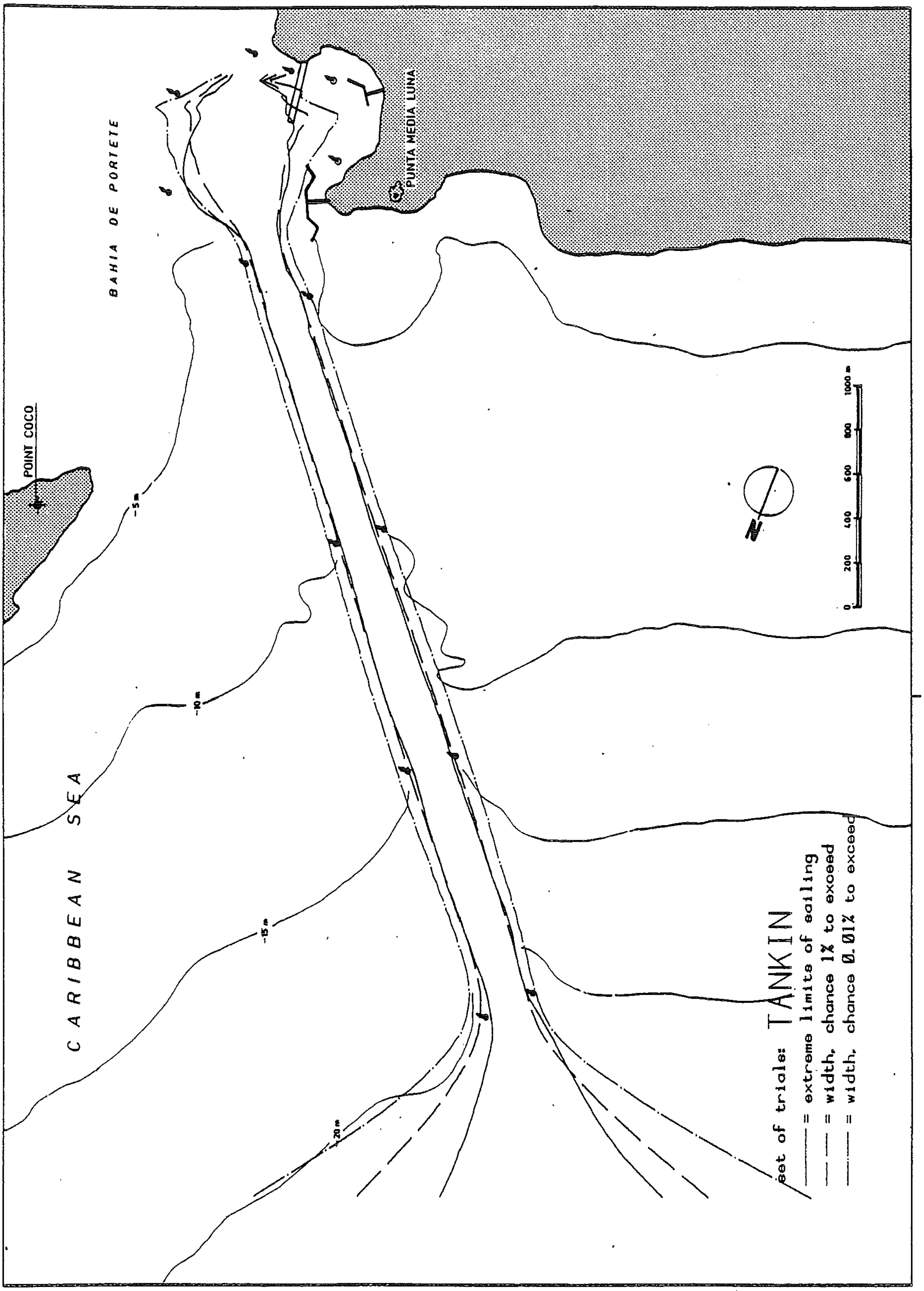


Fig 6.3.: Exceedance frequency lines. Entering tanker.

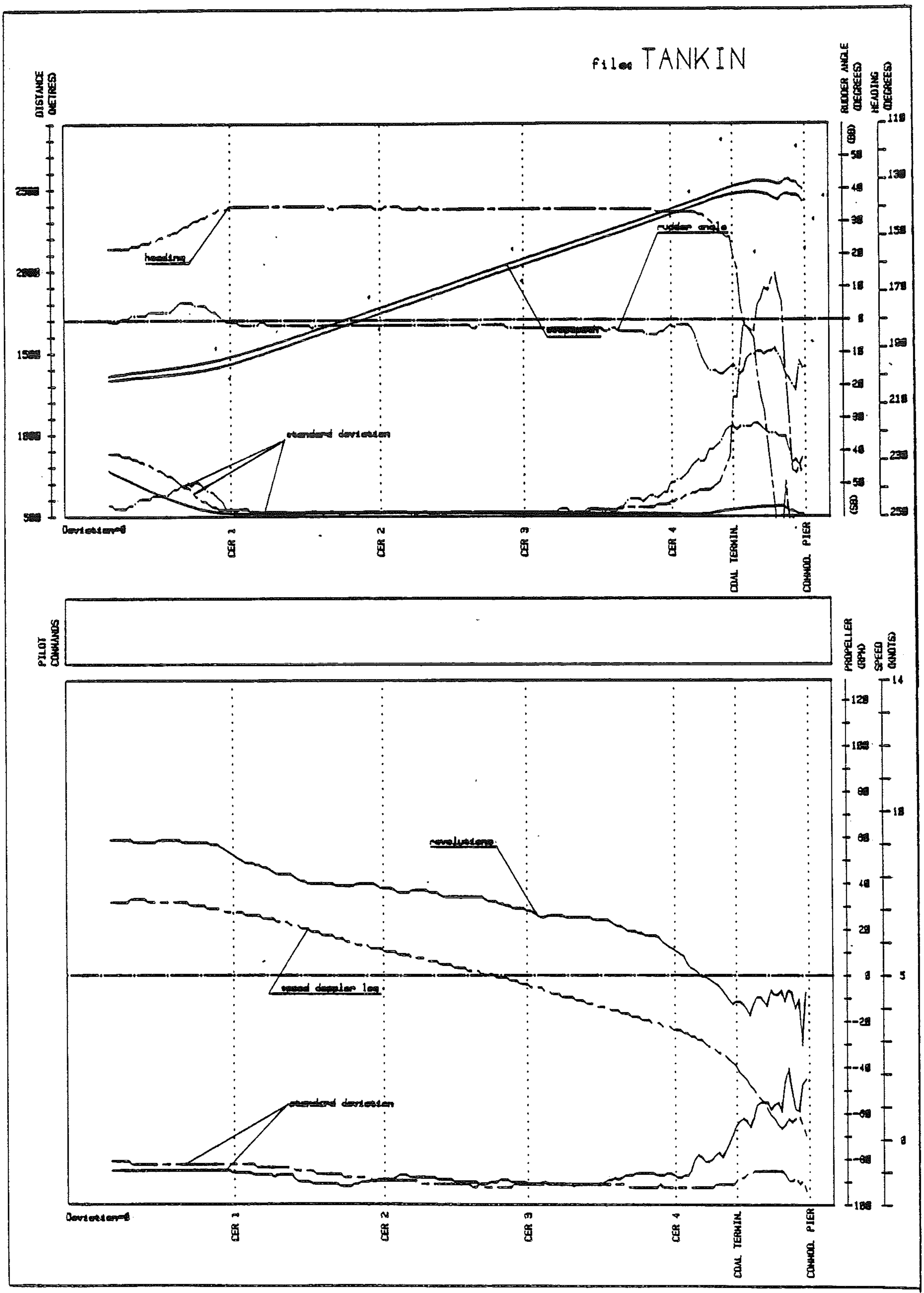


Fig 6.4.: Manoeuvre parameters and trial results. Tanker entry.

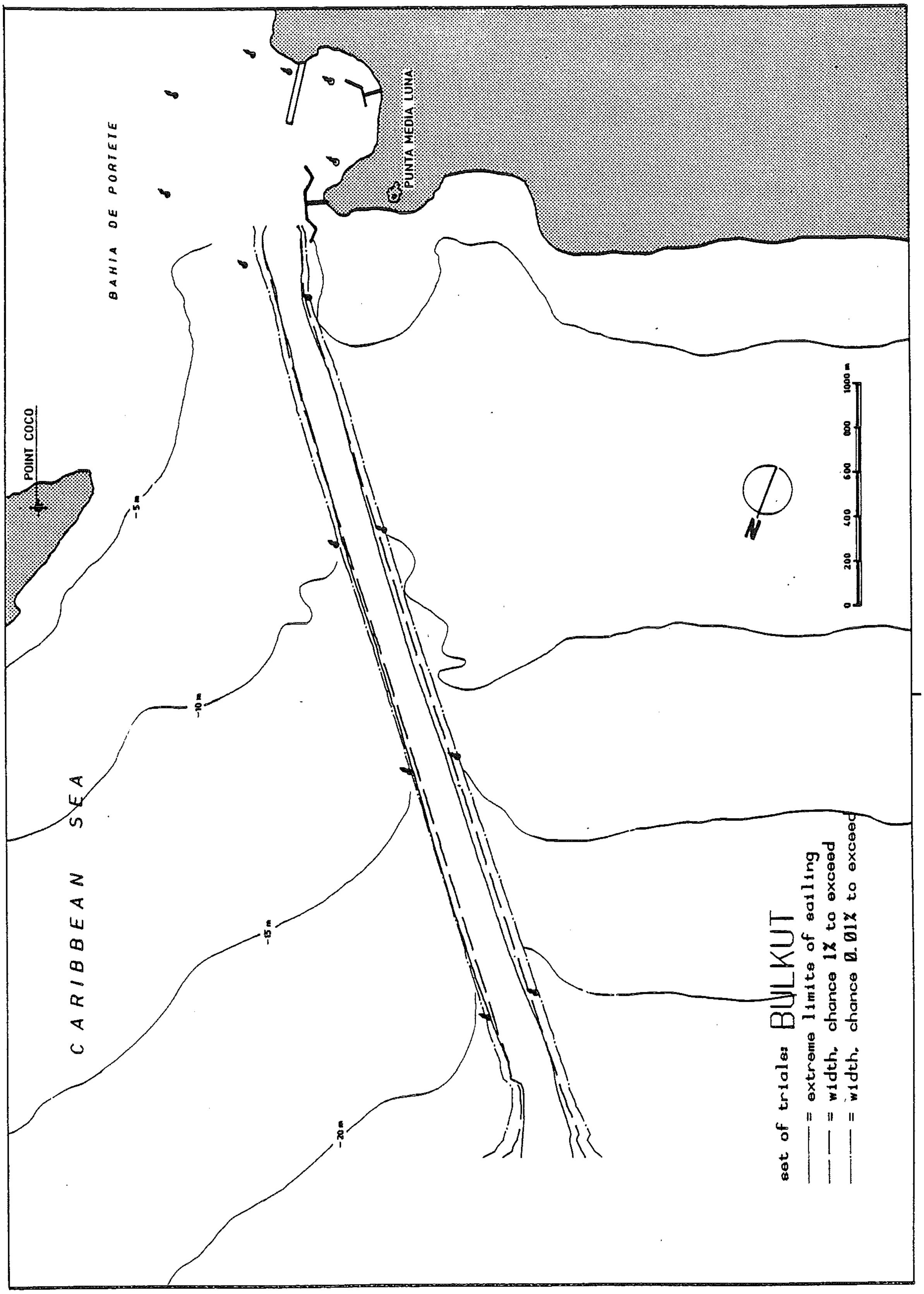


Fig 6.5.: Exceedance frequency lines. Leaving coal carrier.

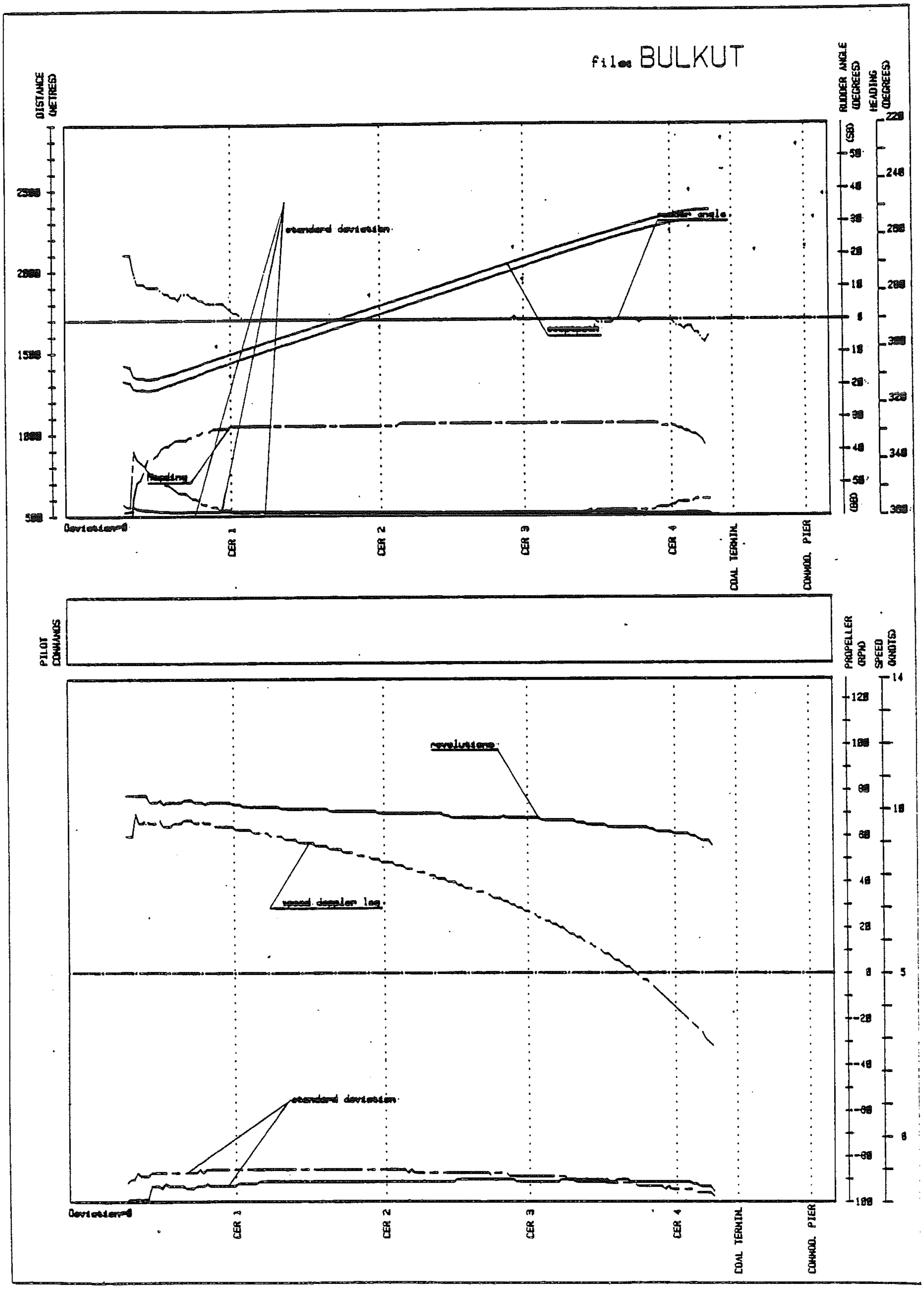


Fig 6.6.: Manoeuvre parameters and trial results. Coal carrier leaving.

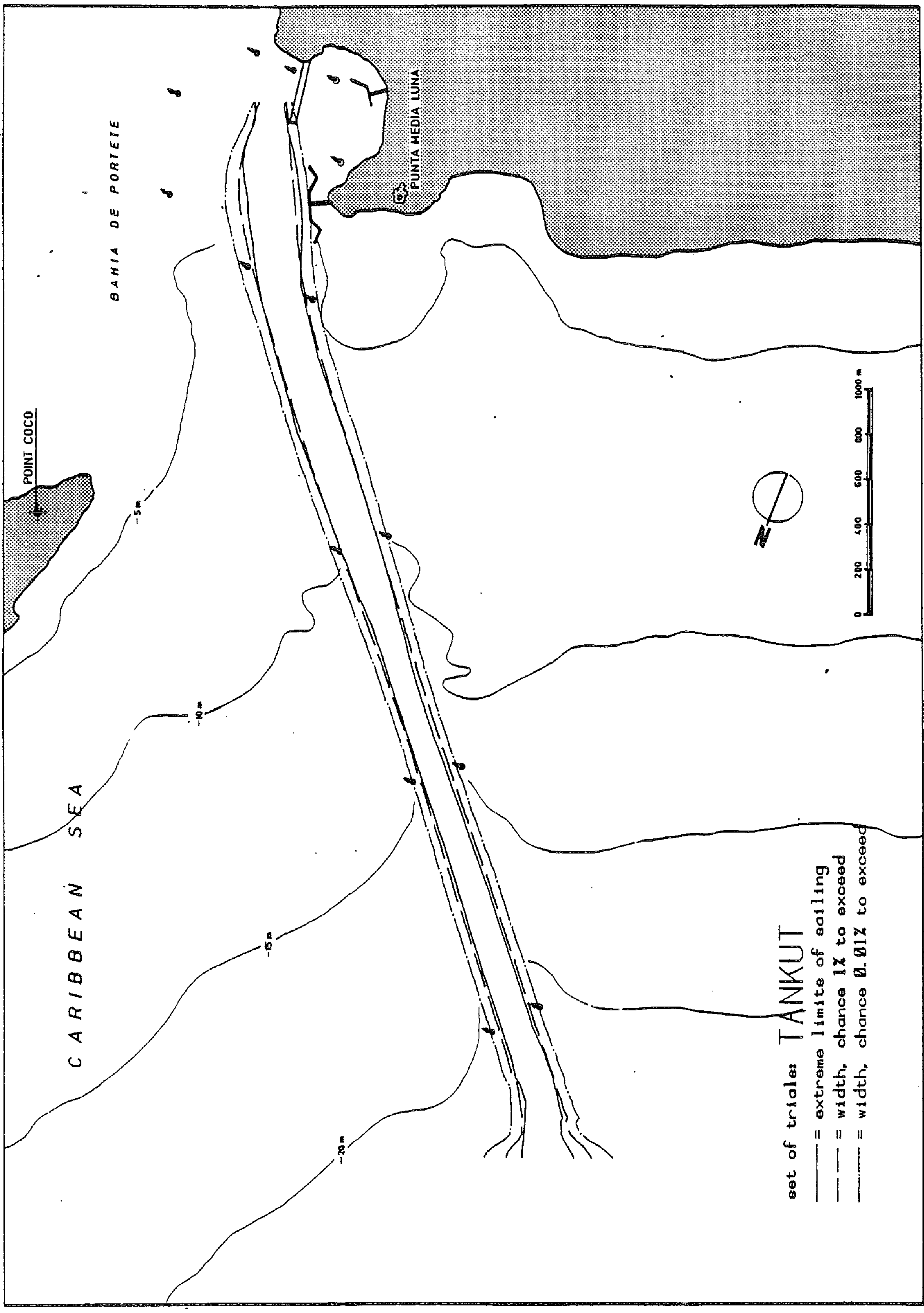


Fig 6.7.: Exceedance frequency lines. Leaving tanker.

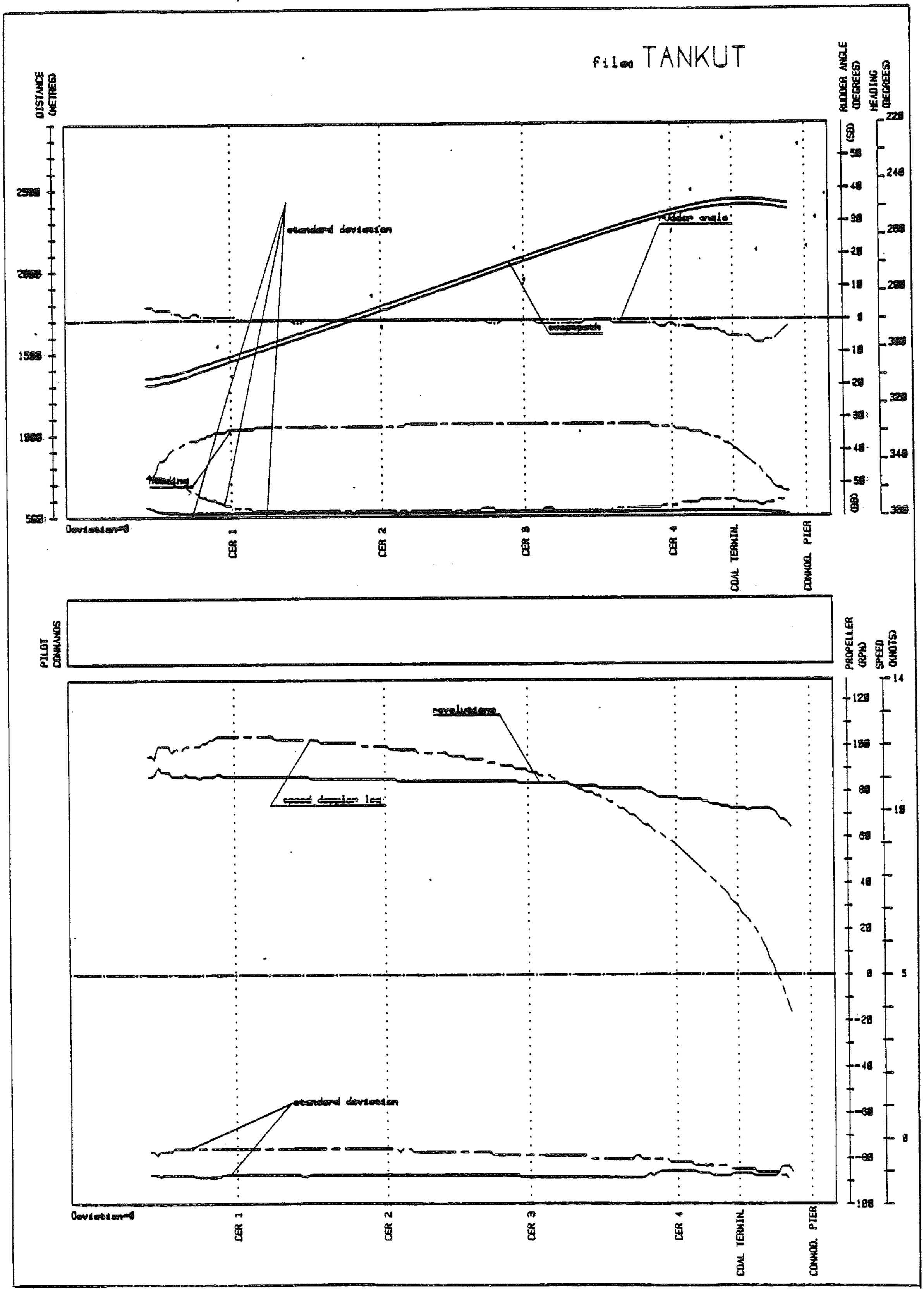


Fig 6.8.: Manoeuvre parameters and trial results.
Tanker leaving.

In annex 2 the numerical data of these plots are summarized. Some representative cross sections can be found with the following x-direction co-ordinates for the buoys:

buoy:	CER1	x-dir.: 1200
	CER2	2275
	CER3	3310
	CER4	4375
	coal terminal	4800
	commodities pier	5325

From the figures it can be seen that the entering manoeuvres give more difficulty than the leaving manoeuvres, and that the entering coal carrier needs more space than the entering tanker.
The solid line gives an idea of the difficulty, especially for the entering coal carrier, where every buoy at the south side of the channel has had to be avoided at least once in the trails by a special manoeuvre (hard starboard followed by hard port to keep the stern free of the buoy).
The figures even indicate that the 1 and 0.01 per cent values are beyond the channel borders, but this means little as the statistical methods play a role here: it is still a limited test carried out at random.

6.2. Required Channel Width

Since the test is still a limited sample, it would be irresponsible to make a definite decision over the required channel width.
It is only possible to test with such a limited sample whether a certain channel width is sufficient. Consequently what has been tested in this case is whether the channel width of 225 m is sufficient.

Based upon statistical Sample theory the minimum and maximum safe channel borders have been determined. As regards the space between these minimum and maximum channel borders, the assumption that the channel will be wide enough is still just valid (the assumption is 95 per cent reliable).
These minimum and maximum channel borders are obtained as follows:

The average of a complete statistical population can be determined from a limited sample by:

$$u = m \pm (t * s)/\sqrt{n}$$

where: u average of the complete population
m average of the limited sample

- t statistical t-type distribution ($t=2.00$ for a sample of 54 manoeuvres and $t=2.05$ for a sample of 27 manoeuvres)
- s standard deviation of sample
- n number of manoeuvres included in sample (54 or 27)

The standard deviation of the population can be determined from a statistical s/σ - distribution, where σ is the standard deviation of the complete population.

For the sample of 54 <u>entering</u> manoeuvres: $u = m \pm 0.272 * s$ and $0.834\ s < \sigma < 1.16\ s$; both u and σ are determined by the average and standard deviation of the sample.

The exceedance frequency of 0.01 per cent, which was considered as completely safe, is obtained for a value of $u + 3.50 * \sigma$.

The minimum values for the safe channel borders can then be determined by taking the value:

$$m - 0.272 * s + 3.5 \times 0.834 * s = m + 2.647 * s$$

In the same way the maximum values for the safe channel borders can be determined by taking:

$$m + 0.272 * s + 3.50 * 1.16 * s = m + 4.332 * s$$

In the figures 6.9 and 6.10 the reliability area, limited by the minimum and maximum value for safe channel borders, is indicated for both sides of the channel for the entering of the coal carrier and the tanker, respectively. Also indicated is the channel bottom as proposed at present.
As soon as the proposed channel's borders go beyond the reliability area, the proposed channel is too wide. If the borders do not reach the reliability area, the proposed channel is not wide enough. If the borders are in the releability area, the channel is well designed.
The method used by Hydronamic is to design the width of the channel so that the bottom borders coincide with those of the minimum safe channel border. The extra space between the buoyed channel and the point on the slope of the channel where a ship is liable to ground, forms a safety margin that almost coincides with the reliability area (chapter 6.3).

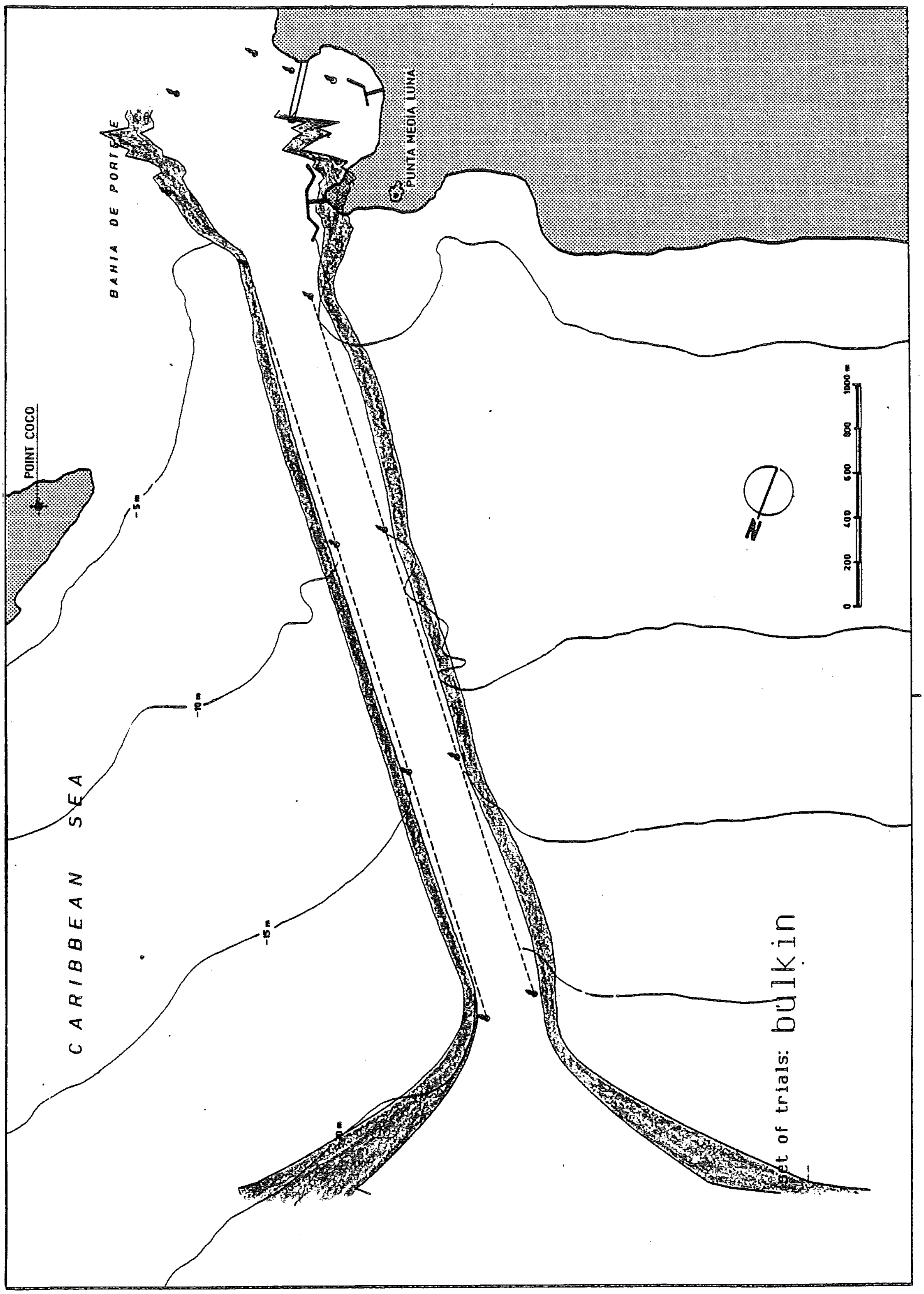


Fig 6.9.: Reliability area. Entering coal carrier

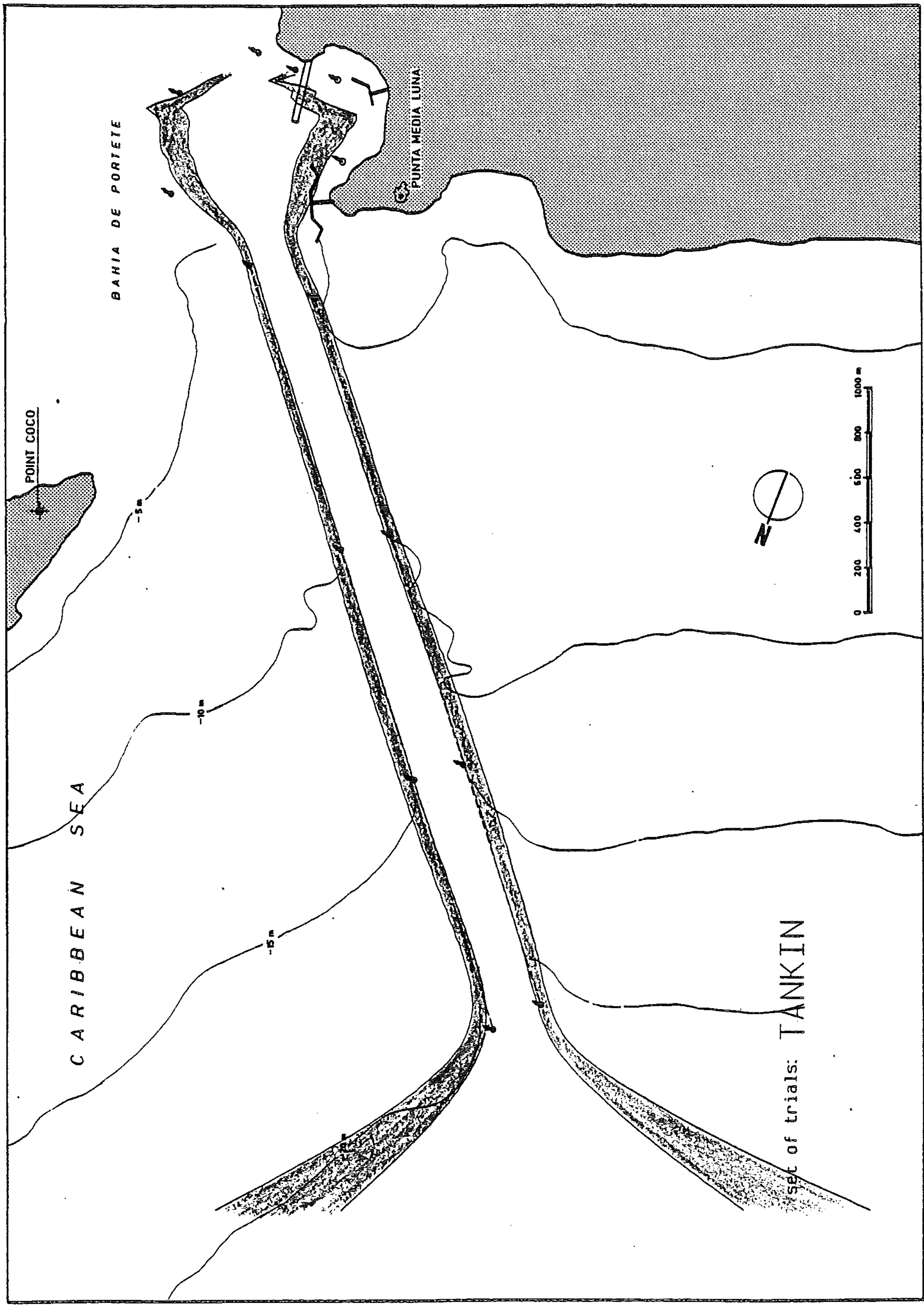


Fig 6.10.: Reliability area. Entering tanker.

In the same way the minimum and maximum safe channel border can be determined for the sample of 27 leaving manoeuvres.
The minimum safe channel border:

$$m - 0.395 * s + 3.50 * 0.770 * s = m + 2.30 * s$$

and the maximum safe channel border:

$$m + 0.395 * s + 3.50 * 1.22 * s = m + 4.67 * s$$

It should be clear from the above that the larger the sample, the closer together the two lines of the reliability area can be.

In the figures 6.11 and 6.12, the reliability area is indicated for the outbound manoeuvres for both sides of the channel.

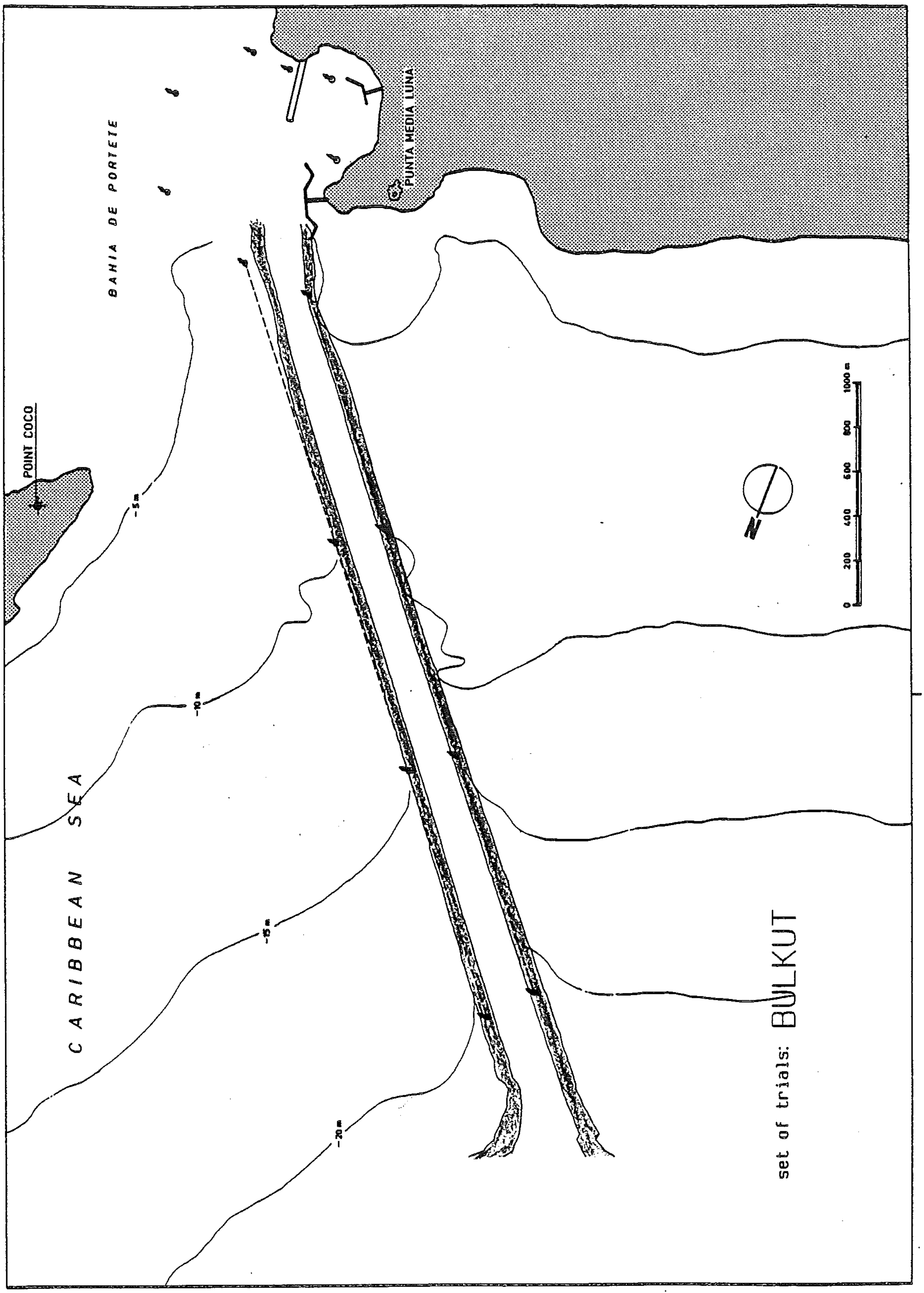


Fig 6.11.: Reliability area. Leaving coal carrier.

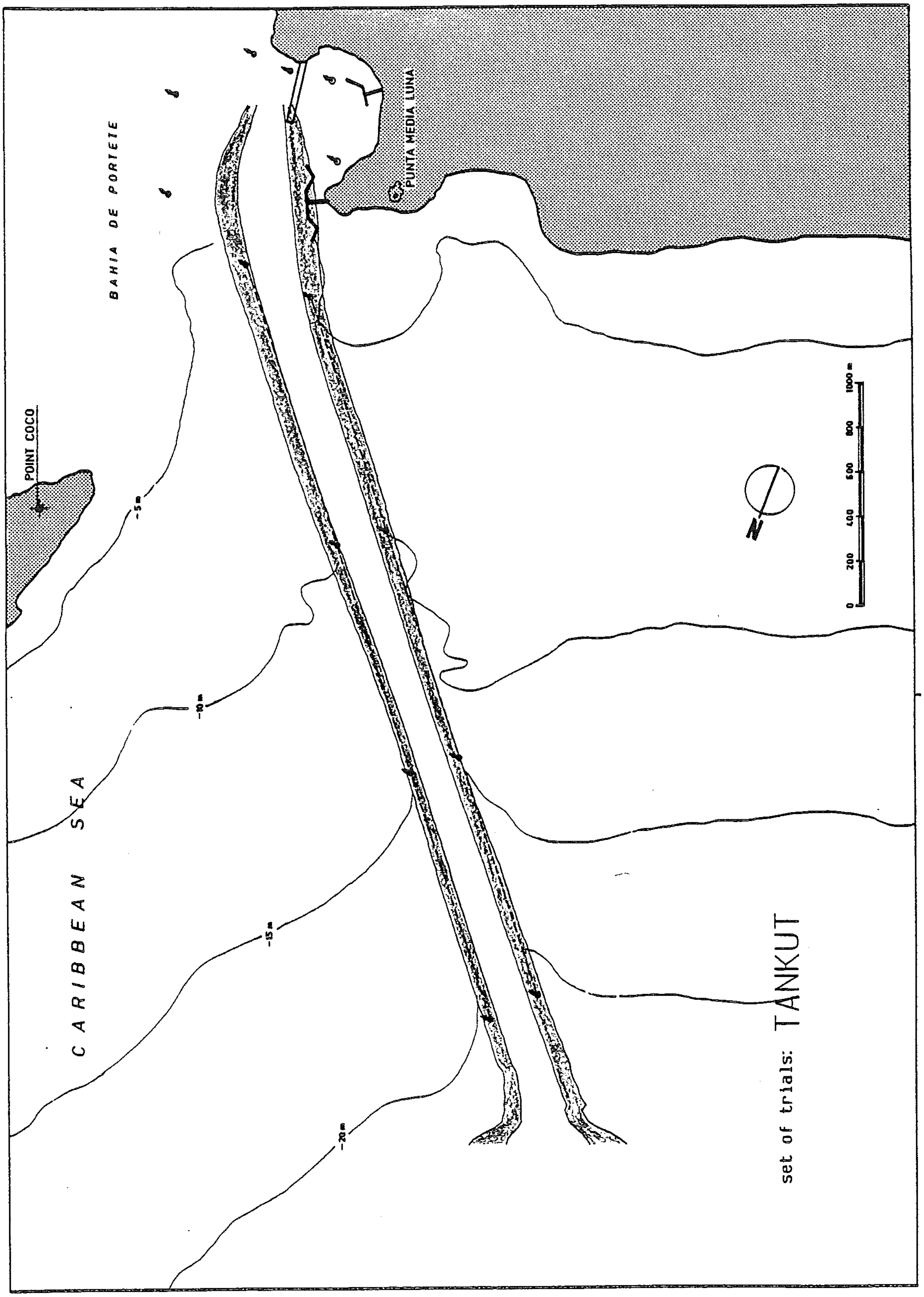


Fig 6.12.; Reliability area. Leaving tanker.

6.3. Chance of Grounding

The ballasted coal carrier has the highest chance of exceeding the borders of the buoyed channel. Therefore, somewhat more attention is paid to the chances of this type of ship grounding. 'Buoyed channel' has been written to indicate the delimitation of the channel bottom. The channel border can be defined as the line on the slope that is at the same depth as the draught of a certain ship.

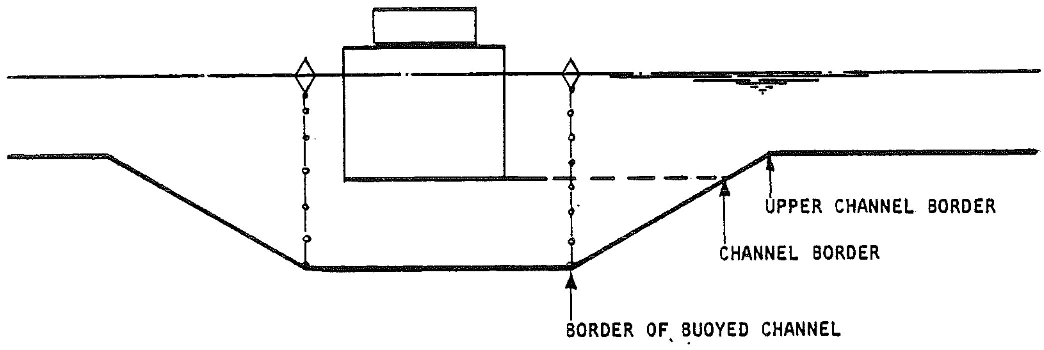


Fig 6.13.: Nomenclature of borders

When ship's stern or bow goes beyond the borders of the buoyed channel, a stranding will not be the immediate result. The space between the border of the buoyed channel and the place of stranding is determined by the keel clearance of the ship and the slope of the channel.

M-K. drawing 31661A-D4203 indicates two types of slope at the south side of the channel viz. 1:6 and 1:2.5. In the 'middle reach' of the channel (from CER3 buoy to CER4 buoy) the planned channel depth is 20 m. The draught of the ballasted coal carrier is 8.7 m. The keel clearance of 11.3 m give a space for the two slopes before a stranding occurs of about 67 and 28 m, respectively.

The 'middle reach' is an area of interest only for the ballasted coal carrier because the water depth at the upper channel border (see fig, 6.9) is less than 9 m. An actual stranding can occur.

Fig 6.9 shows a distance between the border of the buoyed channel and those of minimum safe channel border of 88 m (mid of CER3 - CER4) and 58 m near the CER4 buoy. This is indicated by the line of the reliability area which is closest to the line of buoys (minimum safe channel border).

The conclusion would be, that the chance of grounding is higher than the proposed 10 - 15 % (chapter 6.1) and that the planned 'middle reach' is not wide enough for ballasted coal carriers of 150,000 dwt.

It is possible that the high chance of groundings is enlarged by strong wind or current. To have an idea of the influence of wind on the ballasted coal carrier, we have made a statistical analysis for the three separate wind speeds (10, 20 and 30 knots). Please note that this statistical analysis is based upon a sample taken at random from the complete population (see also chapter 6.2). The results are shown in the figures below.

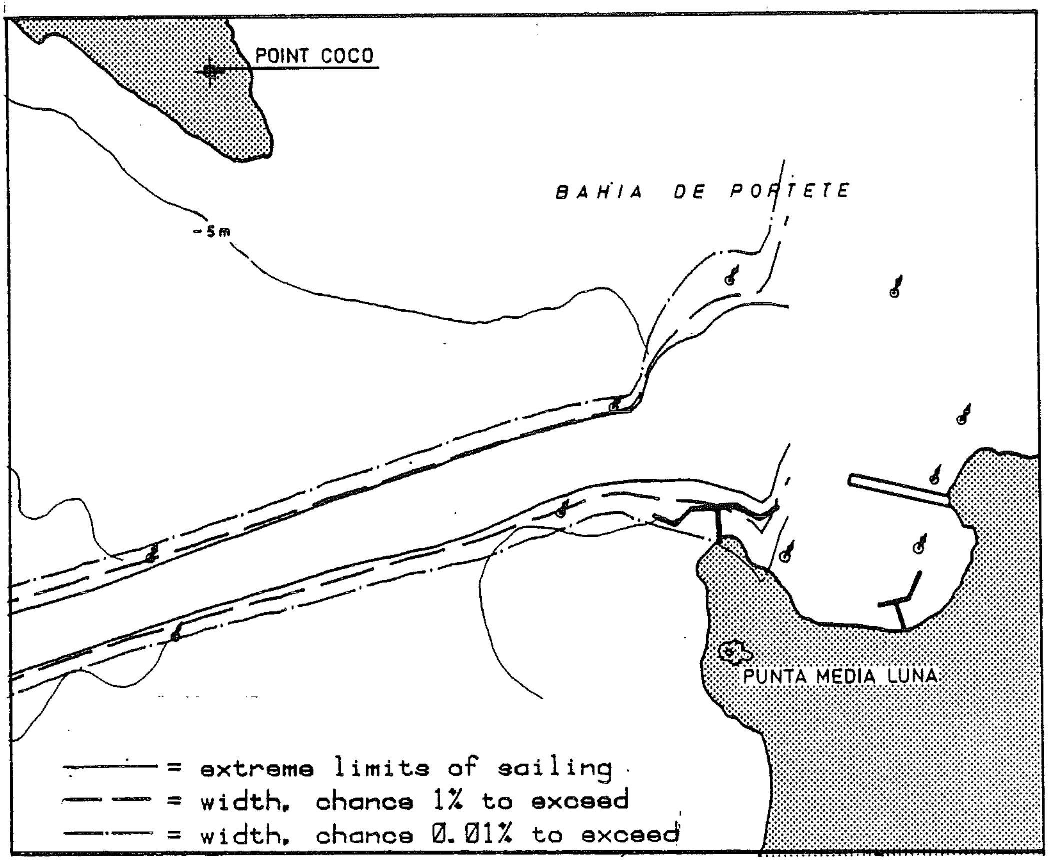


Fig 6.14.: Exceedance frequency lines. Entering coal carrier 10 knot wind.

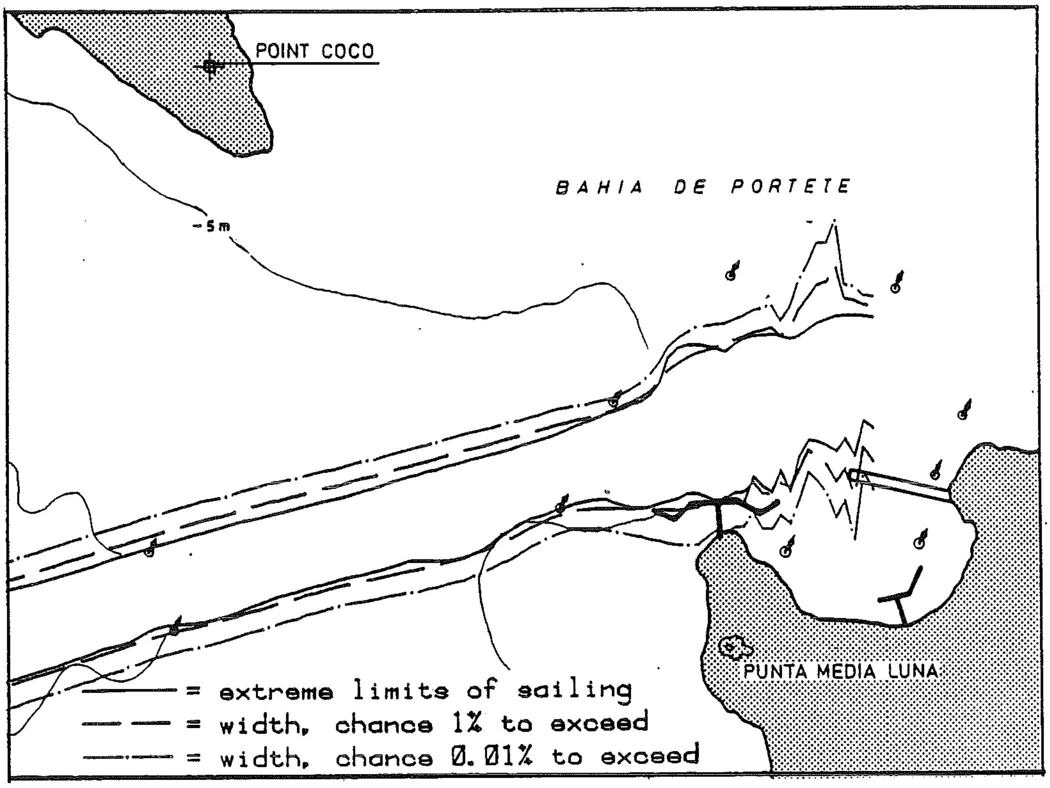
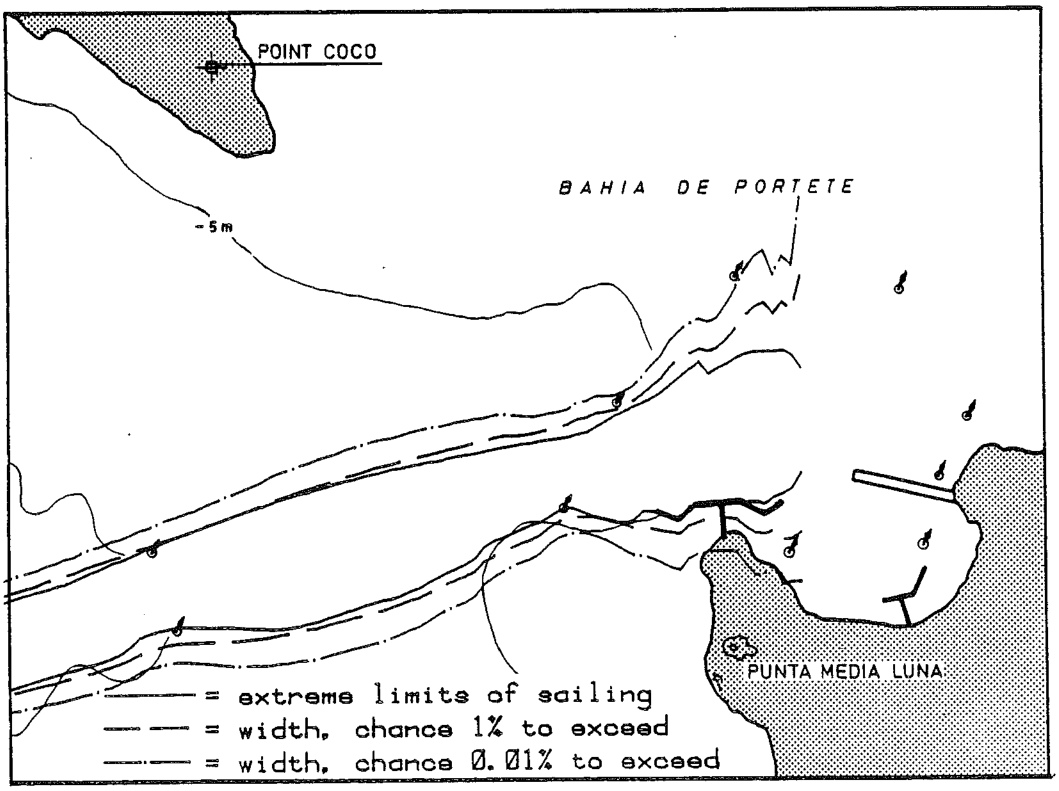


Fig 6.15.: Exceedance frequency lines. Entering coal carrier 20 knot wind.

Fig 6.16.: Exceedance frequency lines. Entering coal carrier 30 knot wind.



It is clear from the figures that the trials, executed in a 30 knot wind, contribute a more important amount to the high frequency of exceedance than the trials, executed in a 20 knot wind.

At the end of the channel just before the turning basin, the ship's speed is low, the wind force is strong and a great drift angle is necessary to keep the ship in the channel.
This effect is strengthend when the CER3 buoy has already been passed with the special manoeuvre earlier described. In a wind force of 30 knots the figures show that this will give real difficulties. An additional study with a position information system, followed by a training can solve this problem.

6.4. Concluding Remarks Concerning Required Channel Width

- Fig. 6.9 shows that the proposed channel borders do not reach the reliability area, over the whole length of the channel. This means that the buoyed channel is not wide enough for the entering coal carrier.

- In the 'middle reach' occurs a higher chance of grounding than the proposed 10 - 15 %.

- It is difficult to keep the coal carrier's stern free of the buoys (south side of the channel).
  This is shown by the shape of the reliability area which bends towards the proposed channel border just before every buoy (fig. 6.9). Just beyond the buoy the shape curves away. Each pair of buoys form a narrowing which can only be passed by a special manoeuvre.

- The buoy CER5 is the only buoy which lies in the reliability area, but the coal terminal itself lies in between the two reliability areas. The terminal is therefore not safe enough with this shape of turning basin.
  We think that this can be improved by repositioning buoy CER5 about 50 m to the north east. (See also pilots' comments)

- Fig. 6.10 shows that the buoyed channel is wide enough for the entrance of the laden 25000 dwt tanker, with the exception of the pair of buoys CER1

- It is possible to pass the first pair of buoys but it is difficult. This is shown by the widening of the reliability areas near the CER2 buoys.

- The pilots found it easy to enter with the laden tanker because there was enough room. (See chapter 4. Pilots' comments).

The statistical analysis on the contrary shows that all space was used. The manoeuvre has been executed apparently less carefully, because there was enough space.

- Fig. 6.10 also shows that the north corner of the commodities pier is unsafe.
  The turning manoeuvre has been carried out very close to this corner whereas enough space was available. Possibly it was done to prevent the distance between ship and pier becoming too great and thus needing time to bring the ship back.

- The total space in the planned turning basin is sufficient.

- The planned width of the buoyed channel is enough for the leaving coal carrier (Fig. 6.11)

- The reliability area is small. This indicates little deviation from the execution of trials.

- Fig. 6.12 shows a designed channel wide enough for the leaving ballasted tanker.

- The reliability area is somewhat wider for the leaving tanker than for the leaving coal carrier. In general, the ballasted ships show more deviation in the execution of manoeuvres, shown by the greater drift angles which are necessary in the turns (See also fig. 6.1, 6.3, 6.5 and 6.7).

7. CONCLUSIONS AND FINAL RECOMMENDATIONS

7.1. Conclusions

The following points form the concluding remarks concerning the width of the channel, size of the turning circle and the use of tugs:

- For an entering laden tanker, the leaving laden coal carrier and ballasted tanker is the channel safe and 'adequately designed'. There is in the lifetime of the channel (estimated at 15 years) a chance lower than 10-15 per cent that these ships will exceed the buoyed channel border.

- The proposed channel width is not safe for the entering ballasted coal carrier.
  The chance that during the lifetime of the channel a coal carrier will have a collision with a buoy (exceed the buoyed border) is higher than permitted.
  There is even a chance, higher than permitted, of an actual grounding

- The effect of the wind prevails over the effect of the current. In the last stage of the berthing manoeuvre of the coal carrier (bringing the ship right into her berth) the current affects the manoeuvre perceptibly.

- The dimensions of the turning basin are wide enough to carry out the stopping and turning manoeuvre for the coal carrier and tanker under all the circumstances investigated. But the size had better changed.

- The position of the CER5-buoy forces the manoeuvres too much to the south.

- The tugs are used mostly to swing the ship around. All available power is then used.
  Only when the coal carrier has to be stopped to her berth in a 30 knot wind, is the total tugpower (3 time 40 ton bollard pull) hardly enough.

- Sometimes the pilots use the tugs to reduce the drift angle. For the tugs' power to be really effective, it is necessary to reduce the forwards speed to 3 knots.
  But the ship is then more susceptible to changes in wind and current.
  The ship's position becomes unstable and the pilot finds it difficult to give the tugs the correct orders for keeping the ship in line with the leading lights.

7.2. Recommendations

The following recommendations can be made:

- Increase the distance between the CER1-buoys. Then a smoother entrance can be made.

- Change the shape of the turning circle by repositioning the CER5 buoy more to the north-east. The figure below contains the recommended lay-out of the channel and turning circle.

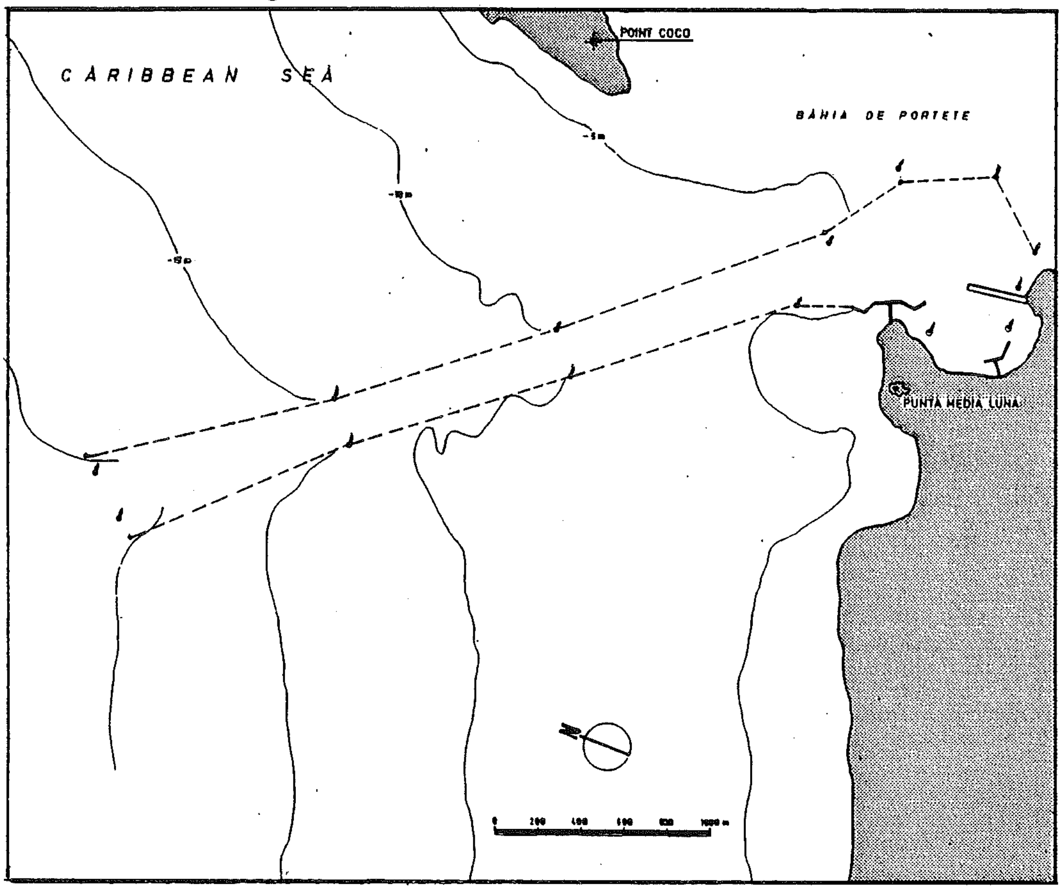


Fig. 7.1.: Recommended shape of channel and turning circle.

- The entering manoeuvre with the coal-carrier can be carried out safely in a wind force up to 20 knots.

- It is necessary to optimize the entrance manoeuvres or to say it in other words, the manoeuvre must be carried out more exactly. For this the pilot needs more information and/or training.

We envisage using two different methods, or a combination of both, to optimize the entrance manoeuvres:

1. Install a position information system and train the pilots in using this new system.

2. Study and train with local pilots the best method of sailing through the channel, and stopping and turning.
For example: the pilot can sail faster through the channel, which reduces the drift angle and the ship therefore needs less space. But the unsolved question is how fast can the pilot sail and stop the ship safely, taking into account eventual engine and/or rudder failure and tug ropes breaking?

ANNEX 1

ANNEX 1: THE SHIP MANOEUVRING SIMULATOR

The ship manoeuvring simulator can be divided into two parts. Part one contains the calculation model and part two the instrumentation necessary for control and visualization. The basis of the calculation model is a mathematical ship. 2) To sail the ship to every position we want, helm and machine orders have to be given. When the new orders have been given, the computer calculates in time steps the new position of the ship, the new heading, speed in transverse and in longitudinal direction and the rate of turn. The ship we use in the simulator is defined by a file with the characteristics for acceleration, turning speed, effective of rudder, propulsion force depending on engine revolutions and so on.
The program uses the characteristics from the file it needs at that moment.

When ships new information has been observed by the pilot, new commands can be given. The computer calculates in a new time step, the following position.

The way in which the positions and other necessary information is presented (visualisation) and what kind of method is used for the input of new commands (to run), depends of the purposes for which the simulator is being employed.
The photo below shows the portable trainingsimulator, installed in the pilot station of Zeebrugge in Belgium. For the visualisation of ship's position in the entrance channel or in the harbour, we use in this case a bird eye view, reproduced on a grafic display.

2) The mathematical background of this model was described in a paper given at the International Harbour Congress, Antwerp 1978. (A. Burgers, A Mathematical Model for calculating the Harbour Entrance Manoeuvre).

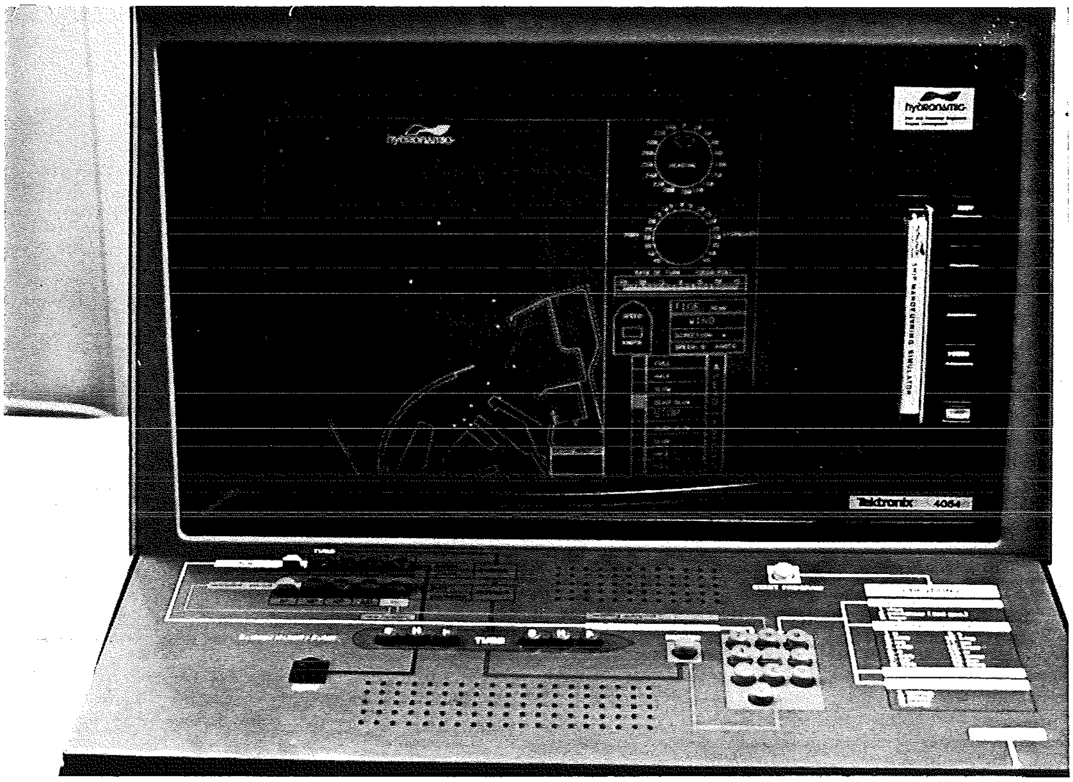


Fig 1.: Ship manoeuvring simulator with horizontal representative (portable type)

The calculation model described up to now is reproduced in the following diagram:

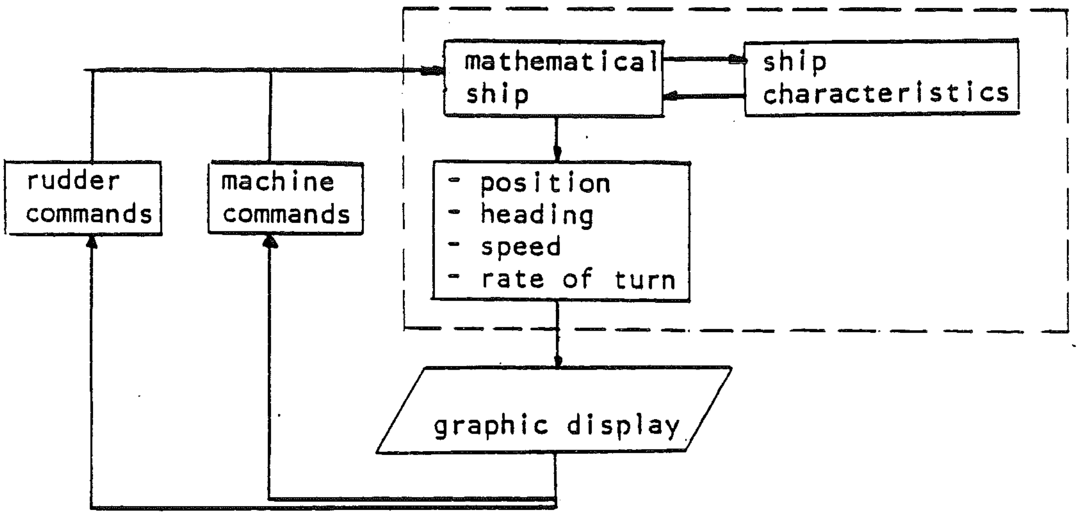


Fig. 2.: Basis scheme of calculation method

The ship's position is always influenced by external circumstances.
Wind, current, waves and bottom profile (under keel-clearance) influence the ship's position, speed and course. Therefore it is necessary to work these influences into the programme. The forces effected by wind, current, waves, etc. are determined also by the ship's dimensions and her form.

Dimensions and form are translated into coefficients and put in the file of the ship's characteristics.

The current can either be calculated by a mathematical current or tidal model, or measured in an extensive measuring campaign (at each meshpoint the velocity has to be measured during an average tide).
The currents are entered into the calculation process via a file where the current data for grid are stored. The water depths at the different points of the grid system are also stored in this file.
At each location the ship selects the right current and water depth data from then on hydrodynamic equations describing the ship's path are constantly solved (once a second). In this way not only is the average current acting on the ship taken into account, but also current moments caused by a gradient in the current.
These current gradients can cause considerable turning of the ship and are therefore very important.

If the pilot wants to give course instead of rudder commands, he uses the autopilot which means that the ship automatically remains on the given course by using the rudder.
The ship in the mathematical model behaves just like a ship in actual practice.
The simulator described up to now is called the training simulator.
The figure below shows it in diagrammatic form:

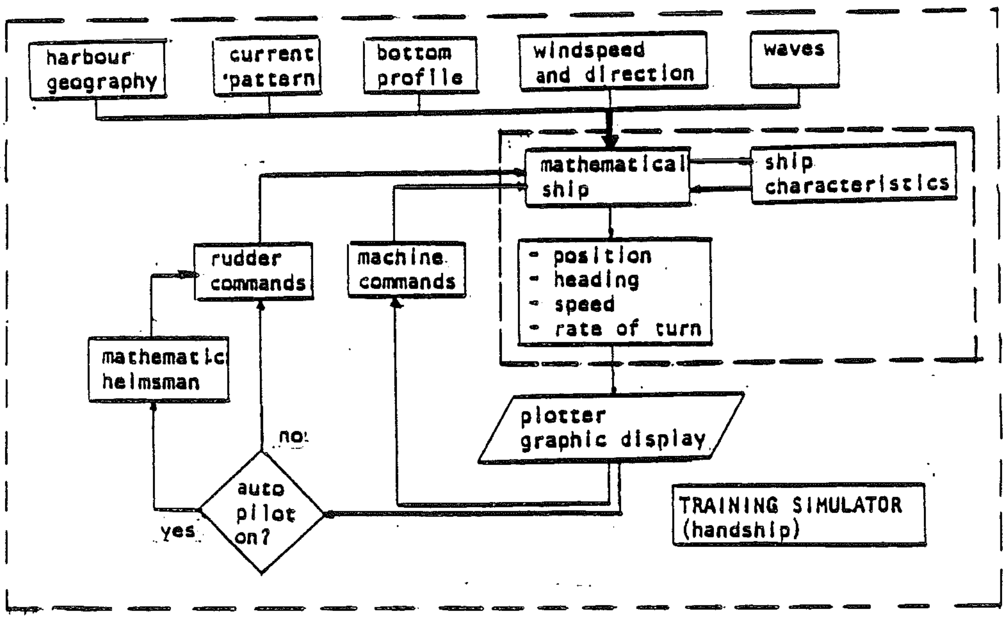


Fig. 3.: Schematization of the training simulator

To complete, the facilities offered by our simulator, we are able to couple three extensions on the 'Training simulator' viz.:

- a unit for tug assistance,
- a unit for manoeuvring analysis,
- a unit for port design optimisation.

The pilot can choose when to use the tugs by adjusting the pulling angle relative to the ship and the pulling force. Changing a tug's pulling angle and force takes time, and the same applies to propeller RPM and rudder angle. This is also simulated.

For making a statistical analysis of certain types of manoeuvre, a number of manoeuvres is made by different pilots. The unit for manoeuvring analysis collects data from every manoeuvre. When the manoeuvres are finished, the analysis starts and provides the results, such as average figures for ship's path, heading, speed, revolutions of the propeller, but also the standard deviation and a so-called swept path.
A swepth path is the space between the two lines formed by the outermost points of the sailing ship.
Especially when the entering manoeuvres are carried out in a cross current, the swept path gives more information about the width used than the path of the ship's centre of gravity. (The navigator of a ship sailing in a cross current adjusts her course, to compensate for the drift caused by the cross current).

In using the unit for port design optimisation, the human influences are excluded. This is necessary since different physical conditions can be compared only if the pilot reacts always in the same way.
Therefore we designed a method, based on the principle of constant human reaction and interpretation under all circumstances. The ship sails along so-called pilot line, a predesigned ideal path. A steering automaton with a certain adjustment steers the ship as well as possible along the pilot line. Even small differences in current appear or other physical conditions now in the form of different use of rudder and in another distance from the pilot line.

The total capacity of Hydronamic's manoeuvring simulator is showed in the following diagram:

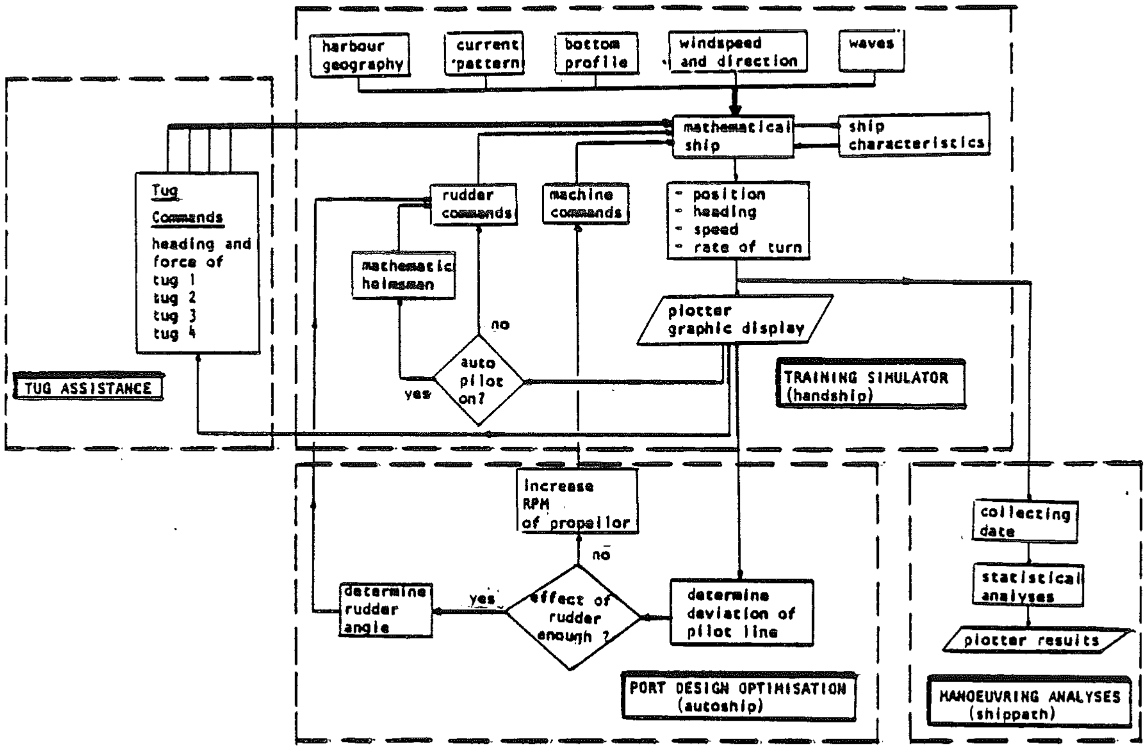


Fig. 4.: Schematization of Hydronamic's shipmanoeuvring simulator

The emphasis when developing the calculation model lay very much on correct representation of the physical/mathematical behaviour of the ship in its surroundings. Right from the start the model has been extensively tested and updated with the aid of prototype measurements.
Before a new ship type is entered into the data file of the model, it is calibrated in the model with the aid of prototype data.

There are two versions of the model available. The first provides the pilot with a horizontal image (radar type), enabling him to watch the reactions of his ship as if he were an outsider (figure 1).
This version of the simulator is implemented on a Tektronix 4054 micro-computer which can be installed wherever the client wishes. It can be used for training purposes, for example.

The second version of the simulator supplies the pilot with the image he would see in reality from the bridge of the ship. When he is navigating in a channel, therefore, he watches himself

manoeuvring past the buoys (Chapter 2.1). When a button is pressed, the outside display changes to a radar display.
This version of the simulator is implemented via input/output units on Hydronamic's HP 3000 computer, and is therefore not transportable.

The version on the HP-3000 computer was used here however, since it is more suitable for purposes of study and design, when it is often necessary to make a lot of plots, for instance of the ship's path, the applied rudder angles and propeller RPM, the courses sailed and the applied tug forces.

ANNEX 2

HYDRONAMAC BV
PORT AND WATERWAY ENGINEERS
SLIEDRECHT HOLLAND

SHIP MANOEUVRING SIMULATOR
RESULTS OF STATISTICAL ANALYSIS

FILE: BULKIN

CONSTANT PARAMETERS:

SHIP TYPE(S) : Coal carrier in ballast condition
CHANNEL WIDTH : 225 M.
WIND SPEED : 10, 20 and 30 knots
WIND DIRECTION: north to north-east
CURRENT : normal spring tide, flood, ebb and slack.

THE FOLLOWING TRIAL NUMBERS (TOTAL 54 TRIALS) ARE TAKEN INTO ACCOUNT:
23 38 140 2 30 58 66 100 126 127 154 167 6 84 108 141 145 196 47 190
197 3 7 16 40 59 73 83 128 129 48 94 114 155 187 191 101 130 174 17
36 60 74 102 115 118 146 170 20 51 103 142 178 198

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
X-dir [m]	SWEPTPATH north-side		SWEPTPATH south-side		Heading [degr]		Speed [knots]		Propeller [RPM]		Rudder [degr]		Ships-Centre [off LL]		Max.Distance [off LL]		Path width		Channel bounder exc.frequency	
	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	north	south	1%	.01%	north	south
350	1295	339	1223	315	138	21	7.3	.9	48	11	-2	7	-48	327	535	368	1519	2388	34.77	6.04
375	1451	305	1374	287	147	20	7.6	1.0	48	12	-4	6	91	296	519	350	1386	2171	52.06	7.04
400	1484	279	1406	263	148	18	7.8	1.0	48	12	-4	6	114	271	502	334	1275	1993	55.78	2.42
425	1489	267	1409	250	148	18	7.8	1.0	48	12	-4	7	110	258	484	321	1223	1909	55.61	1.90
450	1494	255	1412	238	148	17	7.8	1.0	48	12	-4	7	107	246	468	306	1172	1826	55.39	1.35
475	1498	243	1415	226	147	17	7.8	1.0	48	12	-5	8	102	235	451	292	1121	1744	55.11	.81
500	1503	232	1417	214	147	16	7.8	1.0	48	12	-5	8	98	223	434	280	1071	1664	54.76	.21
525	1507	221	1420	202	147	16	7.7	1.0	48	12	-5	8	94	212	418	267	1022	1584	54.40	9.53
550	1512	210	1423	191	147	15	7.7	1.0	48	12	-5	9	90	200	402	254	974	1507	53.99	8.84
575	1516	200	1426	179	146	15	7.7	1.0	49	12	-5	9	86	189	387	240	927	1430	53.51	8.11
600	1521	189	1429	168	146	14	7.7	1.0	49	12	-5	11	82	178	371	229	880	1354	52.98	7.29
625	1525	179	1432	157	145	13	7.7	1.0	48	12	-6	12	78	167	356	218	834	1279	52.45	6.40
650	1530	168	1435	146	145	13	7.7	.9	48	12	-6	12	75	157	341	209	789	1206	51.87	5.45
675	1535	158	1438	136	145	12	7.7	.9	48	12	-6	12	71	147	326	198	745	1135	51.23	4.55
700	1540	148	1441	126	144	11	7.6	.9	48	12	-7	13	67	136	312	187	702	1066	50.50	3.56
725	1545	138	1444	116	144	11	7.6	.9	48	12	-8	13	63	127	297	178	660	998	49.61	2.53
750	1549	129	1446	107	144	10	7.6	.9	48	12	-8	13	59	117	283	170	620	932	48.58	1.42
775	1554	120	1449	97	143	9	7.6	.9	48	12	-9	13	55	108	268	161	581	869	47.44	.26
800	1559	111	1452	88	143	8	7.5	.9	48	12	-9	13	51	99	255	152	543	807	45.98	8.95
825	1563	103	1455	79	142	8	7.5	.9	48	12	-10	13	47	90	242	143	508	750	44.34	7.65
850	1567	96	1458	71	141	7	7.5	.9	47	12	-10	13	43	82	228	135	473	694	42.43	6.24
875	1572	89	1461	63	141	6	7.5	.9	47	12	-10	13	39	75	214	130	441	642	40.27	4.90
900	1576	82	1465	56	140	6	7.4	.9	46	12	-9	13	35	68	201	124	411	593	37.81	3.69
925	1580	75	1469	49	140	5	7.4	.9	46	12	-9	12	32	61	189	116	383	548	35.03	2.60
950	1585	69	1472	43	139	5	7.4	.9	45	12	-9	12	28	55	176	109	357	507	31.96	1.80
975	1589	64	1477	39	138	5	7.3	.9	45	12	-8	12	24	49	164	105	335	471	28.58	1.22

****
* SHIP MANOEUVRING SIMULATOR *
* RESULTS OF STATISTICAL ANALYSIS *
****

FILE: BULKIN (CONTINUED)

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
X-dir [m]	SWEPTPATH north-side av	dev	south-side av	dev	Heading [degr] av	dev	Speed [knots] av	dev	Propeller [RPM] av	dev	Rudder [degr] av	dev	Ships-Centre [off LL] av	dev	Max.Distance [off LL] north	south	Path width 1%	.01%	Channel bounder exc.frequency north	south
1000	1594	59	1481	35	138	4	7.3	.9	44	12	-8	11	21	44	153	99	315	440	24.96	.86
1025	1598	54	1486	33	137	4	7.3	.9	44	12	-6	10	18	40	140	95	299	414	21.22	.67
1050	1603	50	1492	31	137	4	7.2	.9	44	12	-5	8	16	37	130	92	286	393	17.67	.62
1075	1608	46	1497	31	136	4	7.2	.9	43	12	-3	7	13	34	120	90	275	377	14.17	.68
1100	1613	42	1503	31	136	4	7.2	.9	43	12	-3	7	11	32	114	91	267	364	11.11	.81
1125	1619	39	1510	31	136	5	7.2	.9	43	12	-3	7	9	30	109	94	261	355	8.48	1.03
1150	1624	37	1516	33	136	5	7.1	.9	44	12	-3	6	7	29	106	96	257	349	6.33	1.38
1175	1631	35	1523	34	135	4	7.1	.9	43	12	-2	5	6	29	102	97	253	344	4.63	1.77
1200	1637	33	1530	35	135	4	7.1	.9	43	11	-2	5	5	29	100	99	252	342	3.50	2.25
1225	1643	32	1537	36	135	4	7.1	.9	42	11	-2	6	4	30	98	107	251	341	2.67	2.78
1250	1650	31	1545	38	135	4	7.1	.9	42	11	-2	6	3	30	101	115	252	342	2.12	3.39
1275	1657	30	1553	39	135	4	7.1	.9	42	11	-1	6	2	31	105	125	253	345	1.77	4.10
1300	1664	30	1560	41	135	4	7.1	.9	42	11	-1	6	2	33	109	134	256	351	1.64	4.83
1325	1671	31	1568	43	135	4	7.1	.9	41	11	-2	6	1	34	113	143	261	358	1.69	5.59
1350	1679	31	1576	45	135	4	7.0	.9	41	11	-2	5	1	36	115	151	266	366	1.78	6.45
1375	1686	32	1583	46	135	4	7.0	.9	41	11	-1	3	1	37	116	160	271	374	1.84	7.30
1400	1693	32	1591	48	135	4	7.0	.9	41	11	-1	3	0	39	119	166	276	383	1.98	8.14
1425	1701	33	1599	49	135	4	7.0	.9	40	10	-1	3	0	40	121	169	279	388	2.12	8.59
1450	1709	33	1607	50	135	4	7.0	.9	39	10	-1	3	0	41	123	172	282	393	2.23	9.01
1475	1716	34	1615	51	135	4	7.0	.9	38	10	-2	3	0	41	125	171	284	397	2.37	9.26
1500	1724	35	1622	51	135	4	6.9	.9	38	10	-2	3	-1	42	126	171	287	401	2.57	9.47
1525	1731	36	1630	51	134	4	6.9	.9	38	11	-2	3	-1	42	127	171	288	403	2.74	9.55
1550	1739	36	1638	51	134	4	6.9	.9	38	11	-2	3	-1	43	127	172	289	405	2.82	9.60
1575	1747	36	1646	51	134	4	6.9	.9	38	11	-1	3	-1	43	128	174	290	406	2.91	9.60
1600	1755	37	1654	51	134	4	6.8	.9	38	11	-1	3	-1	43	128	176	290	407	3.00	9.54
1625	1763	37	1662	51	134	4	6.8	.8	38	11	-1	3	-1	43	128	179	290	407	3.07	9.45
1650	1771	37	1671	51	134	4	6.8	.8	38	10	-1	2	-1	43	128	180	291	407	3.16	9.35
1675	1779	37	1679	51	134	4	6.8	.8	38	10	-1	2	0	44	126	181	291	408	3.26	9.20
1700	1787	37	1687	51	134	4	6.8	.8	38	10	-1	2	0	44	124	182	290	407	3.28	9.01
1725	1795	37	1696	51	134	4	6.7	.8	38	10	-1	2	0	44	124	181	290	408	3.39	8.84
1750	1803	38	1704	51	134	4	6.7	.8	37	10	-1	2	1	43	124	180	289	406	3.52	8.43
1775	1811	38	1713	50	134	4	6.7	.8	36	11	-1	2	1	43	124	178	289	406	3.72	8.16
1800	1819	38	1722	50	134	4	6.7	.8	36	11	0	2	2	43	125	176	288	404	3.77	7.72
1825	1828	38	1730	49	134	4	6.7	.8	36	12	0	2	2	43	125	173	286	402	3.81	7.32
1850	1836	38	1739	49	134	4	6.6	.8	35	13	0	3	3	43	124	169	284	399	3.88	6.89
1875	1844	38	1748	48	134	4	6.6	.8	35	12	0	3	3	42	124	161	283	398	4.06	6.46
1900	1853	38	1756	48	135	4	6.6	.8	35	13	0	3	4	42	123	155	282	395	4.10	6.05
1925	1861	38	1765	47	135	4	6.6	.8	36	13	-1	3	5	42	123	149	280	392	4.18	5.62
1950	1870	38	1774	46	135	4	6.6	.8	36	13	-1	3	5	41	123	142	277	389	4.24	5.15
1975	1878	37	1783	46	135	4	6.5	.8	35	13	-1	4	6	41	122	132	275	385	4.28	4.68

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* SHIP MANOEUVRING SIMULATOR *
* RESULTS OF STATISTICAL ANALYSIS *
****

FILE: BULKIN (CONTINUED)

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
X-dir [m]	SWEPTPATH north-side av	north-side dev	south-side av	south-side dev	Heading [degr] av	dev	Speed [knots] av	dev	Propeller [RPM] av	dev	Rudder [degr] av	dev	Ships-Centre [off LL] av	dev	Max.Distance [off LL] north	south	Path width 1%	.01%	Channel bounder exc.frequency north	south
2000	1886	37	1791	45	135	4	6.5	.8	35	13	0	5	6	40	121	122	272	381	4.32	4.22
2025	1895	37	1800	44	135	4	6.5	.8	35	13	0	5	7	40	121	114	270	377	4.34	3.77
2050	1903	37	1809	43	135	4	6.5	.8	34	12	-1	3	8	39	120	114	267	374	4.42	3.40
2075	1911	37	1817	42	135	4	6.5	.8	33	11	-1	3	8	39	118	113	265	370	4.42	3.07
2100	1920	36	1826	42	135	4	6.4	.8	32	11	0	5	9	38	117	111	264	368	4.51	2.81
2125	1928	36	1834	41	135	4	6.4	.8	32	11	-1	3	9	38	115	108	261	363	4.56	2.43
2150	1937	36	1843	40	135	4	6.4	.8	31	12	-1	2	10	37	113	106	258	359	4.52	2.15
2175	1945	36	1851	39	135	4	6.4	.8	31	11	-1	2	10	37	112	106	256	355	4.49	1.90
2200	1953	36	1860	39	135	4	6.3	.8	30	10	-1	3	11	36	111	106	255	354	4.56	1.77
2225	1962	35	1868	39	135	4	6.3	.8	29	10	-1	3	11	36	111	106	254	352	4.60	1.65
2250	1970	35	1876	39	135	4	6.3	.8	29	9	-1	3	11	36	112	107	254	353	4.74	1.63
2275	1979	35	1884	39	135	4	6.2	.7	28	8	-2	3	12	36	112	106	254	352	4.75	1.60
2300	1987	35	1892	39	135	4	6.2	.8	27	8	-2	4	12	36	111	106	254	352	4.78	1.64
2325	1995	35	1901	39	135	4	6.1	.7	27	8	-2	4	12	36	110	107	255	353	4.85	1.66
2350	2004	35	1909	40	135	4	6.1	.7	27	8	-1	4	12	36	109	108	256	354	4.88	1.76
2375	2012	35	1917	40	135	4	6.1	.7	27	9	-1	4	13	37	110	110	257	356	4.92	1.89
2400	2020	35	1925	41	135	4	6.0	.7	27	9	-1	4	13	37	110	114	259	359	5.08	2.02
2425	2028	35	1933	42	135	4	6.0	.7	26	9	-1	4	13	37	111	119	261	362	5.30	2.18
2450	2037	35	1941	42	135	4	5.9	.7	26	9	-1	4	13	38	113	124	262	365	5.43	2.30
2475	2045	35	1949	43	135	4	5.9	.7	26	9	-1	4	14	38	115	128	263	366	5.50	2.39
2500	2053	35	1957	43	135	4	5.9	.7	25	9	-1	3	14	38	117	132	264	368	5.62	2.47
2525	2061	35	1965	43	135	4	5.8	.7	25	9	-1	3	14	38	120	135	266	370	5.84	2.51
2550	2070	35	1973	44	135	4	5.8	.7	25	9	-1	3	15	38	122	136	267	371	6.04	2.54
2575	2078	35	1981	44	135	4	5.8	.7	25	10	-1	3	15	38	122	134	266	371	5.99	2.57
2600	2086	35	1990	44	135	4	5.7	.7	24	10	-1	3	15	38	123	134	267	371	5.99	2.58
2625	2094	35	1998	44	135	4	5.7	.7	24	10	-1	3	15	38	124	133	266	371	5.97	2.57
2650	2102	34	2006	44	135	4	5.6	.7	24	11	-1	3	15	38	125	133	266	370	5.88	2.61
2675	2110	34	2014	44	135	4	5.6	.7	23	11	-1	3	15	38	125	132	266	370	5.88	2.61
2700	2118	34	2022	44	135	4	5.6	.7	23	11	-1	3	15	38	126	131	266	369	5.81	2.59
2725	2126	34	2029	44	135	4	5.5	.7	22	11	-1	2	15	38	126	130	266	369	5.80	2.60
2750	2135	34	2037	44	136	4	5.5	.7	21	12	-1	2	15	38	128	127	265	369	5.89	2.54
2775	2142	34	2045	44	136	4	5.5	.7	22	12	-1	3	16	38	128	127	265	369	5.87	2.55
2800	2150	34	2053	44	136	4	5.4	.6	21	12	-1	3	15	38	129	126	265	368	5.84	2.51
2825	2158	34	2061	44	136	4	5.4	.7	21	12	-1	2	15	38	128	126	265	368	5.82	2.51
2850	2166	34	2069	44	136	4	5.4	.6	21	12	-2	2	15	38	127	125	265	368	5.83	2.55
2875	2174	34	2076	43	136	4	5.3	.7	21	12	-2	2	15	38	126	125	265	368	5.77	2.54
2900	2182	34	2084	44	136	4	5.3	.6	20	12	-2	2	15	38	124	125	265	369	5.80	2.61
2925	2190	34	2091	44	136	4	5.3	.7	20	12	-2	2	15	38	123	125	266	369	5.84	2.68
2950	2197	34	2099	44	136	4	5.2	.6	20	13	-2	2	14	38	121	126	267	370	5.84	2.77
2975	2205	34	2106	44	136	4	5.2	.7	20	13	-2	2	14	38	121	127	268	372	5.86	2.92

SHIP MANOEUVRING SIMULATOR
RESULTS OF STATISTICAL ANALYSIS

FILE: BULKIN (CONTINUED)

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
X-dir [m]	SWEPTPATH north-side av	dev	south-side av	dev	Heading [degr] av	dev	Speed [knots] av	dev	Propeller [RPM] av	dev	Rudder [degr] av	dev	Ships-Centre [off LL] av	dev	Max.Distance [off LL] north	south	Path width 1%	.01%	Channel bounder exc.frequency north	south
3000	2213	35	2114	44	136	4	5.1	.6	19	13	-1	3	14	38	121	127	269	373	5.93	3.00
3025	2221	35	2121	44	136	4	5.1	.7	19	13	-1	3	13	38	120	128	269	374	5.95	3.02
3050	2228	35	2128	44	136	4	5.1	.7	19	13	-1	2	13	38	119	129	270	375	5.93	3.13
3075	2236	35	2136	44	136	4	5.0	.7	19	13	-1	3	12	39	120	130	271	376	5.95	3.23
3100	2243	35	2143	44	136	4	5.0	.7	19	13	-1	3	12	39	120	130	271	376	5.92	3.27
3125	2251	36	2150	43	136	4	5.0	.7	18	13	-1	4	12	39	121	129	271	376	5.95	3.30
3150	2258	36	2158	43	136	4	4.9	.7	18	13	0	7	11	38	121	124	270	374	5.87	3.17
3175	2266	36	2166	42	136	4	4.9	.7	17	14	1	9	11	38	121	114	269	373	5.90	2.99
3200	2273	36	2173	41	136	4	4.9	.7	16	13	0	8	11	37	121	99	266	369	5.84	2.65
3225	2281	36	2181	40	136	4	4.8	.7	16	13	0	7	10	37	123	97	265	367	5.79	2.50
3250	2288	37	2188	40	136	4	4.8	.7	15	13	-2	4	10	37	125	98	266	367	5.75	2.56
3275	2296	37	2195	40	136	4	4.7	.7	15	12	-3	6	9	37	128	100	266	368	5.62	2.74
3300	2303	37	2202	41	136	4	4.7	.7	15	12	-3	6	8	38	129	102	269	372	5.60	3.10
3325	2311	37	2208	41	136	4	4.7	.7	14	12	-3	5	7	38	130	111	272	376	5.54	3.58
3350	2318	37	2215	42	136	4	4.6	.7	14	12	-3	5	6	39	131	120	275	381	5.42	4.23
3375	2325	37	2221	43	136	4	4.6	.7	14	12	-3	5	5	39	133	129	278	385	5.32	4.92
3400	2332	38	2228	44	135	4	4.5	.7	13	12	-2	5	4	40	135	136	281	390	5.21	5.64
3425	2340	38	2234	45	135	4	4.5	.7	13	12	-2	4	3	40	136	142	285	395	5.18	6.41
3450	2347	38	2241	46	135	4	4.4	.7	13	12	-3	4	2	41	137	152	288	400	5.11	7.14
3475	2354	39	2247	47	135	4	4.4	.7	13	12	-3	4	1	41	138	161	291	405	5.12	7.82
3500	2361	39	2254	47	135	4	4.4	.7	12	12	-3	4	0	42	137	170	294	408	5.04	8.46
3525	2368	40	2261	48	135	4	4.3	.7	12	12	-3	4	-1	42	137	178	296	412	5.00	9.05
3550	2375	40	2268	48	135	4	4.3	.7	13	12	-3	4	-2	43	138	187	299	416	5.00	9.74
3575	2382	40	2275	49	135	4	4.2	.7	12	13	-2	3	-3	43	139	192	300	419	4.87	.36
3600	2389	41	2281	49	135	4	4.2	.7	11	12	-2	3	-3	43	139	197	301	420	4.77	.82
3625	2397	41	2288	49	135	4	4.2	.7	10	13	-2	3	-4	43	139	200	302	421	4.62	1.23
3650	2404	41	2296	49	135	4	4.1	.7	11	13	-2	4	-5	43	137	201	303	422	4.46	1.71
3675	2411	41	2302	49	135	4	4.1	.7	11	13	-2	4	-6	44	137	203	304	423	4.38	2.17
3700	2418	41	2309	49	135	4	4.1	.7	12	14	-3	4	-7	44	136	202	304	424	4.24	2.57
3725	2426	41	2316	50	135	4	4.0	.7	13	15	-3	5	-7	44	136	202	305	425	4.07	3.17
3750	2433	41	2323	50	134	5	4.0	.7	14	16	-3	5	-8	44	135	202	306	426	3.87	3.83
3775	2440	41	2329	50	134	5	4.0	.7	13	17	-3	5	-9	44	132	202	306	427	3.75	4.43
3800	2447	41	2336	50	134	5	3.9	.7	12	16	-3	6	-10	44	131	201	307	427	3.48	5.18
3825	2454	40	2343	51	134	5	3.9	.7	11	15	-3	6	-11	44	130	201	308	429	3.34	6.02
3850	2461	40	2349	51	134	5	3.8	.7	10	15	-4	6	-13	44	128	202	309	430	3.15	6.89
3875	2468	40	2355	51	134	5	3.8	.7	10	15	-4	6	-14	44	126	205	310	431	2.97	7.70
3900	2476	40	2362	51	133	5	3.8	.7	10	16	-3	7	-14	44	123	204	310	431	2.83	8.26
3925	2483	40	2369	51	133	5	3.7	.7	10	16	-3	7	-15	44	121	201	310	430	2.68	8.72
3950	2490	40	2376	51	133	6	3.7	.7	9	16	-1	7	-16	44	119	200	310	431	2.55	9.35
3975	2497	40	2383	50	133	6	3.7	.8	7	15	-1	7	-17	43	116	193	308	428	2.38	9.43

SHIP MANOEUVRING SIMULATOR
RESULTS OF STATISTICAL ANALYSIS

FILE: BULKIN (CONTINUED)

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
X-dir [m]	SWEPTPATH north-side av	dev	south-side av	dev	Heading [degr] av	dev	Speed [knots] av	dev	Propeller [RPN] av	dev	Rudder [degr] av	dev	Ships-Centre [off LL] av	dev	Max.Distance [off LL] north	south	Path width 1%	.01%	Channel bounder exc.frequency north	south
4000	2504	39	2391	50	133	6	3.6	.8	6	14	-1	8	-17	43	111	188	306	424	2.15	9.26
4025	2511	39	2399	49	133	6	3.6	.8	6	13	-1	8	-18	43	112	184	304	421	2.05	9.08
4050	2519	39	2407	49	133	6	3.5	.8	6	13	0	9	-18	42	114	180	302	419	1.95	8.90
4075	2526	39	2415	49	133	7	3.5	.8	5	14	2	8	-18	42	114	178	301	417	1.75	8.81
4100	2534	38	2424	49	133	7	3.5	.8	4	17	3	10	-18	41	114	169	297	412	1.59	8.22
4125	2542	37	2434	46	134	7	3.4	.8	1	16	3	10	-17	40	114	156	289	400	1.44	5.93
4150	2550	37	2443	45	134	7	3.4	.8	-2	16	2	9	-16	39	115	148	283	392	1.33	4.40
4175	2558	36	2452	44	134	7	3.3	.8	-3	16	2	11	-15	38	116	138	278	383	1.16	3.16
4200	2566	34	2462	43	135	8	3.2	.8	-3	16	3	13	-14	37	116	136	271	374	.89	2.20
4225	2575	32	2471	43	135	8	3.2	.8	-2	17	3	16	-14	36	114	133	266	365	.66	1.35
4250	2583	31	2480	42	136	8	3.1	.8	-2	18	3	17	-13	35	115	129	260	358	.54	.21
4275	2591	31	2490	41	137	9	3.1	.8	-3	18	2	19	-12	34	114	131	256	352	.49	9.14
4300	2599	30	2500	39	137	8	3.0	.7	-6	17	0	21	-11	33	112	121	249	342	.43	7.40
4325	2607	30	2509	38	138	8	3.0	.7	-8	20	-2	21	-10	32	112	116	245	336	.40	6.42
4350	2615	30	2518	38	138	9	2.9	.7	-10	23	-4	22	-10	31	111	116	243	333	.36	6.10
4375	2623	29	2525	39	139	9	2.8	.7	-13	25	-7	24	-10	31	109	130	244	334	.33	6.45
4400	2631	29	2532	40	139	10	2.8	.7	-15	28	-8	25	-11	31	108	148	247	338	.30	7.49
4425	2639	29	2539	42	139	12	2.7	.7	-16	31	-8	24	-11	31	106	165	252	346	.27	9.06
4450	2648	28	2544	45	140	14	2.5	.7	-17	33	-8	25	-12	32	104	180	260	357	.23	1.57
4475	2657	26	2550	48	140	16	2.4	.7	-18	34	-6	24	-13	33	101	192	268	367	.16	4.48
4500	2666	26	2555	52	141	19	2.3	.8	-21	34	-6	24	-13	34	96	200	280	384	.17	7.73
4525	2675	27	2559	56	141	22	2.2	.8	-24	34	-6	24	-14	36	94	200	294	405	.27	.94
4550	2686	31	2564	59	143	26	2.0	.9	-26	33	-5	25	-14	38	108	185	315	434	.89	3.73
4575	2698	39	2570	62	145	31	1.9	.9	-25	36	-3	26	-14	43	177	195	347	481	3.91	6.24
4600	2709	46	2576	66	147	36	1.7	.9	-26	37	-5	24	-13	47	206	211	375	523	7.63	8.39
4625	2723	53	2583	69	152	42	1.6	.9	-27	36	-4	24	-10	51	220	222	404	566	13.15	9.50
4650	2733	57	2589	73	156	45	1.5	.9	-28	35	-5	22	-10	54	229	232	425	597	16.18	1.47
4675	2744	59	2597	71	158	51	1.3	.9	-30	36	-6	23	-9	55	231	210	429	602	18.23	.74
4700	2757	60	2603	72	170	58	1.1	.9	-28	35	-5	24	-7	55	230	221	440	615	20.99	2.18
4725	2765	62	2617	69	175	55	.9	.9	-29	39	-2	23	-4	57	237	226	432	606	21.71	8.62
4750	2778	62	2622	70	182	59	.8	.9	-24	39	-2	23	-3	58	256	229	442	618	24.21	.19
4775	2790	64	2622	73	198	66	.6	.9	-22	38	-1	25	-5	59	266	237	465	646	27.03	4.91
4800	2802	67	2625	75	203	65	.5	.9	-21	38	-1	23	-6	61	271	246	486	675	30.02	7.83
4825	2814	70	2627	79	210	67	.4	.9	-9	37	3	22	-6	65	272	250	507	704	32.69	.99
4850	2819	73	2630	78	221	65	.3	.9	-4	42	6	26	-10	66	268	250	514	714	31.75	3.44
4875	2824	76	2622	84	232	68	.3	.9	-8	40	4	27	-19	70	260	266	547	758	31.22	1.41
4900	2834	65	2631	81	248	67	.3	.8	-9	38	6	25	-17	65	251	254	518	712	29.78	.77
4925	2843	66	2650	75	243	47	.4	.6	-11	41	9	24	-12	63	239	253	498	685	30.61	5.24
4950	2839	78	2653	82	251	44	.5	.5	-15	36	9	22	-20	71	228	259	531	743	27.75	7.91
4975	2844	100	2682	70	255	39	.3	.4	-22	35	9	22	-12	80	236	216	531	756	31.07	6.03

SHIP MANOEUVRING SIMULATOR
RESULTS OF STATISTICAL ANALYSIS

FILE: BULKIN (CONTINUED)

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
X-dir	SWEPTPATH north-side		SWEPTPATH south-side		Heading [degr]		Speed [knots]		Propeller [RPM]		Rudder [degr]		Ships-Centre [off LL]		Max.Distance [off LL]		Path width		Channel bounder exc.frequency	
[m]	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	north	south	1%	.01%	north	south
5000	2889	85	2713	48	245	32	.3	.2	-6	38	14	18	18	58	242	142	461	636	44.57	5.47
5025	2887	99	2702	54	253	34	.3	.2	4	34	21	17	4	72	244	156	516	719	41.21	9.12
5050	2913	98	2707	64	249	29	.5	.4	-1	38	18	19	11	76	245	174	554	769	48.43	3.76
5075	2932	105	2702	77	248	28	.5	.6	-4	32	21	19	10	90	244	195	623	865	53.01	2.77
5100	2975	66	2721	67	242	8	.2	.4	2	26	18	20	32	64	240	169	536	712	74.31	5.46
5125	2976	66	2706	86	248	9	.3	.4	17	11	18	20	18	72	235	222	594	794	70.84	9.42
5150	2992	66	2734	43	249	2	.4	.2	4	41	23	20	31	52	225	138	489	634	74.83	.99
5175	2987	64	2714	44	256	3	.4	.3	-1	48	23	20	12	50	211	166	501	645	68.41	5.49
5200	2954	0	2726	0	260	0	.5	.0	20	0	35	0	0	0	0	0	0	0	.00	.00

HYDRONAMAC BV
PORT AND WATERWAY ENGINEERS
SLIEDRECHT HOLLAND

****
* SHIP MANOEUVRING SIMULATOR *
* RESULTS OF STATISTICAL ANALYSIS *
****

FILE: TANKIN

CONSTANT PARAMETERS:

SHIP TYPE(S) : Tanker in a laden condition   CHANNEL WIDTH : 225 M.
WIND SPEED : 10, 20 and 30 knots.
WIND DIRECTION: north to north-east
CURRENT : normal spring tide flood, ebb and slack.

THE FOLLOWING TRIAL NUMBERS (TOTAL 54 TRIALS) ARE TAKEN INTO ACCOUNT:
75 171 192 49 67 91 96 122 147 156 172 186 4 13 52 61 125 139 24 97
148 8 14 15 50 53 68 104 149 199 21 69 92 133 173 193 88 99 194 9
54 62 90 93 119 131 143 188 5 98 120 121 157 179

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
X-dir	SWEPTPATH				Heading		Speed		Propeller		Rudder		Ships-Centre		Max.Distance		Path width		Channel bounder exc.frequency	
	north-side		south-side		[degr]		[knots]		[RPM]		[degr]		[off LL]		[off LL]					
[m]	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	north	south	1%	.01%	north	south
325	1480	325	1449	324	154	23	7.3	1.4	61	16	0	4	156	325	543	385	1471	2332	57.46	.66
350	1484	314	1452	312	154	23	7.3	1.4	61	16	0	4	151	313	524	369	1419	2250	57.21	.22
375	1498	302	1454	301	154	23	7.3	1.4	61	16	0	3	147	301	506	353	1369	2169	56.91	9.80
400	1491	291	1457	289	154	23	7.3	1.4	61	16	0	3	142	290	488	338	1318	2087	56.55	9.34
425	1494	279	1459	277	154	22	7.3	1.4	61	16	-1	3	137	278	469	323	1267	2006	56.14	8.89
450	1497	268	1462	265	154	22	7.3	1.4	61	16	-1	3	132	267	451	307	1216	1924	55.68	8.37
475	1500	257	1464	254	154	22	7.4	1.3	61	16	-1	4	127	255	434	293	1166	1844	55.15	7.86
500	1503	246	1467	242	153	21	7.4	1.3	60	16	-2	4	122	244	419	278	1117	1764	54.57	7.33
525	1506	235	1469	231	153	21	7.4	1.3	60	16	-2	5	117	233	403	265	1068	1685	53.92	6.78
550	1509	224	1471	219	153	20	7.4	1.3	60	16	-2	6	112	222	387	256	1019	1608	53.21	6.23
575	1511	213	1473	208	152	20	7.4	1.3	60	16	-2	6	106	211	369	247	971	1531	52.36	5.63
600	1514	203	1475	197	152	19	7.3	1.3	60	16	-2	6	101	200	353	237	924	1455	51.46	4.97
625	1517	192	1477	186	152	19	7.3	1.3	60	16	-3	6	96	189	338	230	877	1380	50.45	4.26
650	1519	182	1490	176	151	18	7.3	1.3	60	16	-3	7	91	179	323	222	831	1306	49.34	3.56
675	1522	172	1482	165	151	17	7.3	1.3	61	16	-3	7	86	169	308	214	786	1234	48.15	2.78
700	1525	162	1484	155	150	17	7.3	1.3	61	16	-3	7	80	159	293	208	743	1164	46.83	2.01
725	1528	153	1486	145	150	16	7.3	1.3	61	16	-3	7	75	149	279	202	701	1096	45.37	1.19
750	1531	144	1488	135	149	15	7.3	1.3	61	16	-3	7	70	139	264	196	659	1030	43.70	.35
775	1534	135	1491	126	149	15	7.3	1.3	61	16	-3	8	65	130	249	190	619	965	41.88	9.46
800	1537	126	1493	117	148	14	7.3	1.3	61	16	-4	9	61	121	234	185	580	902	39.85	8.54
825	1541	118	1496	108	148	13	7.3	1.3	61	16	-5	9	56	113	220	179	542	841	37.63	7.58
850	1544	109	1498	99	147	12	7.3	1.3	60	16	-6	10	51	104	207	175	506	782	35.24	6.63
875	1548	102	1501	90	146	11	7.3	1.3	60	16	-6	10	47	96	193	169	470	725	32.61	5.62
900	1552	94	1504	82	146	11	7.2	1.3	60	16	-6	11	42	88	179	164	436	671	29.75	4.61
925	1555	87	1507	74	145	10	7.2	1.3	60	16	-6	10	38	81	166	159	404	618	26.61	3.61
950	1559	80	1511	67	144	8	7.2	1.3	60	16	-5	11	34	73	153	154	372	568	23.36	2.67

HYDRONAMAC BV
PORT AND WATERWAY ENGINEERS
SLIEDRECHT HOLLAND

****
* SHIP MANOEUVRING SIMULATOR *
* RESULTS OF STATISTICAL ANALYSIS *
****

FILE: TANKIN (CONTINUED)

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
X-dir	SWEPTPATH north-side		SWEPTPATH south-side		Heading [degr]		Speed [knots]		Propeller [RPM]		Rudder [degr]		Ships-Centre [off LL]		Max.Distance [off LL]		Path width		Channel bounder exc.frequency	
[m]	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	north	south	1%	.01%	north	south
975	1563	73	1514	60	144	7	7.2	1.3	60	16	-5	11	30	66	139	149	342	519	19.91	1.85
1000	1568	67	1518	54	143	6	7.2	1.3	60	16	-5	10	26	60	127	145	315	475	16.49	1.19
1025	1572	62	1522	48	143	6	7.1	1.3	60	16	-5	9	23	55	115	141	291	437	13.15	.75
1050	1577	56	1527	44	142	5	7.1	1.3	59	16	-4	8	20	50	107	135	270	403	10.08	.45
1075	1582	52	1532	40	141	4	7.1	1.3	59	16	-3	8	17	45	102	129	251	373	7.41	.27
1100	1587	48	1537	37	141	4	7.1	1.3	59	16	-3	7	14	42	96	122	236	349	5.22	.17
1125	1592	45	1542	35	140	3	7.1	1.3	58	16	-2	6	12	39	91	117	223	329	3.57	.11
1150	1598	42	1548	33	140	3	7.0	1.3	57	16	-1	5	10	37	87	110	214	313	2.34	.09
1175	1604	39	1554	32	140	3	7.0	1.3	56	16	0	3	8	35	85	102	205	299	1.50	.08
1200	1610	37	1560	31	139	3	7.0	1.3	55	15	0	2	6	33	82	95	199	289	.94	.07
1225	1616	35	1567	31	139	3	7.0	1.3	54	15	0	2	5	32	80	92	193	281	.60	.07
1250	1622	34	1574	31	139	3	7.0	1.3	53	15	0	2	4	31	79	91	190	276	.40	.08
1275	1629	33	1581	31	139	3	7.0	1.3	52	15	1	3	3	31	78	90	187	271	.26	.09
1300	1636	32	1588	31	139	3	6.9	1.3	51	15	1	3	2	31	78	89	185	268	.18	.10
1325	1643	31	1596	31	139	3	6.9	1.3	51	15	1	3	1	31	80	89	184	267	.14	.12
1350	1650	31	1603	32	139	3	6.9	1.3	51	14	1	2	0	31	81	92	183	266	.11	.14
1375	1657	31	1611	32	139	2	6.9	1.2	50	14	1	2	0	31	83	95	183	267	.09	.16
1400	1664	31	1619	33	139	2	6.9	1.2	50	14	1	2	-1	31	84	98	184	268	.09	.19
1425	1671	31	1626	33	139	2	6.8	1.2	49	14	0	2	-1	32	85	100	185	270	.08	.23
1450	1678	31	1634	34	139	2	6.8	1.2	49	14	0	1	-1	32	86	104	186	272	.08	.27
1475	1686	31	1642	34	139	2	6.8	1.2	48	14	1	2	-2	32	87	107	187	274	.08	.30
1500	1693	31	1650	35	139	2	6.8	1.2	47	13	1	2	-2	33	89	109	188	276	.09	.33
1525	1701	32	1658	35	139	2	6.7	1.2	46	14	1	2	-2	33	90	111	189	278	.09	.35
1550	1709	32	1666	35	139	2	6.7	1.2	46	14	1	2	-2	34	92	111	190	280	.10	.38
1575	1716	32	1674	36	139	2	6.7	1.2	46	14	1	2	-2	34	93	112	191	281	.11	.39
1600	1724	33	1682	36	139	2	6.7	1.2	46	14	1	2	-2	34	94	111	192	284	.12	.42
1625	1732	33	1690	36	139	2	6.6	1.2	46	14	1	1	-2	35	95	110	193	285	.13	.44
1650	1740	33	1698	36	139	2	6.6	1.1	45	12	1	1	-2	35	95	108	194	287	.14	.45
1675	1748	34	1706	37	139	2	6.6	1.1	44	11	1	2	-2	35	96	106	195	288	.16	.46
1700	1756	34	1715	37	139	2	6.5	1.1	43	11	1	1	-2	35	98	104	196	290	.18	.45
1725	1764	34	1723	37	139	2	6.5	1.1	43	11	1	1	-2	35	98	102	196	291	.20	.44
1750	1772	35	1731	37	139	2	6.5	1.1	42	11	1	2	-1	36	97	101	197	292	.21	.44
1775	1780	35	1739	37	139	2	6.4	1.1	42	10	1	2	-1	36	97	100	198	293	.22	.45
1800	1788	35	1748	37	139	2	6.4	1.0	42	10	2	2	-1	36	97	100	199	295	.24	.46
1825	1796	35	1756	37	139	2	6.4	1.0	42	10	1	2	-1	36	97	99	200	296	.26	.46
1850	1804	36	1764	38	139	2	6.3	1.0	42	10	1	2	0	37	97	99	201	298	.29	.47
1875	1812	36	1773	38	139	2	6.3	1.0	42	10	1	1	0	37	96	98	202	300	.32	.48
1900	1820	36	1781	38	139	2	6.3	1.0	42	10	1	2	0	37	96	99	203	302	.34	.51
1925	1829	37	1789	39	140	2	6.3	1.0	42	10	1	2	1	38	96	98	204	304	.37	.53
1950	1837	37	1797	39	140	2	6.2	1.0	41	10	1	2	1	38	97	98	206	307	.41	.56

****
* SHIP MANOEUVRING SIMULATOR *
* RESULTS OF STATISTICAL ANALYSIS *
****

FILE: TANKIN (CONTINUED)

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
X-dir	SWEPTPATH north-side		south-side		Heading [degr]		Speed [knots]		Propeller [RPM]		Rudder [degr]		Ships-Centre [off LL]		Max.Distance [off LL]		Path width		Channel bounder exc.frequency	
[m]	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	north	south	1%	.01%	north	south
1975	1845	37	1806	39	140	2	6.2	1.0	41	9	1	2	1	38	96	97	207	309	.44	.58
2000	1853	37	1813	40	139	2	6.2	.9	41	9	1	1	1	38	94	97	208	310	.46	.60
2025	1861	37	1822	40	139	2	6.1	.9	41	9	1	1	1	39	93	95	209	311	.48	.61
2050	1869	38	1830	40	139	2	6.1	.9	41	9	1	2	1	39	92	94	209	312	.51	.60
2075	1877	38	1838	40	139	2	6.1	.9	41	10	1	2	2	39	91	92	210	312	.52	.60
2100	1885	38	1846	40	139	2	6.0	.9	42	10	1	2	2	39	89	91	210	314	.55	.60
2125	1893	38	1854	40	139	2	6.0	.9	42	11	1	1	2	39	88	92	211	314	.56	.61
2150	1902	38	1862	40	139	2	6.0	.9	42	11	1	2	2	39	87	93	211	314	.57	.62
2175	1910	38	1870	40	139	2	6.0	.8	42	11	1	2	2	39	86	92	211	314	.58	.60
2200	1918	38	1878	40	139	2	5.9	.8	42	12	1	2	2	39	85	92	211	315	.60	.60
2225	1926	38	1886	40	139	2	5.9	.8	42	11	1	2	3	39	86	91	211	315	.63	.58
2250	1934	38	1895	40	140	2	5.9	.8	41	12	1	2	3	39	88	91	211	314	.64	.55
2275	1942	38	1903	40	140	2	5.9	.8	40	12	1	2	3	39	89	92	210	314	.63	.53
2300	1950	38	1911	40	140	2	5.8	.8	40	12	1	2	3	39	91	92	210	314	.64	.53
2325	1958	38	1919	40	139	2	5.8	.8	40	12	1	2	3	39	93	92	211	314	.65	.55
2350	1966	38	1927	40	139	2	5.8	.8	40	12	1	2	3	39	95	93	211	315	.65	.56
2375	1975	38	1935	40	139	2	5.8	.8	39	13	1	2	4	39	97	93	212	316	.67	.57
2400	1982	38	1943	40	139	2	5.7	.8	38	14	1	2	4	39	99	93	212	317	.69	.57
2425	1990	38	1951	40	139	2	5.7	.8	38	14	1	2	4	39	101	93	212	316	.69	.56
2450	1998	38	1959	40	140	2	5.7	.8	38	14	1	2	4	39	103	94	212	316	.71	.55
2475	2007	38	1967	40	140	2	5.7	.8	38	13	1	2	4	39	105	94	212	317	.72	.55
2500	2015	38	1975	40	140	2	5.6	.8	39	13	1	1	4	39	107	93	211	315	.72	.52
2525	2023	38	1983	40	140	2	5.6	.8	39	13	1	1	5	39	108	93	211	315	.70	.50
2550	2031	38	1991	40	140	2	5.6	.7	39	13	1	1	5	39	108	92	210	314	.69	.49
2575	2039	38	1999	40	139	2	5.6	.7	39	13	1	2	5	39	108	91	210	313	.66	.49
2600	2047	38	2007	40	140	2	5.5	.7	39	13	1	2	5	38	107	88	209	311	.65	.46
2625	2055	37	2016	39	140	2	5.5	.7	38	13	1	2	5	38	107	87	207	309	.64	.41
2650	2063	37	2024	39	140	2	5.5	.7	38	13	1	1	5	38	106	86	207	308	.64	.38
2675	2071	37	2032	39	140	2	5.5	.7	38	12	1	1	5	38	105	85	206	306	.64	.35
2700	2079	37	2040	38	140	2	5.4	.7	37	12	1	1	5	38	104	84	204	304	.61	.33
2725	2087	37	2048	38	140	2	5.4	.7	36	12	1	1	6	37	104	83	203	303	.59	.31
2750	2095	36	2056	38	140	2	5.4	.7	36	12	1	1	6	37	103	82	202	301	.56	.29
2775	2103	36	2064	38	140	2	5.4	.7	36	12	1	2	6	37	102	82	202	300	.56	.28
2800	2111	36	2072	37	140	2	5.3	.7	36	11	1	2	6	37	101	81	201	298	.54	.26
2825	2120	36	2080	37	140	2	5.3	.7	36	11	1	2	6	37	100	81	200	297	.54	.24
2850	2128	36	2088	37	140	2	5.3	.7	36	11	1	2	6	36	100	81	199	296	.52	.22
2875	2136	36	2096	37	140	2	5.3	.7	36	11	1	2	6	36	99	80	198	294	.51	.21
2900	2144	35	2104	37	140	2	5.2	.7	36	11	1	2	7	36	97	80	197	293	.50	.20
2925	2152	35	2113	36	140	2	5.2	.6	36	11	1	2	7	36	97	79	196	291	.49	.19
2950	2160	35	2121	36	140	2	5.2	.6	36	11	2	2	7	35	96	79	195	289	.47	.17

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*     SHIP MANOEUVRING SIMULATOR     *
*  RESULTS OF  STATISTICAL ANALYSIS  *
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FILE: TANKIN (CONTINUED)

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
X-dir [m]	SWEPTPATH north-side		south-side		Heading [degr]		Speed [knots]		Propeller [RPM]		Rudder [degr]		Ships-Centre [off LL]		Max.Distance [off LL]		Path width		Channel bounder exc.frequency	
	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	north	south	1%	.01%	north	south
2975	2168	35	2129	36	140	2	5.2	.7	36	10	2	2	7	35	94	78	193	287	.45	.15
3000	2176	35	2137	35	140	2	5.1	.6	36	10	1	2	7	35	93	78	192	285	.43	.13
3025	2184	34	2145	35	140	2	5.1	.6	35	10	1	2	8	35	93	78	191	283	.41	.12
3050	2192	34	2153	35	140	2	5.1	.6	34	11	1	2	8	34	91	76	190	281	.39	.11
3075	2200	34	2161	35	140	2	5.1	.6	34	11	1	2	8	34	90	76	189	280	.37	.10
3100	2208	33	2170	34	140	2	5.0	.6	34	11	1	2	8	34	89	75	188	278	.35	.10
3125	2216	33	2178	34	140	2	5.0	.6	33	12	1	2	8	34	90	74	187	276	.33	.09
3150	2224	33	2186	34	140	2	5.0	.6	33	12	1	2	8	33	89	72	185	274	.31	.08
3175	2232	33	2193	34	140	2	5.0	.6	32	12	1	2	8	33	89	71	184	272	.30	.07
3200	2240	32	2201	33	140	2	4.9	.6	32	11	2	2	8	33	89	70	183	270	.27	.06
3225	2248	32	2209	33	140	2	4.9	.7	31	11	2	2	8	32	89	69	182	268	.26	.06
3250	2256	32	2217	33	140	2	4.9	.7	31	11	2	2	8	32	88	67	180	266	.23	.05
3275	2264	32	2225	32	140	2	4.8	.7	31	11	2	2	8	32	88	66	179	264	.22	.05
3300	2272	31	2233	32	140	2	4.8	.7	31	11	2	2	8	32	88	65	178	262	.21	.04
3325	2280	31	2241	32	140	2	4.8	.7	30	10	2	2	8	31	88	66	177	261	.19	.04
3350	2288	31	2249	32	140	2	4.7	.7	30	10	2	2	8	31	88	66	176	259	.18	.04
3375	2296	31	2257	32	140	2	4.7	.7	29	10	2	2	8	31	88	67	176	258	.17	.03
3400	2304	31	2265	31	140	2	4.7	.7	28	10	2	2	8	31	89	68	175	257	.16	.03
3425	2312	30	2272	31	140	2	4.7	.7	27	11	2	2	8	31	90	68	175	257	.16	.03
3450	2320	30	2280	31	140	2	4.6	.7	27	11	2	2	8	31	90	69	174	256	.15	.03
3475	2328	30	2288	31	140	2	4.6	.7	28	10	2	2	8	31	90	69	174	255	.15	.03
3500	2336	30	2296	31	140	2	4.5	.7	28	10	2	2	8	30	91	69	173	254	.14	.03
3525	2344	30	2304	31	140	2	4.5	.7	28	10	2	2	8	30	91	70	173	254	.13	.03
3550	2352	30	2312	31	140	2	4.5	.7	28	10	2	2	8	30	91	71	173	254	.13	.03
3575	2359	30	2321	31	140	2	4.4	.7	28	10	2	3	8	30	91	71	172	253	.13	.03
3600	2368	30	2329	31	140	2	4.4	.7	27	10	2	3	9	30	91	71	172	253	.13	.03
3625	2375	30	2337	31	140	2	4.4	.7	27	10	2	3	9	30	90	72	172	254	.12	.03
3650	2383	30	2345	32	140	2	4.4	.7	27	9	2	2	9	30	91	73	173	254	.12	.03
3675	2391	29	2353	32	140	2	4.3	.7	27	10	2	2	9	30	91	73	173	254	.12	.03
3700	2400	29	2361	32	140	2	4.3	.7	27	10	2	2	9	30	91	72	172	254	.12	.03
3725	2408	29	2369	32	140	2	4.3	.7	27	10	2	2	9	30	92	72	172	253	.12	.03
3750	2416	29	2377	32	140	2	4.2	.7	27	10	2	2	9	30	91	71	172	253	.12	.03
3775	2424	29	2385	32	140	2	4.2	.7	27	10	2	3	10	30	91	71	171	252	.12	.03
3800	2432	29	2393	32	140	3	4.2	.7	26	10	2	3	10	30	90	69	171	252	.11	.03
3825	2440	29	2402	32	140	3	4.1	.7	26	10	2	3	10	30	90	68	170	250	.10	.03
3850	2448	29	2410	32	140	3	4.1	.7	26	10	2	3	10	30	90	67	170	250	.10	.03
3875	2456	29	2418	32	140	3	4.1	.7	26	11	2	2	10	30	88	67	171	251	.10	.03
3900	2464	29	2426	32	140	3	4.1	.7	26	12	3	2	10	30	88	67	170	250	.10	.03
3925	2472	29	2434	32	140	3	4.0	.7	25	12	3	3	11	30	87	68	170	250	.10	.03
3950	2480	28	2442	32	140	3	4.0	.7	24	13	2	2	11	30	87	67	169	249	.10	.02

****
* SHIP MANOEUVRING SIMULATOR *
* RESULTS OF STATISTICAL ANALYSIS *
****

FILE: TANKIN (CONTINUED)

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
X-dir	SWEPTPATH north-side		SWEPTPATH south-side		Heading [degr]		Speed [knots]		Propeller [RPM]		Rudder [degr]		Ships-Centre [off LL]		Max.Distance [off LL]		Path width		Channel bounder exc.frequency	
[m]	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	north	south	1%	.01%	north	south
3975	2488	28	2450	32	140	3	4.0	.7	23	12	2	2	11	30	88	67	169	249	.10	.02
4000	2496	28	2458	32	140	4	3.9	.7	23	13	3	3	11	30	88	67	169	248	.09	.02
4025	2504	28	2467	32	140	4	3.9	.7	22	14	3	3	11	30	89	67	168	247	.09	.02
4050	2512	28	2475	32	140	4	3.9	.6	21	14	3	5	11	30	90	67	168	248	.09	.02
4075	2521	28	2483	32	140	4	3.8	.6	21	14	3	6	12	30	90	66	169	248	.09	.02
4100	2529	28	2491	32	140	4	3.8	.6	21	15	3	6	12	30	91	67	169	248	.09	.03
4125	2537	28	2500	32	140	4	3.8	.6	20	15	3	6	12	30	93	67	169	249	.10	.03
4150	2545	28	2508	32	140	4	3.7	.6	20	15	3	6	13	30	95	66	170	250	.11	.03
4175	2553	28	2517	33	140	4	3.7	.6	19	15	3	5	13	30	97	65	170	251	.12	.03
4200	2562	28	2525	33	140	4	3.7	.6	19	15	4	6	14	30	98	68	169	249	.11	.02
4225	2570	28	2534	33	140	4	3.6	.6	19	15	4	7	14	30	97	74	168	249	.10	.02
4250	2578	28	2542	33	140	4	3.6	.6	19	14	4	7	15	30	93	77	168	248	.11	.02
4275	2587	27	2551	33	141	5	3.6	.7	18	14	4	6	15	30	87	79	167	247	.11	.02
4300	2595	27	2560	33	141	5	3.5	.6	16	14	3	7	16	29	84	79	166	245	.09	.02
4325	2603	27	2568	33	141	5	3.5	.6	15	15	3	8	16	29	84	79	164	243	.08	.02
4350	2612	26	2577	32	141	5	3.5	.6	14	15	2	8	17	29	83	77	162	240	.08	.01
4375	2620	26	2585	32	141	6	3.4	.6	13	14	1	11	17	28	83	74	160	236	.06	.01
4400	2628	25	2593	31	141	6	3.4	.6	12	13	2	11	17	28	83	68	158	232	.06	.01
4425	2637	25	2601	30	141	7	3.4	.6	11	13	1	12	18	27	83	58	155	228	.05	.00
4450	2645	24	2609	29	141	7	3.3	.6	10	14	1	12	18	26	83	50	152	223	.04	.00
4475	2654	24	2618	28	141	8	3.3	.6	7	14	1	13	18	26	82	51	150	220	.04	.00
4500	2662	24	2626	28	141	8	3.2	.6	5	16	1	14	19	25	81	52	149	217	.03	.00
4525	2670	24	2634	28	141	9	3.2	.6	4	21	2	16	19	25	81	53	148	216	.04	.00
4550	2679	24	2642	28	141	9	3.1	.6	3	23	4	17	20	26	81	58	150	219	.05	.00
4575	2688	25	2651	28	142	10	3.1	.6	1	22	8	18	20	26	87	62	153	224	.08	.00
4600	2696	26	2660	29	142	10	3.0	.6	1	20	11	17	21	27	103	69	157	230	.17	.00
4625	2705	28	2669	31	143	10	2.9	.6	0	20	13	18	22	29	121	77	165	244	.35	.00
4650	2715	31	2679	34	144	10	2.9	.6	-1	21	15	21	24	32	142	83	179	266	.77	.01
4675	2724	36	2687	39	145	11	2.8	.7	-2	23	15	21	25	37	178	92	201	300	1.99	.06
4700	2734	41	2696	44	147	12	2.7	.7	-3	24	15	22	26	42	214	100	224	336	4.08	.18
4725	2744	46	2703	48	148	13	2.7	.7	-5	22	16	23	26	46	237	110	248	373	6.50	.45
4750	2753	50	2709	52	149	16	2.6	.7	-7	25	16	25	26	50	249	121	269	405	8.67	.89
4775	2762	54	2715	57	150	19	2.5	.7	-9	28	15	27	26	54	258	135	290	436	10.56	1.55
4800	2770	57	2721	61	150	22	2.4	.7	-11	32	14	28	25	57	261	150	308	464	11.97	2.42
4825	2778	60	2726	64	157	43	2.3	.8	-10	36	13	28	24	60	262	165	325	489	13.21	3.41
4850	2785	63	2730	67	161	43	2.1	.9	-10	38	15	27	21	63	260	178	340	512	13.90	4.55
4875	2791	65	2734	69	174	57	2.0	.9	-11	39	16	28	18	65	257	189	353	531	13.93	5.89
4900	2795	67	2736	72	180	69	1.9	1.0	-13	38	15	28	14	68	248	198	365	550	13.43	7.71
4925	2801	67	2738	75	182	68	1.7	1.0	-16	35	11	28	10	70	239	206	376	565	12.88	9.93
4950	2807	67	2739	78	184	67	1.6	1.1	-11	39	10	28	6	71	227	212	389	583	12.57	2.62

****
* SHIP MANOEUVRING SIMULATOR *
* RESULTS OF STATISTICAL ANALYSIS *
****

FILE: TANKIN (CONTINUED)

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
	SWEPTPATH				Heading		Speed		Propeller		Rudder		Ships-Centre		Max.Distance		Path width		Channel bounder	
X-dir [m]	north-side		south-side		[degr]		[knots]		[RPM]		[degr]		[off LL]		[off LL]				exc.frequency	
	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	north	south	1%	.01%	north	south
4975	2814	70	2738	82	186	66	1.4	1.1	-8	45	10	29	1	74	215	218	410	613	13.05	6.16
5000	2815	72	2734	86	200	76	1.3	1.1	-8	46	9	29	-8	76	202	219	428	638	11.60	1.05
5025	2814	73	2730	90	207	78	1.2	1.1	-10	46	9	28	-18	78	187	226	443	660	9.85	6.34
5050	2813	73	2725	92	212	82	1.0	1.1	-12	46	10	27	-28	79	169	249	450	669	7.72	1.54
5075	2812	74	2720	93	225	81	.8	1.1	-5	43	9	26	-39	80	151	268	458	680	6.28	6.69
5100	2807	74	2706	96	235	85	.7	1.1	-7	45	9	26	-56	80	130	277	471	696	4.36	6.14
5125	2798	78	2691	96	248	87	.5	1.1	-7	46	8	26	-74	81	109	272	488	718	3.39	5.41
5150	2790	84	2683	94	270	81	.4	1.1	-5	42	10	25	-90	84	108	256	497	734	2.98	2.15
5175	2800	90	2713	84	257	77	.5	1.0	-10	55	12	25	-78	85	113	264	467	698	4.10	3.15
5200	2824	73	2727	73	237	51	.7	.8	-5	61	16	25	-68	69	88	275	416	609	2.70	.78
5225	2830	51	2725	62	250	36	.6	.8	-6	51	17	21	-73	50	63	281	349	499	.26	7.05
5250	2806	46	2714	61	249	17	.7	.9	-13	43	19	17	-97	51	9	256	326	468	.02	8.92
5275	2805	36	2718	47	255	16	.8	.7	-9	42	21	18	-104	37	-23	219	267	377	.01	6.54
5300	2775	34	2705	18	266	19	.5	.8	-29	54	12	16	-132	24	-61	190	183	252	.01	9.86
5325	2758	24	2675	30	275	15	.2	.5	-6	56	14	19	-161	26	-86	230	199	270	.01	9.90
5350	2703	0	2635	0	294	0	.3	.0	-31	0	0	0	0	0	0	0	0	0	.00	.00

HYDRONAMAC BV
PORT AND WATERWAY ENGINEERS
SLIEDRECHT HOLLAND

PROJECT: P 629
DATE : MON, NOV 29, 1982

****
* SHIP MANOEUVRING SIMULATOR *
* RESULTS OF STATISTICAL ANALYSIS *
****

FILE: BULKUT

CONSTANT PARAMETERS:

SHIP TYPE(S) : Coal carrier in a laden condition.
WIND SPEED : 10, 20 and 30 knots.
WIND DIRECTION: north to north-east.
CURRENT : normal spring tide, flood, ebb and slack.

CHANNEL WIDTH : 225 M.

THE FOLLOWING TRIAL NUMBERS (TOTAL 27 TRIALS) ARE TAKEN INTO ACCOUNT:
70 159 195 11 33 46 34 37 152 43 153 189 12 45 76 1 41 107 113 162
201 29 81 89 26 72 111

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
X-dir [m]	SWEPTPATH north-side		SWEPTPATH south-side		Heading [degr]		Speed [knots]		Propeller [RPM]		Rudder [degr]		Ships-Centre [off LL]		Max.Distance [off LL]		Path width		Channel bounder exc.frequency	
	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	north	south	1%	.01%	north	south
500	1462	65	1374	53	354	23	9.9	.9	79	1	15	7	58	58	169	49	344	500	42.18	.51
525	1448	54	1366	42	348	20	9.6	.8	79	1	11	9	40	47	159	52	292	420	26.35	.22
550	1451	50	1369	39	347	19	9.6	.8	79	1	11	9	35	43	149	54	275	392	21.27	.16
575	1449	44	1369	34	344	18	9.7	.8	79	1	11	8	27	38	139	57	250	353	13.15	.08
600	1440	45	1362	36	340	16	9.6	.9	76	7	10	8	12	40	130	72	253	359	6.71	.54
625	1445	41	1367	34	340	15	9.6	.9	76	7	10	8	9	37	120	72	241	340	4.56	.44
650	1449	38	1372	32	339	15	9.6	.9	76	7	10	8	6	34	111	73	230	323	2.85	.38
675	1451	36	1375	30	338	14	9.7	.9	77	6	10	7	1	32	103	72	218	306	1.35	.35
700	1461	31	1387	30	336	12	9.5	.9	75	8	9	8	3	30	96	71	206	287	.68	.21
725	1467	28	1395	28	335	11	9.5	.9	76	7	8	8	3	27	89	71	195	270	.27	.13
750	1473	27	1402	28	335	11	9.5	.9	76	7	8	8	1	27	82	71	191	265	.15	.15
775	1478	24	1409	26	334	10	9.6	.9	76	7	7	8	0	24	75	71	178	245	.03	.08
800	1485	23	1416	26	333	9	9.6	.9	76	7	7	8	-1	24	68	73	176	242	.01	.09
825	1494	24	1427	28	333	8	9.6	.9	76	7	6	8	1	26	70	76	181	251	.03	.14
850	1504	29	1435	28	333	8	9.7	.9	77	6	8	10	2	28	106	79	193	269	.29	.11
875	1511	29	1442	28	333	8	9.7	.9	77	6	8	10	1	28	102	83	192	268	.21	.13
900	1518	29	1450	28	332	7	9.7	.9	77	6	8	10	1	28	99	86	191	267	.17	.15
925	1524	27	1457	27	332	6	9.6	.9	76	7	7	10	-1	27	96	87	185	257	.08	.11
950	1531	28	1466	28	331	6	9.6	1.0	76	7	7	10	-1	27	98	88	185	258	.09	.11
975	1542	28	1477	28	331	5	9.7	.9	76	7	6	9	2	28	100	87	186	261	.14	.10
1000	1550	27	1485	28	330	4	9.6	1.0	75	8	6	9	2	27	102	87	184	257	.10	.08
1025	1559	28	1495	29	330	4	9.6	1.0	76	7	5	9	4	29	104	87	189	266	.19	.11
1050	1567	28	1503	30	330	3	9.6	1.0	76	7	5	9	4	29	106	87	189	266	.18	.12
1075	1574	28	1512	29	329	3	9.5	1.0	76	7	5	9	4	28	107	84	186	262	.15	.10
1100	1582	27	1520	29	329	3	9.5	1.0	76	7	5	9	4	28	108	82	183	258	.12	.08
1125	1590	27	1528	29	329	2	9.5	1.0	76	7	5	9	4	28	108	79	183	258	.11	.08
1150	1597	27	1536	29	329	2	9.5	1.0	76	7	5	8	4	28	109	77	183	258	.11	.09

****
* SHIP MANOEUVRING SIMULATOR *
* RESULTS OF STATISTICAL ANALYSIS *
****

FILE: BULKUT (CONTINUED)

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
X-dir [m]	SWEPTPATH north-side av	dev	south-side av	dev	Heading [degr] av	dev	Speed [knots] av	dev	Propeller [RPM] av	dev	Rudder [degr] av	dev	Ships-Centre [off LL] av	dev	Max.Distance [off LL] north	south	Path width 1%	.01%	Channel bounder exc.frequency north	south
1175	1605	27	1544	29	329	2	9.5	1.0	76	7	4	7	4	28	110	74	183	258	.10	.08
1200	1613	27	1552	29	328	2	9.5	1.0	75	7	3	6	4	28	111	72	182	256	.10	.07
1225	1620	27	1560	29	328	1	9.4	1.0	75	8	2	6	4	28	112	69	181	255	.10	.07
1250	1628	27	1568	28	328	1	9.4	1.0	75	8	2	6	4	28	114	66	180	254	.09	.06
1275	1636	27	1576	28	328	1	9.4	1.0	74	8	1	4	4	28	115	65	180	254	.09	.06
1300	1644	27	1584	28	328	1	9.4	1.0	74	8	0	2	3	28	116	63	179	253	.10	.05
1325	1651	27	1592	28	328	1	9.4	1.0	74	8	0	1	3	27	115	63	179	251	.08	.05
1350	1659	27	1600	28	328	1	9.3	1.0	74	8	0	1	3	27	115	62	178	251	.08	.05
1375	1667	27	1607	28	328	1	9.3	1.0	74	9	0	1	3	27	115	61	178	251	.07	.06
1400	1674	27	1615	28	328	1	9.3	1.0	74	9	0	1	3	27	114	59	177	249	.06	.05
1425	1682	26	1623	28	328	1	9.3	1.0	74	9	0	1	2	27	114	58	177	248	.06	.05
1450	1689	26	1630	27	328	1	9.3	1.0	74	9	0	1	2	27	113	57	176	247	.05	.05
1475	1697	26	1638	27	328	1	9.2	1.0	74	9	0	1	2	27	114	57	176	247	.05	.05
1500	1705	26	1646	27	328	1	9.2	1.0	74	9	0	1	2	27	114	57	175	246	.05	.05
1525	1712	26	1653	27	328	1	9.2	1.0	74	9	0	1	1	27	115	57	175	246	.05	.05
1550	1720	26	1661	27	328	1	9.2	1.0	73	9	0	1	1	27	114	57	174	245	.04	.04
1575	1728	26	1669	27	328	1	9.1	1.0	73	9	0	1	1	26	114	57	173	243	.04	.04
1600	1735	26	1676	26	328	1	9.1	1.0	73	9	0	1	0	26	113	58	172	242	.03	.04
1625	1743	26	1684	26	328	1	9.1	1.0	73	9	0	1	0	26	113	58	172	241	.03	.04
1650	1751	26	1691	26	328	1	9.1	1.0	73	9	0	1	0	26	112	59	172	240	.03	.04
1675	1758	25	1699	26	328	1	9.0	1.0	73	9	0	1	0	26	111	59	171	239	.02	.04
1700	1766	25	1707	26	328	1	9.0	1.0	73	9	0	1	-1	26	111	59	170	239	.02	.04
1725	1774	25	1714	26	328	1	9.0	1.0	73	9	0	1	-1	26	111	59	170	239	.02	.04
1750	1781	25	1722	26	328	1	9.0	1.0	73	9	0	2	-1	26	111	58	170	238	.02	.04
1775	1789	25	1730	25	328	1	9.0	1.0	73	9	0	2	-1	25	110	57	169	236	.02	.03
1800	1797	25	1738	25	328	1	8.9	1.0	73	9	0	2	-1	25	109	57	168	234	.02	.03
1825	1804	25	1745	25	328	1	8.9	1.0	73	9	0	1	-2	25	109	57	167	233	.01	.03
1850	1812	25	1753	25	328	1	8.9	1.0	73	9	0	1	-2	25	108	57	167	233	.01	.03
1875	1820	25	1761	25	328	1	8.9	1.0	73	9	0	1	-2	25	107	58	166	231	.01	.03
1900	1827	24	1768	25	328	1	8.8	1.0	72	9	0	1	-2	25	106	58	165	231	.01	.03
1925	1835	24	1776	25	328	1	8.8	1.0	72	9	0	1	-3	24	105	58	165	230	.01	.03
1950	1843	24	1784	25	328	1	8.8	1.0	72	9	0	1	-3	24	104	58	164	229	.01	.03
1975	1850	24	1792	25	328	1	8.8	1.0	72	9	0	1	-3	24	103	59	164	228	.01	.02
2000	1858	24	1799	24	328	1	8.7	1.0	72	9	0	1	-3	24	101	59	163	226	.01	.02
2025	1866	24	1807	24	328	1	8.7	1.0	72	9	0	1	-3	24	100	59	162	225	.00	.02
2050	1874	23	1815	24	328	1	8.7	1.0	72	9	0	1	-3	24	99	59	161	224	.00	.02
2075	1882	23	1823	24	328	1	8.7	1.0	72	9	0	1	-4	23	98	59	160	223	.00	.02
2100	1889	23	1830	24	328	1	8.6	1.0	72	9	0	1	-4	24	98	59	161	223	.00	.02
2125	1897	23	1838	24	328	1	8.6	1.0	72	9	0	1	-4	23	97	60	160	222	.00	.02
2150	1905	23	1846	23	328	1	8.6	1.0	72	9	0	1	-4	23	96	60	159	221	.00	.02

HYDRONAMAC BV
PORT AND WATERWAY ENGINEERS
SLIEDRECHT HOLLAND

PAGE : 3
PROJECT: P 629
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****
* SHIP MANOEUVRING SIMULATOR *
* RESULTS OF STATISTICAL ANALYSIS *
****

FILE: BULKUT (CONTINUED)

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
X-dir [m]	SWEPTPATH north-side		south-side		Heading [degr]		Speed [knots]		Propeller [RPM]		Rudder [degr]		Ships-Centre [off LL]		Max.Distance [off LL]		Path width		Channel bounder exc.frequency	
	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	north	south	1%	.01%	north	south
2175	1912	23	1854	23	328	1	8.6	1.0	72	9	0	2	-4	23	95	60	158	220	.00	.01
2200	1920	23	1862	23	328	1	8.5	1.0	72	9	0	2	-4	23	94	60	158	219	.00	.01
2225	1928	23	1869	23	328	1	8.5	1.0	72	9	0	2	-4	23	94	61	158	220	.00	.01
2250	1936	23	1877	23	328	1	8.5	1.0	71	9	0	2	-4	23	94	61	157	218	.00	.01
2275	1943	23	1885	23	328	1	8.4	1.0	71	9	0	2	-5	23	93	61	158	218	.00	.01
2300	1951	23	1893	23	328	1	8.4	1.0	71	9	0	2	-5	23	92	61	157	218	.00	.01
2325	1959	22	1901	23	328	1	8.4	1.0	71	9	0	1	-5	23	91	61	157	217	.00	.01
2350	1967	22	1908	23	328	1	8.4	1.0	71	9	0	1	-5	23	91	60	157	217	.00	.01
2375	1975	22	1916	23	328	1	8.3	1.0	71	9	0	1	-5	23	90	59	156	216	.00	.01
2400	1982	22	1924	23	328	1	8.3	1.0	71	9	0	1	-5	22	89	58	155	215	.00	.01
2425	1990	22	1932	22	327	1	8.3	1.0	71	9	0	1	-5	22	88	57	154	213	.00	.01
2450	1998	22	1940	22	327	1	8.2	.9	71	9	0	1	-5	22	88	57	154	213	.00	.01
2475	2006	22	1948	22	327	1	8.2	1.0	71	9	0	1	-6	22	88	57	153	212	.00	.01
2500	2013	22	1956	22	327	1	8.2	.9	71	9	0	1	-6	22	87	56	153	211	.00	.01
2525	2021	22	1963	22	327	1	8.1	.9	71	9	0	1	-6	22	87	56	153	211	.00	.01
2550	2029	22	1971	22	327	1	8.1	.9	71	9	0	1	-6	22	86	56	152	210	.00	.01
2575	2037	21	1979	22	327	1	8.1	.9	71	9	0	1	-6	22	85	54	151	209	.00	.01
2600	2045	21	1987	22	327	1	8.0	.9	71	9	0	1	-6	21	84	53	150	208	.00	.01
2625	2052	21	1995	22	327	1	8.0	.9	71	9	0	1	-6	21	83	52	150	207	.00	.01
2650	2060	21	2003	22	327	1	8.0	.9	71	9	0	1	-6	21	81	52	149	205	.00	.01
2675	2068	21	2010	22	327	1	7.9	.9	71	9	0	1	-7	21	82	52	149	205	.00	.01
2700	2076	21	2018	21	327	1	7.9	.9	71	9	0	1	-7	21	82	52	148	205	.00	.01
2725	2083	21	2026	21	327	1	7.9	.9	70	9	0	1	-7	21	81	52	148	204	.00	.01
2750	2091	21	2034	21	327	1	7.8	.9	70	9	0	1	-7	21	80	53	148	204	.00	.01
2775	2099	20	2042	21	327	1	7.8	.9	69	9	0	1	-7	21	78	53	147	202	.00	.00
2800	2107	21	2050	21	327	1	7.8	.9	69	10	0	1	-7	21	78	52	147	202	.00	.00
2825	2115	21	2058	21	327	1	7.7	.9	69	10	0	1	-7	21	79	54	147	202	.00	.00
2850	2123	21	2065	21	327	1	7.7	.9	69	10	0	1	-7	21	79	55	147	203	.00	.00
2875	2130	21	2073	21	327	1	7.6	.9	69	10	0	1	-7	21	79	56	147	202	.00	.00
2900	2138	21	2081	21	327	1	7.6	.9	69	10	0	0	-7	21	79	56	148	203	.00	.01
2925	2146	21	2089	21	327	1	7.6	.9	69	10	0	1	-7	21	79	57	148	204	.00	.01
2950	2154	21	2097	21	327	1	7.5	.9	69	10	0	1	-7	21	80	57	148	204	.00	.01
2975	2162	21	2105	21	327	1	7.5	.9	69	10	0	1	-7	21	80	58	148	205	.00	.01
3000	2170	21	2113	21	327	1	7.5	.9	69	10	0	1	-7	21	79	58	148	204	.00	.01
3025	2178	21	2121	22	327	1	7.4	.9	69	10	0	1	-7	21	79	58	148	204	.00	.01
3050	2186	21	2129	22	327	1	7.4	.8	69	10	0	1	-7	21	80	58	149	206	.00	.01
3075	2193	21	2137	22	327	1	7.3	.9	69	10	0	1	-7	22	80	59	150	207	.00	.01
3100	2201	21	2145	22	327	1	7.3	.9	69	10	0	1	-7	22	80	59	150	207	.00	.01
3125	2209	22	2153	22	327	1	7.3	.9	69	10	0	1	-7	22	80	60	151	209	.00	.01
3150	2217	22	2161	22	327	1	7.2	.9	70	10	0	1	-7	22	80	61	151	209	.00	.01

****
* SHIP MANOEUVRING SIMULATOR *
* RESULTS OF STATISTICAL ANALYSIS *
****

FILE: BULKUT (CONTINUED)

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis.

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
X-dir [m]	SWEPTPATH north-side av	north-side dev	south-side av	south-side dev	Heading [degr] av	Heading dev	Speed [knots] av	Speed dev	Propeller [RPM] av	Propeller dev	Rudder [degr] av	Rudder dev	Ships-Centre [off LL] av	Ships-Centre dev	Max.Distance [off LL] north	Max.Distance south	Path width 1%	Path width .01%	Channel bounder exc.frequency north	Channel bounder exc.frequency south
3175	2225	22	2169	22	327	1	7.2	.8	69	10	0	1	-7	22	78	61	151	209	.00	.01
3200	2233	22	2177	23	327	1	7.1	.8	69	10	0	1	-7	22	77	62	151	210	.00	.01
3225	2241	22	2185	23	327	1	7.1	.8	69	9	0	1	-7	22	77	63	152	210	.00	.01
3250	2249	22	2193	23	327	1	7.0	.8	69	9	1	1	-7	22	78	64	152	211	.00	.01
3275	2256	22	2201	23	327	1	7.0	.8	69	9	0	1	-7	22	76	65	151	210	.00	.01
3300	2264	21	2209	23	327	1	6.9	.8	69	9	0	2	-7	22	74	67	151	210	.00	.02
3325	2272	21	2217	23	327	1	6.9	.8	69	9	0	2	-7	22	72	68	151	210	.00	.02
3350	2280	21	2226	23	327	1	6.8	.8	69	9	0	2	-7	22	71	69	150	209	.00	.01
3375	2287	21	2234	23	327	1	6.8	.8	69	9	0	2	-7	22	69	70	149	208	.00	.01
3400	2295	21	2241	23	327	1	6.7	.8	69	9	0	1	-7	22	68	71	149	208	.00	.01
3425	2302	21	2249	23	327	1	6.7	.8	68	9	0	2	-7	22	66	72	149	207	.00	.01
3450	2310	21	2257	23	327	1	6.6	.8	68	9	0	2	-7	22	65	72	149	207	.00	.01
3475	2318	21	2265	23	327	1	6.6	.8	68	9	0	2	-8	22	64	73	149	208	.00	.01
3500	2325	21	2273	23	327	1	6.5	.8	68	9	0	1	-8	22	62	74	149	208	.00	.01
3525	2333	22	2280	23	327	1	6.5	.8	68	9	0	1	-8	22	61	75	149	208	.00	.01
3550	2341	22	2288	23	327	1	6.4	.8	68	10	0	1	-8	22	61	76	149	208	.00	.02
3575	2348	22	2296	23	327	1	6.4	.8	68	10	0	1	-9	23	60	77	150	209	.00	.02
3600	2355	22	2303	24	327	1	6.3	.7	68	10	0	1	-9	23	60	79	150	211	.00	.02
3625	2363	22	2311	24	327	1	6.2	.7	68	10	0	1	-10	23	59	80	150	210	.00	.03
3650	2370	22	2319	24	327	1	6.2	.7	68	9	0	1	-10	23	57	80	150	210	.00	.03
3675	2377	22	2326	24	327	1	6.1	.7	67	9	0	1	-11	23	56	81	150	211	.00	.03
3700	2384	22	2334	24	327	1	6.1	.7	67	9	0	1	-11	23	55	83	151	212	.00	.04
3725	2392	22	2341	24	327	1	6.0	.7	67	9	0	1	-12	23	54	84	150	211	.00	.04
3750	2399	22	2349	24	327	1	5.9	.7	66	9	0	1	-12	23	54	86	151	212	.00	.05
3775	2406	22	2356	24	327	2	5.9	.7	66	9	0	2	-13	23	53	89	151	213	.00	.06
3800	2414	22	2363	25	327	2	5.8	.7	66	9	0	1	-13	23	52	90	152	215	.00	.07
3825	2421	23	2371	25	327	2	5.8	.7	66	9	0	1	-14	24	52	91	152	215	.00	.07
3850	2428	22	2378	25	327	2	5.7	.7	66	9	-1	2	-15	23	53	92	152	214	.00	.08
3875	2435	22	2385	25	327	2	5.6	.6	66	10	-1	3	-15	23	52	94	151	214	.00	.10
3900	2442	22	2392	25	327	2	5.6	.6	65	9	-1	3	-16	23	49	95	150	212	.00	.11
3925	2449	22	2400	25	327	2	5.5	.6	65	9	-1	3	-17	23	48	94	150	211	.00	.11
3950	2456	21	2407	25	327	2	5.4	.6	65	10	-1	3	-18	23	46	94	149	210	.00	.11
3975	2463	21	2414	24	327	2	5.4	.6	65	10	0	2	-18	23	45	95	148	208	.00	.11
4000	2470	21	2421	24	327	2	5.3	.6	65	10	0	2	-19	22	45	94	147	206	.00	.10
4025	2478	21	2428	23	327	2	5.2	.6	65	10	0	3	-20	22	44	92	145	204	.00	.09
4050	2485	21	2434	23	327	2	5.2	.6	65	9	0	3	-21	22	41	90	144	202	.00	.09
4075	2492	21	2441	22	327	2	5.1	.6	65	9	0	4	-22	21	38	88	144	201	.00	.09
4100	2499	20	2448	21	327	2	5.0	.5	65	9	0	4	-23	21	34	85	141	196	.00	.07
4125	2506	20	2454	20	327	2	4.9	.5	65	9	0	3	-24	20	34	83	138	191	.00	.05
4150	2513	19	2461	19	327	2	4.8	.5	65	9	-1	5	-25	19	34	82	135	187	.00	.04

****
* SHIP MANOEUVRING SIMULATOR *
* RESULTS OF STATISTICAL ANALYSIS *
****

FILE: BULKUT (CONTINUED)

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
X-dir	SWEPTPATH north-side		SWEPTPATH south-side		Heading [degr]		Speed [knots]		Propeller [RPM]		Rudder [degr]		Ships-Centre [off LL]		Max.Distance [off LL]		Path width		Channel bounder exc.frequency	
[m]	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	north	south	1%	.01%	north	south
4175	2520	18	2467	19	327	2	4.8	.5	65	9	0	6	-26	18	35	81	132	181	,00	.03
4200	2527	17	2473	18	327	2	4.7	.5	64	9	0	5	-27	17	35	80	129	176	,00	.02
4225	2534	17	2479	17	327	2	4.6	.5	64	9	0	5	-29	17	34	80	128	173	,00	.02
4250	2541	16	2485	16	327	2	4.5	.5	63	9	0	4	-30	16	31	79	125	169	,00	.01
4275	2548	16	2491	15	327	3	4.4	.5	63	9	0	4	-32	16	30	80	125	167	,00	.01
4300	2554	16	2497	15	328	3	4.3	.4	63	9	0	4	-34	15	27	79	124	166	,00	.01
4325	2560	17	2503	15	328	3	4.2	.5	63	9	0	4	-36	15	23	81	125	167	,00	.02
4350	2565	17	2509	15	328	3	4.1	.4	63	9	0	7	-38	16	17	88	125	168	,00	.05
4375	2570	18	2515	16	328	4	4.0	.4	62	9	0	9	-40	17	15	94	129	175	,00	.16
4400	2575	19	2519	17	328	4	3.9	.4	62	9	-1	12	-43	18	16	100	135	184	,00	.55
4425	2581	20	2523	19	329	5	3.8	.4	62	9	-2	12	-46	19	16	109	142	193	,00	1.60
4450	2585	21	2525	19	329	5	3.7	.4	62	9	-2	11	-51	20	16	121	146	200	,00	3.20
4475	2589	22	2527	19	330	5	3.6	.4	62	9	-3	9	-55	20	17	131	150	205	,00	6.27
4500	2592	24	2529	18	330	5	3.5	.4	61	8	-2	7	-61	20	18	138	154	210	,00	1.31
4525	2595	24	2529	18	331	5	3.4	.3	61	8	-2	9	-67	20	16	144	156	212	,00	9.39
4550	2597	26	2530	17	331	6	3.3	.3	60	7	-4	12	-73	20	13	150	159	215	,00	2.25
4575	2599	25	2530	17	332	6	3.2	.3	59	7	-4	11	-80	20	8	156	160	216	,00	1.08
4600	2600	25	2528	16	333	6	3.0	.3	59	7	-6	10	-87	19	1	162	159	214	,01	1.73
4625	2600	24	2526	15	335	6	2.9	.3	59	7	-7	10	-96	17	-11	168	156	207	,01	1.11
4650	2601	26	2521	10	335	6	2.8	.2	57	5	-5	12	-106	15	-29	158	155	203	,01	9.96

****
* SHIP MANOEUVRING SIMULATOR *
* RESULTS OF STATISTICAL ANALYSIS *
****

FILE: TANKUT

CONSTANT PARAMETERS:

SHIP TYPE(S) : Tanker in a ballast condition. CHANNEL WIDTH : 225 M.
WIND SPEED : 10, 20 and 30 knots.
WIND DIRECTION: north to north-east.
CURRENT : normal spring tide flood, ebb and slack.

THE FOLLOWING TRIAL NUMBERS (TOTAL 26 TRIALS) ARE TAKEN INTO ACCOUNT:
27 39 116 64 77 86 25 31 63 18 169 35 55 65 19 28 42 32 134 182
10 22 56 71 85 144

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
	SWEPTPATH				Heading		Speed		Propeller		Rudder		Ships-Centre		Max.Distance		Path width		Channel bounder	
X-dir	north-side		south-side		[degr]		[knots]		[RPM]		[degr]		[off LL]		[off LL]				exc.frequency	
[m]	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	av	dev	north	south	1%	.01%	north	south
575	1454	69	1404	68	346	14	11.7	1.6	88	13	4	5	46	68	158	57	350	532	25.67	1.85
600	1457	64	1407	62	345	14	11.7	1.6	88	13	4	5	41	63	149	51	327	494	21.98	1.32
625	1457	55	1406	53	346	14	11.6	1.5	89	13	4	5	33	53	138	46	287	430	14.63	.78
650	1459	44	1409	42	344	14	12.0	1.6	92	12	3	4	28	42	128	39	238	352	7.59	.16
675	1463	36	1418	35	340	14	12.0	1.6	90	13	3	4	27	35	118	35	202	297	3.33	.02
700	1469	34	1423	33	340	14	12.0	1.6	90	13	3	4	24	33	109	43	192	280	1.97	.01
725	1474	31	1428	31	339	13	12.0	1.6	90	13	3	4	22	30	100	48	181	263	1.00	.01
750	1473	32	1428	35	337	13	11.8	1.7	88	13	3	4	14	32	91	63	191	280	.61	.07
775	1479	30	1436	33	336	12	11.9	1.7	88	13	2	4	13	30	82	63	179	262	.25	.04
800	1485	29	1443	32	335	11	11.9	1.7	88	13	2	4	12	30	74	64	176	257	.16	.04
825	1492	28	1449	32	335	11	11.9	1.7	88	13	2	4	10	29	68	67	173	253	.10	.04
850	1499	26	1457	31	334	10	12.0	1.7	89	13	1	5	10	28	68	70	167	243	.05	.03
875	1505	25	1463	30	334	10	12.0	1.7	88	13	1	5	8	27	69	72	163	236	.02	.02
900	1511	25	1471	30	333	9	12.0	1.7	88	12	1	5	7	27	70	73	161	234	.02	.02
925	1521	27	1481	32	333	9	12.0	1.7	88	12	2	5	9	29	80	74	170	248	.06	.04
950	1530	27	1490	32	333	8	12.0	1.7	87	12	2	5	10	29	76	74	170	248	.07	.03
975	1538	27	1498	31	332	7	12.1	1.7	88	12	1	5	10	28	74	73	165	241	.05	.02
1000	1545	27	1506	31	332	7	12.1	1.7	88	12	1	4	10	28	71	72	164	240	.05	.02
1025	1551	27	1512	31	331	6	12.2	1.7	88	12	1	4	8	28	71	72	164	240	.04	.02
1050	1558	27	1520	30	331	6	12.2	1.7	88	12	1	3	8	28	72	69	162	238	.03	.02
1075	1568	27	1531	30	330	6	12.3	1.7	89	12	1	3	10	28	72	67	161	237	.04	.01
1100	1576	27	1539	30	330	5	12.3	1.7	89	13	1	3	10	28	72	64	160	235	.04	.01
1125	1583	27	1547	30	330	5	12.3	1.7	88	13	1	4	10	28	72	61	159	234	.04	.01
1150	1591	26	1555	29	330	4	12.3	1.7	88	13	1	4	10	28	72	58	158	232	.03	.01
1175	1599	27	1563	29	329	4	12.3	1.7	88	13	1	4	10	28	72	58	157	230	.04	.01
1200	1606	27	1571	29	329	4	12.3	1.7	88	13	1	3	10	28	73	58	157	230	.04	.01
1225	1614	27	1579	29	329	3	12.3	1.7	88	13	1	3	10	28	73	58	157	230	.04	.01

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* SHIP MANOEUVRING SIMULATOR *
* RESULTS OF STATISTICAL ANALYSIS *
****

FILE: TANKUT (CONTINUED)

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
X-dir [m]	SWEPTPATH north-side av	north-side dev	south-side av	south-side dev	Heading [degr] av	Heading dev	Speed [knots] av	Speed dev	Propeller [RPM] av	Propeller dev	Rudder [degr] av	Rudder dev.	Ships-Centre [off LL] av	Ships-Centre dev	Max.Distance [off LL] north	Max.Distance south	Path width 1%	Path width .01%	Channel bounder exc.frequency north	Channel bounder exc.frequency south
1250	1622	27	1587	29	329	3	12.3	1.7	88	13	0	2	10	28	73	58	156	230	.04	.01
1275	1630	27	1595	29	329	3	12.3	1.7	88	13	0	2	10	28	73	58	157	230	.04	.01
1300	1638	27	1603	29	329	3	12.3	1.7	88	13	0	2	10	28	74	58	157	230	.04	.01
1325	1646	27	1611	29	329	3	12.3	1.7	88	13	0	2	10	28	74	58	157	231	.04	.01
1350	1653	27	1619	29	329	2	12.3	1.7	88	13	0	2	10	28	74	58	157	231	.04	.01
1375	1661	27	1627	29	328	2	12.3	1.7	88	13	0	2	10	28	74	58	156	230	.04	.01
1400	1669	27	1635	29	328	2	12.3	1.7	88	13	0	2	10	28	74	58	156	230	.04	.01
1425	1677	27	1643	29	328	2	12.3	1.7	88	13	0	2	10	28	74	58	156	230	.04	.01
1450	1685	27	1651	29	328	2	12.3	1.7	88	13	0	2	10	28	73	57	156	229	.04	.01
1475	1693	27	1659	29	328	2	12.3	1.7	88	13	0	2	10	28	73	57	155	229	.04	.00
1500	1701	27	1667	28	328	2	12.2	1.7	88	13	0	1	10	28	73	57	155	229	.04	.00
1525	1709	27	1675	28	328	2	12.2	1.7	88	13	0	1	10	28	73	57	155	229	.04	.00
1550	1716	27	1683	28	328	2	12.2	1.7	88	13	0	1	10	28	72	56	155	229	.04	.00
1575	1724	27	1691	28	328	2	12.2	1.7	88	13	0	1	10	28	72	56	155	228	.04	.00
1600	1732	27	1699	28	328	2	12.2	1.7	88	13	0	1	10	28	72	56	155	228	.04	.00
1625	1740	27	1707	28	328	2	12.2	1.7	88	13	0	1	10	28	71	56	154	228	.03	.00
1650	1748	27	1715	28	328	2	12.2	1.7	88	13	-1	1	10	28	70	56	154	227	.03	.00
1675	1756	27	1722	28	328	2	12.2	1.7	88	12	-1	1	10	28	70	56	155	228	.03	.00
1700	1764	27	1730	28	328	2	12.2	1.7	88	12	-1	1	10	27	69	56	154	227	.03	.00
1725	1772	27	1738	28	328	2	12.2	1.7	88	13	0	1	9	27	69	56	154	227	.03	.00
1750	1779	27	1746	28	328	2	12.2	1.7	87	13	0	1	9	27	68	56	154	226	.03	.00
1775	1787	27	1754	28	328	2	12.2	1.7	87	13	0	1	9	27	67	55	153	225	.03	.00
1800	1795	26	1762	28	328	2	12.2	1.7	87	13	0	1	9	27	67	54	152	224	.03	.00
1825	1803	26	1769	28	328	2	12.1	1.7	87	13	0	1	9	27	67	54	151	223	.02	.00
1850	1811	26	1777	27	328	2	12.1	1.7	87	13	0	1	9	27	67	53	151	222	.02	.00
1875	1819	26	1785	27	328	2	12.1	1.7	87	13	0	1	9	26	66	52	150	220	.02	.00
1900	1827	26	1793	27	328	2	12.1	1.7	87	13	0	1	9	26	66	51	148	218	.02	.00
1925	1835	25	1801	26	328	2	12.1	1.7	87	13	0	1	10	26	66	50	147	216	.02	.00
1950	1843	25	1809	26	328	2	12.1	1.7	87	13	0	1	10	26	66	50	147	215	.02	.00
1975	1851	25	1817	26	328	2	12.1	1.7	87	13	0	1	10	26	67	49	146	214	.01	.00
2000	1859	25	1826	26	328	2	12.1	1.7	87	13	0	1	10	25	67	49	145	213	.01	.00
2025	1867	25	1834	26	328	2	12.1	1.7	87	13	0	1	10	25	67	48	144	212	.01	.00
2050	1875	25	1842	26	328	2	12.1	1.7	87	13	0	1	10	25	67	48	144	211	.01	.00
2075	1883	25	1850	25	328	2	12.1	1.7	87	13	0	1	10	25	67	47	143	210	.01	.00
2100	1891	24	1858	25	328	2	12.1	1.7	87	13	0	1	10	25	68	47	143	209	.01	.00
2125	1899	24	1866	25	328	2	12.0	1.7	87	13	0	1	10	25	68	46	142	207	.01	.00
2150	1907	24	1874	25	328	2	12.0	1.7	87	13	0	1	10	25	69	45	141	207	.01	.00
2175	1915	24	1882	25	328	2	12.0	1.7	87	13	0	1	11	24	69	44	140	205	.01	.00
2200	1923	24	1890	25	328	2	12.0	1.7	87	13	0	1	11	24	69	43	139	204	.01	.00
2225	1931	24	1898	25	328	2	12.0	1.7	87	13	0	1	11	24	70	42	140	204	.01	.00

****
* SHIP MANOEUVRING SIMULATOR *
* RESULTS OF STATISTICAL ANALYSIS *
****

FILE: TANKUT (CONTINUED)

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
X-dir [m]	SWEPTPATH north-side av	dev	south-side av	dev	Heading [degr] av	dev	Speed [knots] av	dev	Propeller [RPM] av	dev	Rudder [degr] av	dev	Ships-Centre [off LL] av	dev	Max.Distance [off LL] north	south	Path width 1%	.01%	Channel bounder exc.frequency north	south
2250	1940	24	1906	24	328	2	12.0	1.7	87	13	0	1	11	24	70	41	139	203	.01	.00
2275	1948	24	1914	24	328	2	12.0	1.7	87	13	0	1	11	24	70	40	138	201	.01	.00
2300	1956	24	1922	24	328	2	12.0	1.7	87	13	0	1	11	24	70	40	138	202	.01	.00
2325	1964	23	1930	24	328	2	11.9	1.7	87	13	0	1	11	24	70	39	137	200	.01	.00
2350	1972	23	1938	24	328	2	11.9	1.7	87	13	0	1	12	24	70	38	137	200	.01	.00
2375	1980	23	1947	24	328	2	11.9	1.6	86	13	0	1	12	24	70	38	137	200	.01	.00
2400	1988	23	1955	24	328	2	11.9	1.7	86	13	0	1	12	23	70	36	136	199	.01	.00
2425	1996	23	1963	24	328	2	11.9	1.7	86	13	0	1	12	24	71	35	136	199	.01	.00
2450	2004	23	1971	24	327	2	11.9	1.7	86	13	0	1	13	24	71	35	137	200	.01	.00
2475	2013	23	1980	24	327	2	11.9	1.6	86	13	0	1	13	24	71	34	136	199	.01	.00
2500	2021	23	1988	24	327	2	11.9	1.6	86	13	0	1	13	24	71	34	137	200	.01	.00
2525	2029	23	1996	24	327	2	11.8	1.6	86	13	0	1	13	24	72	33	137	200	.01	.00
2550	2037	23	2004	24	327	2	11.8	1.6	86	13	0	1	14	24	72	34	137	200	.01	.00
2575	2045	24	2012	24	327	2	11.8	1.6	86	13	0	1	14	24	72	34	137	201	.01	.00
2600	2053	24	2021	25	327	2	11.8	1.6	86	13	0	1	14	24	72	34	138	202	.01	.00
2625	2062	24	2029	25	327	2	11.8	1.6	86	13	0	1	14	24	72	35	138	202	.01	.00
2650	2070	24	2037	25	327	2	11.8	1.6	86	13	0	1	15	24	72	35	139	203	.01	.00
2675	2078	24	2046	25	327	2	11.8	1.6	86	13	0	1	15	24	72	35	139	204	.02	.00
2700	2086	24	2054	25	327	2	11.8	1.6	86	13	0	1	15	25	71	36	140	205	.02	.00
2725	2094	24	2062	25	327	2	11.8	1.6	86	13	0	1	16	25	71	37	141	207	.02	.00
2750	2103	24	2070	26	327	2	11.7	1.6	86	13	0	1	16	25	71	38	141	208	.02	.00
2775	2111	25	2079	26	327	2	11.7	1.6	86	13	0	1	16	25	71	40	143	210	.03	.00
2800	2119	25	2087	26	327	2	11.7	1.6	86	13	0	1	17	26	71	42	144	212	.03	.00
2825	2127	25	2095	27	327	2	11.7	1.6	86	13	0	1	17	26	72	44	145	214	.04	.00
2850	2136	25	2103	27	327	2	11.7	1.6	86	13	0	1	17	26	72	46	147	216	.05	.00
2875	2144	26	2112	27	327	2	11.6	1.6	86	13	0	1	18	26	72	47	148	218	.06	.00
2900	2152	26	2120	28	327	2	11.6	1.6	86	13	0	1	18	27	72	47	150	221	.07	.00
2925	2161	26	2128	28	327	2	11.6	1.6	86	13	0	1	18	27	76	48	151	224	.09	.00
2950	2169	27	2137	28	327	2	11.6	1.6	86	13	0	2	19	27	79	50	153	226	.10	.00
2975	2177	27	2145	29	327	2	11.6	1.6	86	13	0	2	19	28	81	51	154	229	.12	.00
3000	2185	27	2154	29	327	3	11.6	1.6	86	13	0	1	20	28	84	53	156	231	.14	.00
3025	2194	28	2162	30	327	3	11.5	1.6	86	13	0	1	20	29	89	54	158	235	.18	.00
3050	2202	28	2170	30	327	3	11.5	1.5	86	13	-1	1	20	29	91	56	160	237	.21	.00
3075	2210	28	2179	30	327	3	11.5	1.5	86	13	-1	1	21	29	91	56	160	239	.23	.00
3100	2218	28	2187	31	327	2	11.5	1.5	86	13	-1	1	21	30	92	58	162	240	.24	.00
3125	2227	29	2195	31	327	2	11.4	1.5	86	13	-1	1	21	30	93	59	162	241	.26	.00
3150	2235	29	2204	31	327	2	11.4	1.5	86	13	0	1	22	30	95	60	163	243	.30	.00
3175	2243	29	2212	31	327	2	11.4	1.5	86	13	0	1	22	30	97	61	164	245	.33	.00
3200	2251	29	2220	32	327	2	11.4	1.5	86	13	0	1	22	31	98	62	166	247	.36	.00
3225	2260	30	2229	32	327	2	11.3	1.5	86	13	0	1	23	31	100	62	166	248	.39	.00

* SHIP MANOEUVRING SIMULATOR *
* RESULTS OF STATISTICAL ANALYSIS *

FILE: TANKUT (CONTINUED)

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
X-dir [m]	SWEPTPATH north-side av	dev	south-side av	dev	Heading [degr] av	dev	Speed [knots] av	dev	Propeller [RPM] av	dev	Rudder [degr] av	dev	Ships-Centre [off LL] av	dev	Max.Distance [off LL] north	south	Path width 1%	.01%	Channel bounder exc.frequency north	south
3250	2268	30	2237	32	327	2	11.3	1.5	85	12	0	1	23	31	101	63	167	250	.42	.00
3275	2276	30	2245	33	327	2	11.3	1.5	85	12	0	1	23	31	102	63	168	251	.44	.01
3300	2284	30	2254	33	327	2	11.3	1.5	85	12	0	1	24	32	104	63	169	253	.50	.01
3325	2292	31	2262	33	327	2	11.2	1.5	85	12	0	1	24	32	105	64	170	255	.54	.01
3350	2300	31	2270	33	327	2	11.2	1.5	85	12	0	1	24	32	106	64	171	256	.57	.01
3375	2308	31	2278	34	327	2	11.2	1.5	85	12	0	1	24	32	107	64	173	259	.63	.01
3400	2316	31	2287	34	327	2	11.1	1.5	85	12	-1	2	25	33	108	64	174	261	.65	.01
3425	2324	32	2295	35	327	2	11.1	1.5	85	12	-1	2	25	33	110	65	176	264	.73	.01
3450	2332	32	2303	35	327	3	11.1	1.5	85	12	-1	3	25	33	111	66	177	266	.77	.01
3475	2340	32	2311	35	327	3	11.1	1.5	85	12	-1	2	25	34	113	66	178	268	.83	.01
3500	2349	32	2319	35	327	3	11.0	1.5	85	12	-1	1	25	34	114	66	178	268	.83	.01
3525	2357	32	2327	35	327	2	11.0	1.5	85	12	-1	1	25	34	115	66	179	269	.86	.01
3550	2364	32	2335	36	327	2	10.9	1.5	85	12	-1	1	25	34	116	65	179	270	.90	.01
3575	2372	33	2343	36	327	2	10.9	1.5	85	12	-1	1	25	34	117	65	179	270	.91	.01
3600	2380	33	2350	36	327	2	10.9	1.5	85	12	-1	1	25	34	118	66	180	270	.91	.01
3625	2388	33	2358	36	327	2	10.8	1.5	84	12	-1	1	25	34	119	66	180	271	.92	.01
3650	2396	33	2366	36	327	2	10.8	1.5	84	12	-1	1	25	34	120	66	180	271	.93	.01
3675	2403	33	2374	36	327	2	10.7	1.5	84	12	-1	1	25	34	121	66	180	271	.91	.01
3700	2411	33	2382	36	327	2	10.7	1.5	84	12	-1	1	25	34	122	66	181	271	.94	.02
3725	2419	33	2390	36	327	2	10.6	1.5	84	12	-1	1	25	34	124	66	181	272	.95	.02
3750	2427	33	2397	36	327	2	10.6	1.4	84	12	0	1	24	34	125	65	181	272	.95	.02
3775	2435	33	2405	36	327	2	10.6	1.4	84	12	0	1	24	34	125	65	181	272	.96	.01
3800	2443	33	2413	36	327	2	10.5	1.4	84	12	0	2	24	34	124	64	180	271	.93	.01
3825	2450	33	2421	35	327	2	10.5	1.4	83	12	0	2	24	34	122	63	179	270	.87	.01
3850	2458	33	2429	35	327	2	10.4	1.4	83	12	0	2	24	34	120	62	178	268	.83	.01
3875	2466	33	2437	35	327	2	10.4	1.4	83	12	0	2	24	34	119	62	178	268	.81	.01
3900	2473	32	2445	35	327	2	10.3	1.4	83	12	0	2	24	34	118	62	177	267	.77	.01
3925	2481	32	2452	35	327	2	10.3	1.4	83	12	0	2	23	34	117	61	177	266	.74	.01
3950	2489	32	2460	35	327	3	10.2	1.4	83	12	-1	2	23.	34	117	61	177	266	.73	.01
3975	2496	33	2467	35	327	3	10.1	1.4	83	12	-1	1	23	34	116	60	177	266	.71	.01
4000	2504	33	2474	35	327	3	10.1	1.4	83	12	-1	1	22	34	116	60	177	266	.71	.01
4025	2511	33	2482	35	327	3	10.0	1.4	83	12	-1	2	21	34	115	60	177	267	.67	.01
4050	2518	33	2489	35	327	3	9.9	1.4	83	12	-1	2	21	33	114	60	177	266	.63	.01
4075	2525	33	2496	35	327	3	9.9	1.5	83	12	-1	2	20	33	113	60	177	266	.59	.02
4100	2533	33	2503	34	327	3	9.8	1.5	83	12	-1	2	19	33	112	61	177	266	.55	.02
4125	2539	33	2510	34	327	3	9.7	1.4	83	12	-1	2	19	33	112	62	176	265	.50	.02
4150	2546	33	2517	34	327	3	9.6	1.4	82	13	-1	2	18	34	111	64	177	266	.49	.02
4175	2553	33	2524	35	327	3	9.6	1.4	81	14	-1	2	17	34	110	66	178	267	.46	.02
4200	2560	33	2531	34	327	3	9.5	1.4	81	13	-1	2	16	34	108	66	178	268	.44	.03
4225	2567	34	2538	35	328	3	9.4	1.4	80	14	-1	2	14	34	107	69	179	270	.43	.03

****
* SHIP MANOEUVRING SIMULATOR *
* RESULTS OF STATISTICAL ANALYSIS *
****

FILE: TANKUT (CONTINUED)

RUDDER ANGLE: negative, means port rudder
SHIPS CENTRE: negative, south of channel axis

DISTANCES COORDINATE AXES					AVERAGE AND STANDARD DEVIATION										REQUIRED SPACE					
X-dir [m]	SWEPTPATH north-side av	dev	south-side av	dev	Heading [degr] av	dev	Speed [knots] av	dev	Propeller [RPM] av	dev	Rudder [degr] av	dev	Ships-Centre [off LL] av	dev	Max.Distance [off LL] north	south	Path width 1%	.01%	Channel bounder exc.frequency north	south
4250	2573	34	2544	35	328	3	9.4	1.4	79	15	-1	2	13	34	105	71	180	272	.43	.04
4275	2580	35	2550	35	328	3	9.3	1.4	79	15	-2	2	11	35	103	73	182	275	.42	.05
4300	2586	35	2557	35	328	4	9.2	1.4	79	15	-2	2	10	35	103	74	184	278	.43	.06
4325	2592	36	2563	36	328	4	9.1	1.3	79	15	-2	2	8	36	100	76	187	281	.41	.08
4350	2599	36	2569	36	328	4	9.1	1.3	79	15	-1	2	7	36	97	78	189	286	.41	.12
4375	2605	37	2575	37	328	4	9.0	1.3	79	15	-1	2	5	37	94	81	192	290	.40	.17
4400	2610	38	2580	37	329	4	8.9	1.3	78	15	-2	2	3	37	91	83	195	294	.38	.23
4425	2616	38	2585	38	329	5	8.8	1.3	78	15	-2	2	0	38	89	89	197	298	.36	.32
4450	2622	38	2591	38	329	5	8.7	1.3	78	15	-2	2	-2	38	86	98	200	302	.33	.43
4475	2627	39	2596	39	329	5	8.6	1.3	78	15	-2	2	-4	39	81	107	202	304	.29	.57
4500	2633	39	2601	39	330	5	8.5	1.2	78	15	-2	3	-7	39	77	115	204	308	.25	.80
4525	2638	39	2605	40	330	5	8.4	1.2	78	14	-2	3	-10	40	73	125	207	312	.21	1.15
4550	2643	40	2609	41	330	5	8.3	1.2	78	14	-3	4	-13	40	67	134	210	316	.18	1.61
4575	2647	40	2613	41	330	6	8.2	1.2	77	14	-3	4	-17	41	62	142	213	321	.15	2.22
4600	2652	40	2617	42	331	6	8.1	1.2	77	14	-3	4	-20	41	58	151	217	327	.12	3.10
4625	2656	41	2621	43	331	6	8.0	1.2	76	13	-3	4	-24	42	55	159	220	332	.10	4.19
4650	2660	41	2624	44	332	6	7.9	1.2	76	13	-3	4	-28	42	52	166	224	337	.09	5.50
4675	2664	42	2627	44	332	6	7.8	1.2	76	13	-3	4	-33	43	48	172	226	340	.07	6.93
4700	2667	42	2630	44	332	6	7.7	1.2	75	13	-3	3	-37	43	44	177	227	342	.05	8.66
4725	2670	43	2632	44	333	6	7.6	1.2	75	13	-4	4	-42	43	37	184	229	345	.04	.98
4750	2673	43	2634	44	334	6	7.5	1.1	75	13	-4	3	-48	43	30	190	230	345	.02	3.58
4775	2675	43	2636	44	334	6	7.3	1.1	74	14	-5	3	-53	43	24	194	229	345	.01	6.64
4800	2676	42	2638	44	335	6	7.2	1.1	74	14	-5	3	-60	43	20	200	228	342	.01	.45
4825	2677	42	2639	43	336	6	7.1	1.1	74	14	-5	4	-66	42	16	205	226	339	.00	4.83
4850	2678	41	2640	43	337	5	6.9	1.1	74	14	-5	4	-73	42	14	209	223	334	.00	3.87
4875	2678	41	2640	42	338	5	6.8	1.1	74	14	-5	4	-80	41	10	214	219	329	.00	5.87
4900	2678	40	2640	41	339	5	6.7	1.1	73	14	-5	4	-87	40	4	219	215	323	.00	2.89
4925	2678	39	2640	39	340	5	6.5	1.1	74	13	-5	4	-95	39	-2	222	210	314	.00	.81
4950	2677	37	2639	38	341	5	6.4	1.0	74	13	-6	5	-104	38	-12	225	204	304	.00	9.84
4975	2675	36	2638	37	342	5	6.2	1.0	74	13	-7	7	-113	36	-23	229	196	293	.01	9.46
5000	2673	34	2636	35	343	4	6.0	1.0	74	13	-7	7	-122	34	-34	231	188	279	.01	9.20
5025	2671	31	2634	33	345	4	5.8	1.0	74	13	-7	7	-132	32	-48	232	179	265	.01	7.75
5050	2668	29	2631	32	346	5	5.5	1.0	74	13	-6	5	-142	30	-63	233	170	251	.01	4.05
5075	2664	27	2628	30	347	5	5.3	1.0	73	13	-6	5	-153	28	-81	233	159	235	.01	7.77
5100	2660	24	2625	28	349	5	5.0	1.0	72	14	-6	5	-164	26	-99	238	149	219	.01	9.47
5125	2656	23	2622	26	350	6	4.8	.9	69	17	-5	5	-175	24	-114	241	141	205	.01	9.94
5150	2653	22	2618	23	350	6	4.5	.9	69	17	-4	4	-186	22	-120	244	132	191	.01	9.99
5175	2649	20	2615	20	351	6	4.2	.8	68	17	-3	3	-196	20	-126	247	122	176	.01	9.99
5200	2648	17	2610	17	351	6	3.9	.8	66	15	-2	3	-207	16	-135	256	110	153	.01	9.99